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EDITORIAL

Agriculture across the world is undergoing a profound transformation shaped by climate change, digital innovations, evolving market demands, demographic transitions and increasing concerns about livelihood security. In this dynamic environment, agricultural extension and education must move beyond the conventional transfer of technology towards facilitating knowledge co-creation, strengthening institutional partnerships and empowering farming communities to make informed decisions. As agricultural challenges increasingly transcend geographical boundaries, international research collaboration and knowledge exchange become indispensable. The *Indian Journal of Extension Education* remains committed to providing a scholarly platform for critical inquiry, methodological innovation and evidence-informed policy and practice.

The *Indian Journal of Extension Education* continues to gain recognition in the global scholarly community. As reported in Scopus, the journal has achieved a Cite Score of 2.9, with 468 documents indexed in its database (https://www.scopus.com/sourceid/21100846015). This progress reflects the collective efforts of authors, reviewers, editors and other stakeholders in advancing the quality, visibility and international reach of extension research.

Current issue containing 33 full length Research Papers, 5 Research Tools, and 10 Research Notes brings together diverse research contributions that illuminate these emerging priorities and reinforce the interdisciplinary and international character of extension research. Climate change and resilience emerge as important themes. Contributions examining farmers' climate adaptation practices in Bangladesh, climate-smart agriculture adoption in India and Indonesia, and global research trends in climate resilience highlight the need to understand not only the availability of scientific technologies but also the social, economic and institutional conditions that influence their adoption. Similarly, research on weather-based sorghum yield prediction and climate-resilient technologies for water-secure farming underscores the importance of integrating scientific evidence, timely advisories and location-specific extension strategies. Strengthening farmers' adaptive capacities requires coordinated efforts among research institutions, extension agencies, policymakers and local communities. Equally significant is the recognition of indigenous knowledge, community institutions and collective action in sustainable agricultural development. The contribution on millet-based entrepreneurship further highlights the relevance of community-based approaches in connecting local resources with livelihood opportunities. Integrating validated indigenous knowledge with scientific innovations can help develop locally appropriate, culturally responsive and environmentally sustainable solutions. The issue also emphasizes the human and institutional dimensions of development. Studies on Generation Z farmers in Indonesia, rural youth aspirations, women's participation in household and farm decision-making, tribal farm women's nutritional security, and the livelihood implications of employment guarantees demonstrate that agricultural development cannot be assessed through productivity alone. Research on ICT-based agricultural extension, service utilisation and the disconnect between academic research and farmers' needs highlights the importance of institutional capacity, credible communication, participatory approaches and continuous feedback. The challenge is to combine digital platforms and data-driven advisory services with human interaction, local knowledge and accountable extension institutions. It is hoped that the contributions in this issue will stimulate further dialogue among researchers, extension professionals, educators and policymakers, strengthening the collective endeavour to build resilient, inclusive and sustainable agricultural and rural systems.

On behalf of the Editorial Board, I extend my sincere appreciation to all reviewers, contributors, and members of the Editorial and ISEE Executive Body for their continued support and commitment. I also acknowledge the ACS publisher for its efforts in maintaining timely publication. Special appreciation is extended to Dr. U.S. Gautam, Dr. J.R. Mishra, Dr. Keshava, Dr. Basvaprabhu Jirli and Dr. Bhanu P. Mishra for their valuable guidance and support. The financial assistance extended by the Indian Council of Social Science Research (ICSSR), New Delhi, towards the publication of the *Indian Journal of Extension Education* is gratefully acknowledged.



(Manjeet Singh Nain)
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Research Article

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Participation of Generation Z Farmers in Agricultural Regeneration in Indonesia: The Role of Internal Factors and Extension-Related Social Support

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HIGHLIGHTS

- Internal factors have a positive and significant effect on the participation of Generation Z farmers in agricultural regeneration (β = 0.836; p = 0.027).
- Extension-Related Social Support had a positive, but not significant, effect on the participation of Generation Z farmers in agricultural regeneration (β = 0.069; p = 0.704).
- The SEM model explained 74.5% of the variation in Generation Z farmers' participation in agricultural regeneration (R^2 = 0.745).
- Internal factors and extension-related social support showed a positive but nonsignificant relationship (r = 0.360; p = 0.433).

ARTICLE INFO

Keywords: Farmer regeneration, Generation Z, Internal factors, Social support related to extension, Social learning, Extension education.

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ABSTRACT

Farmer regeneration is a strategic issue for the sustainability of Indonesian agriculture, given the low participation of the younger generation in the sector. This study aims to analyze the relationships among internal factors, extension-related social support, and the participation of Generation Z farmers in agricultural regeneration. A survey of 160 Generation Z farmers in East Belitung Regency, selected through multistage random sampling was conducted during 2025. The data was analyzed using Structural Equation Modeling (SEM). The results showed that internal factors consisting of motivation, self-efficacy, and social learning were positively and significantly related to the participation of Generation Z farmers (β = 0.836; p = 0.027). In contrast, extension-related social support, represented by peers, community leaders, and the government, showed a positive but nonsignificant relationship (β = 0.069; p = 0.704). The structural model explained 74.5% of the variation in Generation Z farmers' participation (R^2 = 0.745), indicating high explanatory power. Generation Z's participation in agricultural regeneration is more closely related to individual psychological capacity and learning processes than to extension-related social support. The results imply that extension programs targeting the younger generation should be more focused on strengthening motivation, self-efficacy, and social learning through an approach aligned with Generation Z's characteristics.

INTRODUCTION

The farmer regeneration crisis is a global challenge that threatens the sustainability of food systems and agricultural development. In many countries, the increase in the age of farmers is not offset by the entry of younger generations into the agricultural sector, thereby reducing the workforce's future sustainability (FAO, 2025). This condition is increasingly complex because the agricultural sector must compete with the industrial and service sectors, which offer more attractive career and income prospects for the younger generation. Agriculture is often perceived as a high-risk, low-profitability, and limited in career prospects (Pliakoura et al., 2023;

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Salam. This situation makes farmer regeneration one of the strategic issues in extension education, as agricultural extension must increase the involvement of the younger generation through an approach that suits their characteristics (Mohanty et al., 2025; Singh et al., 2026).

Generation Z is a group with the potential to support agricultural regeneration, as it grows in a digital environment that encourages innovation, flexibility, and sustainable learning (Barhate & Dirani, 2021; Pichler et al., 2021). However, their involvement in agriculture is influenced not only by technological developments but also by psychological factors such as motivation, self-efficacy, and social learning, as well as support from the extension system. In this study, extension-related social support is defined as support received by farmers from peers, community leaders, and the government during the extension process. This support provides information, learning, and mentoring that can strengthen the participation of the younger generation. In line with the Agricultural Knowledge and Innovation Systems (AKIS) paradigm, extension no longer functions solely as a medium for technology transfer but also as a facilitator of learning, innovation, and the empowerment of farmers (Davis & Sulaiman, 2014; Tayang et al., 2023).

This study integrates the Theory of Planned Behavior (Ajzen, 1991), Social Cognitive Theory (Bandura, 1977), and Self-Determination Theory (Deci & Ryan, 2000) to explain the relationships among motivation, self-efficacy, social learning, extension-related social support, and participation among Generation Z farmers. Although various studies have shown that both internal and external factors influence the participation of the younger generation, most continue to examine these factors separately or focus on youth in general. The empirical evidence integrating these factors into a single Structural Equation Modeling (SEM) model, especially among Generation Z farmers, remains limited, so the relative contribution of each factor cannot be comprehensively explained.

East Belitung Regency was chosen as the research location because it is undergoing economic transformation driven by the development of the tourism, services, and mining sectors, which may reduce the younger generation's interest in agriculture (Ibrahim et al., 2020). This condition makes this area relevant to examine the factors that affect the participation of Generation Z farmers in agricultural regeneration. Based on these gaps, this study aims to analyze the relationships among internal factors, extension-related social support, and the participation of Generation Z farmers.

METHODOLOGY

This study uses a quantitative, explanatory, cross-sectional survey to analyze the relationships among internal factors, extension-related social support, and the participation of Generation Z farmers in agricultural regeneration. This approach was chosen because it allows testing relationships between latent variables simultaneously using Structural Equation Modeling (SEM) (Creswell & Creswell, 2018). The research was carried out in East Belitung Regency, Bangka Belitung Islands Province, Indonesia, which was purposively selected because it is an agricultural area undergoing economic transformation driven by the development of the mining, tourism, and service sectors.

The study population comprises Generation Z farmers, conceptually aged 15-29 years (Peredy et al., 2024). However, all respondents who participated in the study were aged 18-29 years. The sampling frame uses a database of Generation Z farmers managed by the East Belitung Regency Agriculture and Food Office. The sample was selected using multistage random sampling, namely the determination of the research location purposively, the selection of seven sub-districts based on agricultural potential, the selection of villages based on the area of agricultural land and the number of active farmers, and then the selection of random respondents based on the list of Generation Z farmers in each village (Pranoto et al., 2025). A total of 160 respondents were interviewed. After checking data completeness, missing data, and multivariate outliers using the Mahalanobis distance, 25 data points were removed, leaving 135 respondents for analysis.

Data collection was carried out from October to December 2025 through direct interviews using structured questionnaires in Indonesian. All respondents received an explanation of the research's purpose and provided informed consent before the interview. The instrument was developed through a literature review, adapting validated instruments from previous research and modifying them to reflect the characteristics of Generation Z farmers and the context of agricultural regeneration in East Belitung Regency. The instrument measures three latent constructs: internal factors (60 items) comprising motivation, self-efficacy, and social learning. Furthermore, the Extension-related social support construct (54 items) includes the role of peers, the role of community leaders, and the role of the government, and the participation of Generation Z farmers (18 items) including respect for the farmer's profession, the responsibility to continue the profession, and the freedom to choose a profession, using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree).

Data analysis was conducted using IBM SPSS Statistics version 23 and IBM SPSS AMOS version 22. Descriptive statistics are used to describe the characteristics of respondents. The measurement model was evaluated through Standardized Loading Factor (SLF), Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE). Furthermore, structural models were evaluated using a set of goodness-of-fit indices, including Chi-square, CMIN/DF, CFI, TLI, GFI, AGFI, and RMSEA. The relationship between variables was analyzed using standardized path coefficients at the 95% significance level (Hair et al., 2019; Sarstedt et al., 2017).

RESULTS

Data analysis was conducted on 135 Generation Z farmer respondents who met the criteria. Before analysis, all statement items have been tested for validity and reliability. The results of the validity test showed that all items had a correlation coefficient (r-calculus) ranging from 0.414 to 0.857, exceeding the r-table value of 0.155, indicating that all items were valid. Furthermore, the reliability test results showed that Cronbach's alpha ranged from 0.827 to 0.987, all of which exceeded the minimum limit of 0.70, indicating that the research instrument was reliable and suitable for use in Structural Equation Modeling (SEM) analysis.

Table 1. Descriptive summary and achievement categories of study variables

Variable / Dimension	Achievement (%)	Category
Motivation (X_2)	73	High
Self-Efficacy (X_3)	66	High
Social Learning (X_4)	72	High
Role of Peers (X_6)	54	Moderate
Role of Community Leaders (X_7)	50	Moderate
Role of Government (X_8)	51	Moderate
Appreciation for the farmer's profession (Y_1)	70	High
Responsibility to continue the profession (Y_2)	68	High
Freedom of choice of profession (Y_3)	69	High

Note: 1) Codes X_1 and X_5 are eliminated because they have a < loading factor of 0.50 so that the indicator code is maintained; 2) The percentage of achievement obtained is classified into five categories using the same interval, namely Very Low (0–20%), Low (21–40%), Medium (41–60%), High (61–80%), and Very High (81–100%).

Based on the descriptive analysis in Table 1, internal factors show a higher level of achievement than extension-related social support. Motivation (73%) and social learning (72%) were in the high category, while self-efficacy reached 66%. These findings show that the participation of Generation Z farmers in agriculture is driven more by positive perceptions of agriculture, motivation to farm, confidence in self-worth, and social learning processes gained through interactions and learning experiences.

On the other hand, the extension-related social support variable showed relatively lower achievement. The roles of peers, community leaders, and the government achieved 54%, 50%, and 51%, respectively, all in the medium category. These results indicate that Generation Z farmers have not fully benefited from the social support provided through the social environment and extension services.

In the participation variable, appreciation for the farming profession (70%), the responsibility to continue the profession (68%), and the freedom to choose a profession (69%) were all in the high category. The findings show that respondents have a positive perception of the farming profession and choose to engage in agriculture based on awareness and personal choice. Overall, these results indicate that internal factors have a greater influence on Generation Z farmers' participation in agricultural regeneration than social support for extension.

Based on the trends identified in the descriptive analysis, a structural model was used to evaluate the influence of internal factors and extension-related social support on the participation of Generation Z farmers in agricultural regeneration. The conceptual model tested is presented in Figure 1.

Before conducting structural model testing, the measurement model's quality is evaluated using tests of convergent validity and construct reliability. The evaluation was conducted using standardized loading factor values, Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's alpha. According to Hair et al. (2019), the construct is considered to have adequate convergent validity if the AVE is $\geq$ 0.50 and good reliability if the CR and Cronbach's alpha are $\geq$ 0.70. The standardized loadings indicate that the research indicators have adequate relationships with the latent constructs they represent. Internal factors, Extension-related Social Support, and Generation Z farmer participation demonstrate good reliability and internal consistency, making them suitable for use in structural model testing. A summary of the measurement model's quality is presented in Table 2.

The final structural model shows a good degree of conformity with the empirical data. The results of the goodness-of-fit test resulted in a Chi-square value of 14,617 with a degree of freedom (df) of 16 (p = 0.553) and a ratio of Chi-square to degree of freedom (CMIN/DF) of 0.914. In addition, the RMSEA value of 0.000, GFI of 0.977, AGFI of 0.935, TLI of 1,000, and CFI of 1,000 indicate that the model meets the goodness-of-fit criteria recommended in the Structural Equation Modeling (SEM) analysis.

Overall, the goodness-of-fit index indicates that the proposed model has an adequate fit with the empirical data, so it is feasible

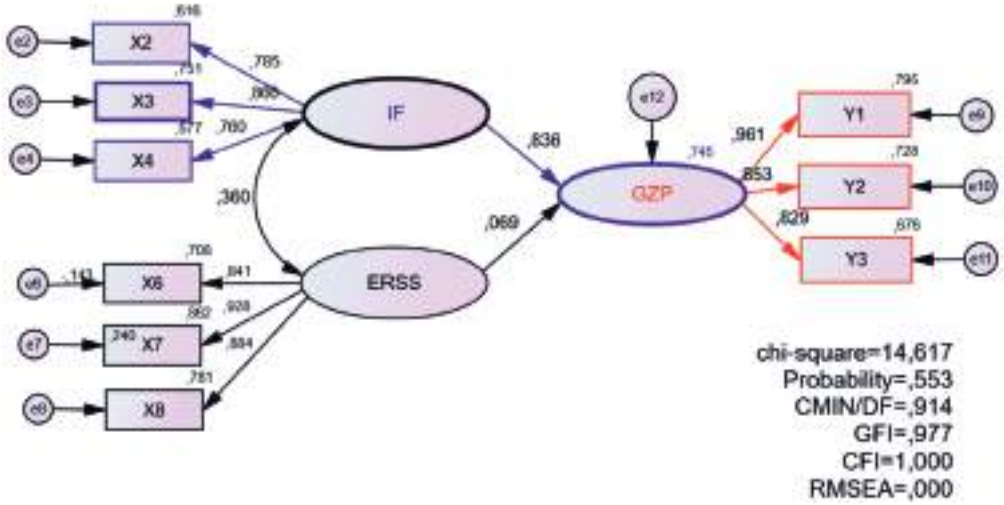


Figure 1. A structural equation model of the factors influencing the participation of Generation Z farmers

Note: IF = Internal Factors; ERSS = Extension-related Social Support; GZP = Generation Z Participation; Motivation (X_2); Self-Efficacy (X_3); Social Learning (X_4); Role of Peers (X_6); Role of Community Leaders (X_7); Role of Government (X_8); Appreciation for the farmer's profession (Y_1); Responsibility to continue the profession (Y_2); Freedom of choice of profession (Y_3).

Table 2. Measurement quality of latent constructs

Latent construct	Standardized loading range	AVE	Composite reliability	Cronbach's alpha
Internal Factors	0.760 - 0.866	0.648	0.846	0.728
Extension-related Social Support	0.841 - 0.928	0.781	0.914	0.859
Generation Z Participation	0.829 - 0.961	0.810	0.927	0.882

Note: AVE = Average Variance Extracted. The standardized loading range represents the minimum and maximum values of the loading factor indicators used to measure each latent construct.

Table 3. Structural relationships among study constructs

Relationship	Statistic	Estimate	p-value	Interpretation
Internal Factors → Participation of Generation Z Farmers	β	0.836	0.027	Positive and significant effect
Extension-related Social Support, → Participation of Generation Z Farmers	β	0.069	0.704	Positive but insignificant effect
Internal Factors ↔ Extension-related Social Support	r	0.360	0.433	Positive but insignificant relationships
Coefficient of Determination of Generation Z Farmers' Participation	R^2	0.745		High explanatory power

Note: β = standardized path coefficient; r = correlation coefficient; R^2 = coefficient of determination

to test the structural relationships among the constructs in this study. The results of the structural relationship estimation are then presented in Table 3.

Based on Table 3, internal factors have a positive and significant effect on the participation of Generation Z farmers in agricultural regeneration (β = 0.836; p = 0.027). These findings show that attitudes, motivation, self-efficacy, and social learning play an important role in encouraging Generation Z's involvement in the agricultural sector. These results indicate that factors within the individual, rather than external environmental influences, more strongly determine the younger generation's participation.

In contrast, social support related to extension did not show a significant association with Generation Z farmer participation (β = 0.069; p = 0.704). Although the path coefficient was positive, the test results indicated that the relationship between extension-related social support and Generation Z farmer participation was not statistically significant.

The relationship between internal factors and extension-related social support was positive but not significant (r = 0.360; p = 0.433). These results show that strengthening young farmers' internal factors is not always accompanied by increased social support. In addition, a determination coefficient (R^2) of 0.745 indicates that the model explains 74.5% of the variation in Generation Z farmers' participation in agricultural regeneration, with the remaining 25.5% influenced by factors outside the research model. The findings indicate that internal factors and extended-related social support together have a high degree of clarity in explaining Generation Z's participation in the agricultural sector.

DISCUSSION

The results showed that internal factors had a positive and significant relationship with Generation Z farmers' participation in agricultural regeneration (β = 0.836; p = 0.027), whereas extension-related social support did not. These findings indicate that internal factors play a greater role in explaining the variation in Generation Z farmers' participation in this research model. The insignificance of extension-related social support can be influenced by the characteristics of construct measurement and the context of agricultural extension in the study area. The findings are in line with the Theory of Planned Behavior, which asserts that a positive attitude towards a profession will increase an individual's tendency to choose and maintain that profession (Lantarsih et al., 2026; Ajzen, 1991). In the context of agricultural regeneration, positive perceptions of business opportunities, innovation and agricultural economic prospects become psychological capital for Generation Z (Pliakoura et al., 2023; Consentino et al., 2023). Thus, the influence of internal factors in this study reinforces previous findings that individual capacity and entrepreneurial competence are important determinants of sustainable youth participation in the agricultural sector (Gowda et al., 2023; Gupta et al., 2023; Singh et al., 2026).

The dominance of internal factors confirms the importance of self-efficacy in shaping Generation Z's decision to continue farming. According to Social Cognitive Theory, belief in one's own abilities plays an important role in encouraging individuals to face risks, adopt innovation, and develop businesses in a sustainable manner (Bandura, 1977). These findings are consistent with research that shows that self-efficacy is the main predictor of agripreneurship interest and youth farmer engagement in the digital transformation era (Kademani et al., 2020; Putri et al., 2025; Wulandari & Ratnawati, 2025; Kademani et al., 2025). In line with this, Mohanty et al. (2025) found that capacity-building and the economic empowerment of youth strengthened the sustainability of their involvement in the agricultural sector.

The high achievement in social learning shows that the learning process remains the foundation for the younger generation's participation, even as learning resources have shifted from conventional agricultural extension to a digital ecosystem. Generation Z is increasingly gaining knowledge through social media, online communities, and young farmer networks, enabling learning to take place more openly and independently. This condition corroborates the findings of Gailhard and Brennen (2022) and Nurfathiyah et al. (2025) that digital communication now plays an important role in shaping the career choices and adaptive capacity of the young generation in the agricultural sector. In addition, research on farmers' use of social media shows that access to digital information increasingly helps them obtain information and make farming decisions (Mishra et al., 2026).

In contrast, extension-related social support did not have a significant effect on the participation of Generation Z farmers in agricultural regeneration ($\beta = 0.069$; $p = 0.704$). These results show that support from peers, community leaders, and the government has not been the main factor determining Generation Z's involvement in the agricultural sector. These findings differ from previous research that established social support as an important driver of youth participation in agriculture (Geza et al., 2021; Giwu et al., 2024). This difference indicates a shift in decision-making patterns among Generation Z, who are more independent, self-development-oriented, and inclined to rely on personal considerations rather than traditional social influences (Barhate & Dirani, 2021; Pichler et al., 2021).

The insignificance of *extension-related social support* may indicate that the form of agricultural extension support received by respondents is not fully related to the participation of Generation Z farmers in this study. One possible explanation for these findings is the discrepancy between the agricultural extension approach applied and the characteristics of Generation Z. Several studies show that the younger generation tends to use faster, interactive, and digital technology-based information sources (Mohanty et al., 2025; Singh et al., 2026). However, this study did not directly measure the use of digital information sources or farmers' preferences for agricultural extension methods. Therefore, this interpretation needs careful consideration and requires further proof in subsequent research. In addition, respondents' low perception of the roles of peers, community leaders, and the government indicates that the available social support has not fully met their expectations. However, this study does not specifically identify the forms of support that Generation Z farmers need most, so this aspect still needs further study (Mdoda et al., 2026; Mollel et al., 2025).

Finally, this study shows that the effectiveness of agricultural extension cannot be measured solely by its ability to transfer information or technology to young farmers. When internal factors are shown to be more decisive for Generation Z participation than the extension of related social support, the role of agricultural extension needs to be repositioned from a technology-transfer paradigm to an innovation-facilitation model that strengthens young farmers' learning capacity, creativity, and independence. This shift is in line with the Agricultural Knowledge and Innovation Systems (AKIS) approach, which views extension workers as no longer the main source of knowledge, but rather facilitators who connect farmers with various sources of innovation, networks, and business opportunities (Tayang et al., 2023; Davis & Sulaiman, 2014). In the context of Generation Z, who are growing up in a digital environment, agricultural extension must adapt to a more open, collaborative, and technology-based learning approach. Therefore, the function of agricultural extension shifts from delivering information to facilitating learning, validating information, developing digital competencies, and strengthening innovation networks (Mollel et al., 2025; Gailhard & Brennen, 2022).

Further implications of these findings, which suggest that extension-related social support is not significantly associated with the participation of Generation Z farmers, require the development of agricultural extension strategies better aligned with the characteristics of young farmers. One approach that can be considered is the development of a digital extension ecosystem, which is an agricultural extension system that integrates extension workers, young farmers, universities, agritech startups, digital communities, and markets into an interconnected learning ecosystem. In this approach, agricultural extension serves as an innovation broker, facilitating knowledge exchange, collaboration, and value creation for young farmers. However, this study did not directly measure digital literacy, access to technology, or farmers' preferences for agricultural extension methods. Therefore, the concept of a digital extension ecosystem in this study is presented as a practical implication supported by recent literature developments, rather than as empirical findings. Previous research has shown that the adoption of technology and the involvement of young generations in agriculture are increasingly influenced by digital literacy and access to the information ecosystem (Otang, 2026; Hapsari et al., 2026). Therefore, further research needs to empirically examine how digital literacy, technology access, and digital-based agricultural extension models affect the participation of Generation Z farmers in agricultural regeneration.

CONCLUSION

This study shows that internal factors are positively and significantly associated with the participation of Generation Z farmers in agricultural regeneration in Indonesia. Motivation, *self-efficacy*, and *social learning* were the aspects most related to Generation Z farmers' participation, while *extension-related social support* showed no significant relationship. These findings indicate that strengthening internal capacity should be a priority in the regeneration strategy for young farmers. For agricultural extension practices, the results of this study imply that the approach needs to be better aligned with the characteristics and needs of Generation Z farmers. Therefore, further research is recommended to integrate these variables to gain a more comprehensive understanding of the participation of Generation Z farmers.

DECLARATIONS

Ethical consideration and consent to participate: This research has been carried out in accordance with the ethical principles of social research. All respondents participated voluntarily after receiving an explanation of the research objectives, the benefits of the research, and assurances of data confidentiality. The identity of the respondents is kept confidential and is only used for academic purposes.

Conflict of interest: The authors state that there are no conflicts of interest, financial or non-financial, that could affect the implementation, analysis, or reporting of the results of this research.

Author's contributions: The first author develops the research concept, designs the methodology, conducts the data analysis, and prepares the manuscript. The second author contributes to data collection, validation of results, and manuscript revision. The third author supervises the research, interprets the results, and conducts a critical review of the manuscript. All authors have contributed to the preparation of the article and approved the final manuscript

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Research Article

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Social Networks of Indigenous Climate Knowledge: Ecological Memory and Resilience in Saora Tribal Communities

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HIGHLIGHTS

- Among the Saora farmers, ecological memory was the most significant factor in climate resilience.
- Social network analysis identified knowledge brokers facilitating intergenerational knowledge transmission.
- Enabling local knowledge networks can enhance tribal community climate adaptation and resilience.

ARTICLE INFO

Keywords: Ecological memory index, Climate resilience, Indigenous knowledge systems, Social network analysis, Knowledge transmission.

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ABSTRACT

Rainfed tribal farming systems are increasingly affected by climatic variability, with indigenous knowledge being a key element to adaptation. This study explored the structure, transmission and ecological memory's contribution to climate resilience of Saora tribal farmers of village Linga in Gajapati district, Odisha, during 2024 to 2026. Household surveys, participatory rural appraisal, seasonal calendars, oral history and key-informant interviews were conducted to collect data with 120 farming households. An Ecological Memory Index (EMI) and Climate Resilience Index (CRI) were created and computed with the application of correlation, regression and t-test statistical analysis, and Social Network Analysis (SNA) was applied to map the pathways of knowledge transmission. Results showed that ecological memory was significantly associated with climate resilience, with ecological memory being the strongest contributing component of climate resilience, with the highest standardised weight ($\beta = 0.61$) among all CRI pillars. Central bridging roles in the knowledge network were occupied by elders, healers and seed keepers who played a significant role in intergenerational knowledge transfer. The study has concluded that the local knowledge network (LKN) can help to improve the climate resilience of a tribal agroecosystem.

INTRODUCTION

Among the livelihoods that are most vulnerable to climate change in South Asia are the smallholder and the tribal farming systems that rely on rain-fed agriculture (Aryal et al., 2020). Formal climate information services are also limited, and adaptation in such contexts is mostly shaped by ecological memory, or the aggregate of observations, stories and practices relating to environmental change that a community and its members accumulated over time and passed on to the next generation (Berkes, 2017). Indigenous lifeways are characterised by their ability to adapt to climate change and remain resilient (Kumar & Saxena, 2024) before it, ranging from the Zabo system in Nagaland to the methods of saving seeds in the Himalayas, but they are under growing stress as climate change exceeds traditional adaptation capacity (Bhattacharjee & Behera, 2021; Mondal & Palit, 2022; Petzold et al., 2024). Oldest among Odisha's Adivasi groups, the Saora have a sophisticated understanding of rainfall forecasting, seed saving, biodiversity

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management and pest control using plants. However, the threat of out-migration, market integration and loss of intergenerational learning runs against its continuity (Damodaran, 2015; Mondal & Palit, 2022). Tribal farm women's limited access to agricultural information and advisory services also poses similar challenges, limiting knowledge sharing and adaptive capacity within tribal communities, as observed by Bahubalendra et al. (2025).

Many TEK scholarship documents content of knowledge, but leaves its social structure under-examined. Knowledge is transmitted through the networks of social relations, and their distribution and movement, as well as their quantity, are important (Crona & Bodin, 2017). There are tools to make this architecture visible, such as social network analysis (SNA), which can determine influential and bridging actors, and community detection, which can detect sub-cultural clustering. Previous research demonstrates how people who occupy "hub" positions in knowledge networks influence the interpretations of eco-signals (Crona & Bodin, 2017) and how an individual's position in a knowledge network tends to hold local ecological knowledge (Calvet-Mir et al., 2012).

India is home to a large indigenous population with their traditional knowledge systems and technologies that have evolved over centuries in tune with their habitats (Lenka & Satpathy, 2020; Bheemappa et al., 2022). IK is deeply rooted in the cultural, social and ecological histories of specific Indigenous communities and is strongly associated with Indigenous connection to land, environment and traditional practices and ways of life (Radcliffe et al., 2021; Kusumastuti et al., 2023). There is a need to critically evaluate the knowledge levels of the tribal farmers to have an insight into the effectiveness of indigenous and livelihood-related practices, as was highlighted in previous studies (Johnson et al., 2023). In addition to scientific knowledge, the use of IK has proven to be an efficient way to improve climate change adaptation and enhance resilience of Indigenous communities in the midst of a changing climate (Chen & Cheng, 2020). There are few studies that provide evidence on the process of how ecological memory is passed across social networks and how it contributes to climate resilience among the Saora tribal community.

METHODOLOGY

A cross-sectional study was conducted in a tribal village called Linga, in Gajapati district, Odisha, a purposively selected representative village of the Saora community where there is a well-defined farming community, high forest dependence, and documented traditional ecological practices and it was found to be well suited for an in-depth sociometric network study. A mixed-methods Participatory Action Research (PAR) design was selected that incorporated both quantitative work related to index construction and statistical analysis, as well as a qualitative community-participatory approach. The study population constituted all the farming households in village Linga, which formed a census-based bounded network (N = 120), as this represented the total farming population of the village. Purposive sampling was used to select knowledge-rich respondents (elders, healers and seed keepers) as key knowledge actors. Relational data were collected in the bounded population by using the name-generator questions. A participatory awareness intervention was implemented over one agricultural season and pre- and post-intervention awareness scores were obtained based on a structured knowledge test. Ecological memory in this study is the household's capacity to remember historical rainfall patterns, drought events, biodiversity changes, traditional forecasting methods, and how often the memory of these forecasts is shared with others (the five dimensions of the EMI built in this study).

Structured household surveys and participatory rural appraisal (PRA) methods such as seasonal calendars, ecological timelines, resource mapping, oral history, focus group discussions, key-informant interviews and participant observation were used to collect data. Network ties were mapped across all 120 nodes, using name-generator questions: (i) "From whom do you learn about traditional farming and ecological practices?"; (ii) "Who do you consult to get information about rainfall prediction and decisions related to the climate?"; (iii) "Who taught you how to save seeds and manage biodiversity?"; (iv) "Who do you turn to for advice when you have problems with your farming? The interview schedule was pre-tested with 15 non-sample respondents and modified prior to data collection.

The Ecological Memory Index (EMI) was constructed from five indicators: historical rainfall knowledge, drought memory, biodiversity memory, traditional forecasting ability and frequency of knowledge transmission. Crop diversity, indigenous adaptation practices, seed self-sufficiency, livelihood diversification and ecological memory were added to the Climate Resilience Index (CRI). Both the indices were computed as arithmetic means of the normalised indicator scores equally weighted across the five indicators: $EMI = (I_1 + I_2 + I_3 + I_4 + I_5)/5$, $CRI = (P_1 + P_2 + P_3 + P_4 + P_5)/5$, where each indicator was scaled to a 0-100 scale before aggregation. Descriptive statistics, Pearson correlation, multiple linear regression and paired t-test were carried out in IBM SPSS Statistics 29 ($p < 0.05$). Normality, homoscedasticity, multicollinearity and independence of errors were tested using regression diagnostics. The social network analysis was performed in UCINET 6 and the visualization in Gephi with a force-directed layout. Network properties (density, average degree, diameter, clustering coefficient) and actor properties (degree, betweenness, closeness, eigenvector) were calculated. The Louvain modularity algorithm was chosen for community detection because it is efficient when applied to medium or large networks, and has been widely adopted in social network analysis.

RESULTS

Table 1 showed that respondents were experienced smallholders (mean age 46.2 years; 24.5 years' farming experience; household size 5.8; landholding 1.72 ha). Ecological memory was unevenly distributed: 42.5% of households scored High, 39.2%

Table 1. Distribution of Ecological Memory Index scores (mean EMI = 72.4; n = 120)

EMI category	Frequency	Percentage
Low	22	18.3
Medium	47	39.2
High	51	42.5
Total	120	100.0

Medium and 18.3% Low, with a mean EMI of 72.4. This concentration foreshadows the centralised network structure reported below.

Perceived climate change and adaptation

Farmers reported pervasive change delayed monsoon (86.7%), rising temperature (81.5%), increased drought frequency (72.4%) and higher pest incidence (69.3%) and responded with memory-rooted adaptations dominated by millet cultivation (91.2%), mixed cropping (88.4%), seed conservation (84.7%), botanical pesticides (79.5%) and water harvesting (65.3%), consistent with adaptive portfolios reported across Indian tribal communities.

Ecological memory as a predictor of resilience

Table 2 represents that Ecological memory was strongly associated with resilience (Pearson $r = 0.73$, $p < 0.001$). Ecological memory had the highest standardised weight ($\beta = 0.61$, $p < 0.001$) amongst the five CRI components, followed by crop diversity ($\beta = 0.38$) and education ($\beta = 0.19$), meaning that this component has the greatest impact on the overall climate resilience score, landholding was non-significant. The model explained 62% of variance ($R^2 = 0.62$; $F = 38.42$; $p < 0.001$). High-memory households achieved markedly higher resilience (CRI = 0.74) than low-memory households (CRI = 0.48). Multicollinearity diagnostics showed no evidence of collinearity among predictor variables, with all VIF values well below the threshold of 10 (EMI = 1.82, Crop Diversity = 1.64, Education = 1.31, Landholding = 1.19). Regression diagnostics further confirmed that model assumptions were satisfied, with normally distributed residuals (Shapiro–Wilk $p = 0.21$), homoscedasticity (Breusch–Pagan $p = 0.34$), and no autocorrelation (Durbin–Watson = 1.94), indicating that the model was statistically robust and suitable for interpretation.

Table 2. Multiple regression predicting the Climate Resilience Index

Predictor	Beta (β)	p-value
Ecological memory	0.61	< 0.001
Crop diversity	0.38	0.002
Education	0.19	0.041
Landholding	0.12	0.083

A participatory awareness intervention produced significant gains in climate awareness (54.8 → 78.5; paired $t = 7.93$, $p < 0.001$) and biodiversity awareness (58.3 → 80.2; paired $t = 8.74$, $p < 0.001$), indicating that memory-based learning is responsive to facilitation.

Network architecture of ecological knowledge

The relational structure of ecological knowledge was examined through six complementary networks, which together depict a centralised, modular system sustained by a small core of elders, healers and seed keepers.

General transmission sociogram

The transmission network consisted of 120 nodes and 487 directed edges, with all nodes representing the complete census of farming households in village Linga, forming a closed and bounded network with an average degree of 8.12, clustering coefficient of 0.41, diameter of 6 and density of 0.034. This resulted in a few direct connections between actors and an efficient structure with the majority of actors being reachable within 6 steps. The main centres were Elder Farmer A (42), Traditional Healer B (39) and Seed Keeper C (37). The knowledge-transmission sociogram is presented in Figure 1, with the size of the nodes, the colour coding, and the direction of the flow of knowledge.

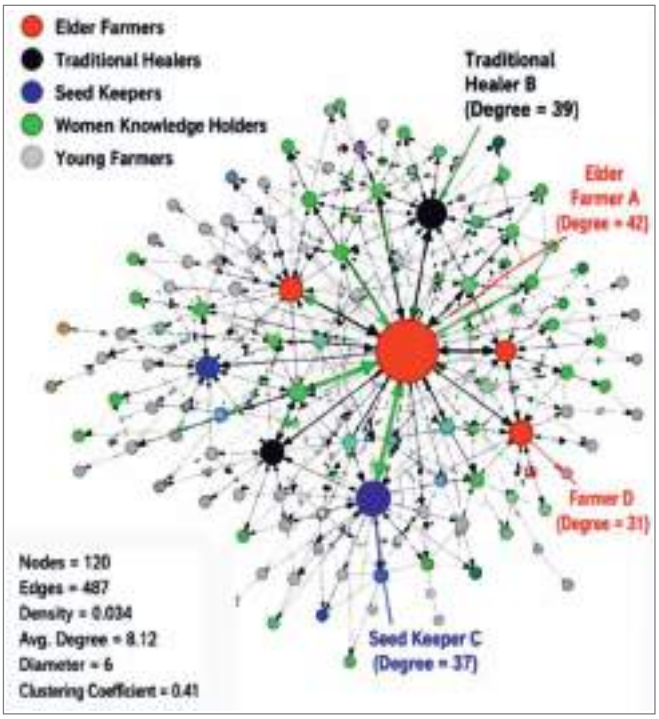


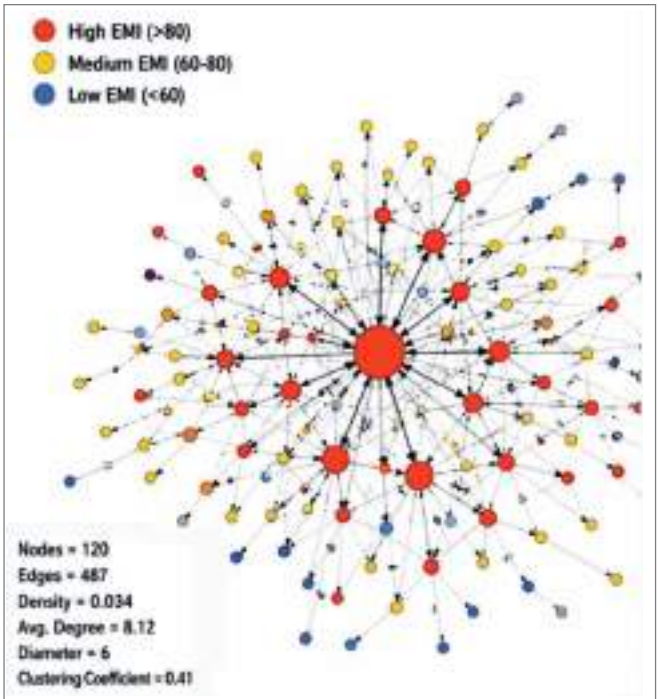
Figure 1. Knowledge-transmission sociogram (120 nodes, 487 edges)

Ecological-memory overlay

By re-colouring the network using the EMI, a clear core-periphery structure emerged: i.e. low (low-EMI, <60) and high (high-EMI, >80) EMI actors were concentrated at the periphery and core of the network respectively. The degrees of centrality had strong and positive Pearson correlation with the knowledge measured by EMI ($r = 0.68$, $p < 0.001$), suggesting that the most knowledgeable individuals are also the most influential in their networks. The concept of ecological-memory overlay is illustrated in Figure 2 with red, amber and blue colours corresponding to high, medium and low EMI levels.

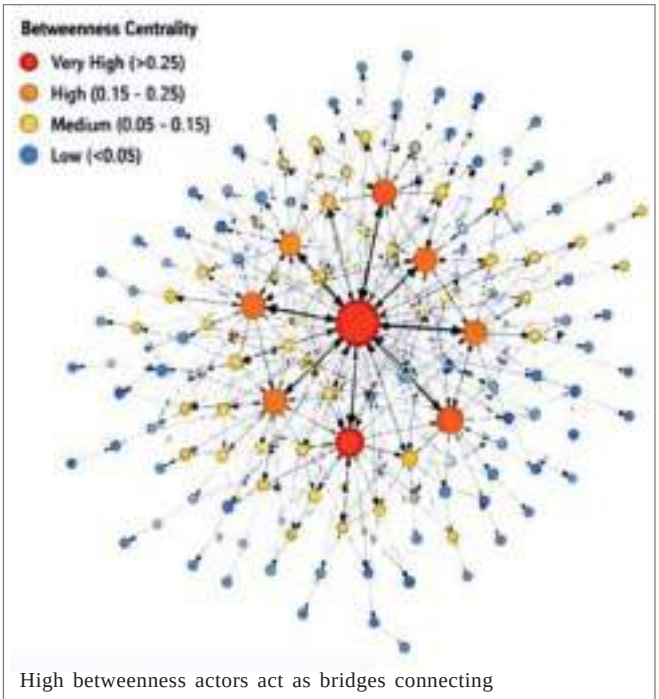
Betweenness centrality and structural vulnerability

The analysis of betweenness showed a varying degree of bridging role of actors in the ecological knowledge network. Normalised betweenness centrality values on the normalised betweenness centrality range (0-1) were used to divide actors into four categories: Low (<0.05), Medium (0.05-0.15), High (0.15-0.25), and Very High (>0.25), in line with the approach of equal interval classification of the observed score distribution adopted for categorisation in SNA studies (Crona & Bodin, 2017). There



Degree centrality positively correlated with EMI ($r = 0.68$, $p < 0.001$)

Figure 2. Ecological-memory overlay coloured by EMI



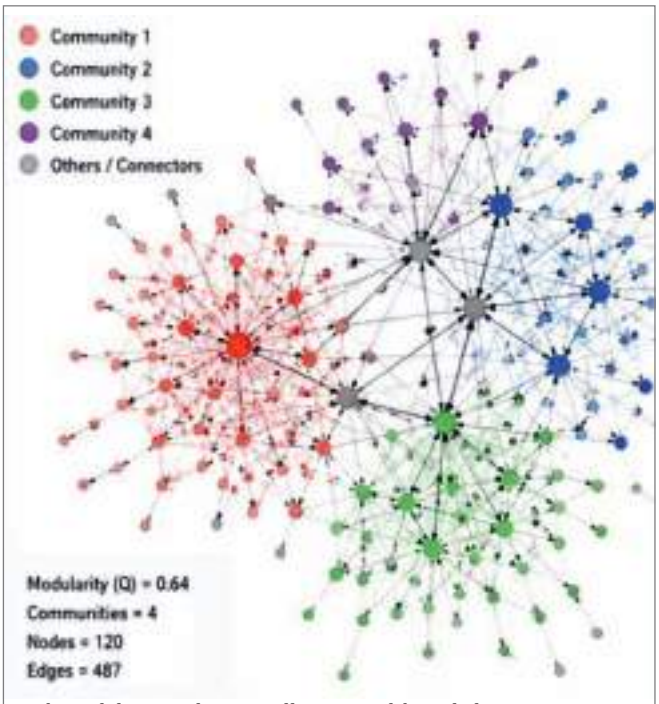
High betweenness actors act as bridges connecting different knowledge clusters

Figure 3. Betweenness Centrality Map

was a high proportion of actors in the low and medium categories, meaning that they had limited involvement in bridging between different knowledge clusters, while a few actors occupied the high and very high betweenness positions and were important bridges in the network. The highest normalized betweenness centrality value was for Elder Farmer A, who had a score of 0.381, indicating that he was in the very high range. This implies that the elimination of this actor might have the effect of breaking up the network and decrease the access of younger farmers to deeper ecological memory source. An example of the distribution of betweenness centrality is shown in Figure 3.

Community structure

The community detection algorithm Louvain identified a well-modular network ($Q = 0.64$) with four different knowledge communities and connector nodes. The high modularity indicates semi-autonomous sub-cultures, probably around the elder farmers, seed saving, healing knowledge and among the younger farmers. A narrow network of intermediaries connected these communities, allowing for inter-community transactions while also supporting intra-community resilience. The community-detection sociogram is presented in Figure 4, and the colours denote the communities; grey nodes represent connectors that link communities.



High modularity indicates will-structured knowledge communities

Figure 4. Community-detection sociogram

Knowledge-broker influence

When considering only influences, a pattern emerges of a few "big guys" on top, some secondary players, the regular members and a periphery. Strength of influence paths concentrates on top brokers, revealing that knowledge of adaptation comes in first through a well-known expert elite, then radiates outwards. The knowledge-broker influence network is presented in Figure 5, where nodes are sized by influence, red and orange highlight the top and secondary knowledge-brokers, blue highlights are regular members, grey are at the periphery, and highlighted edges represent the strongest influence paths.

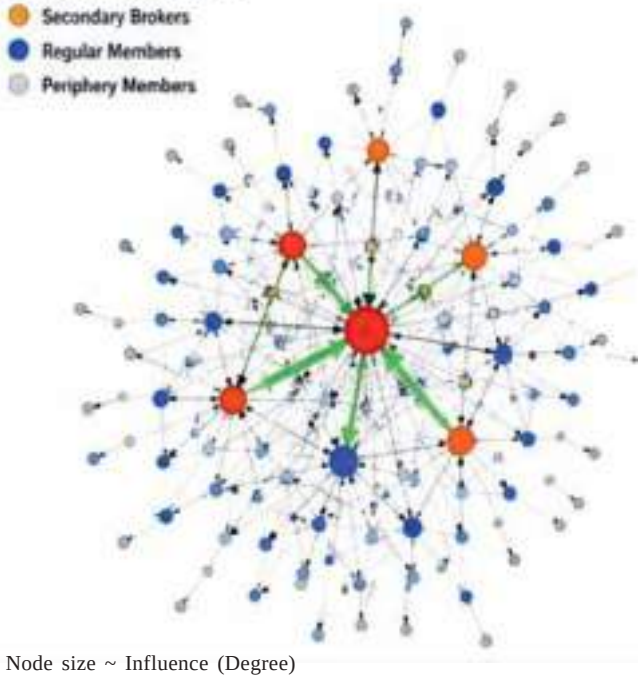


Figure 5. Knowledge-broker influence network

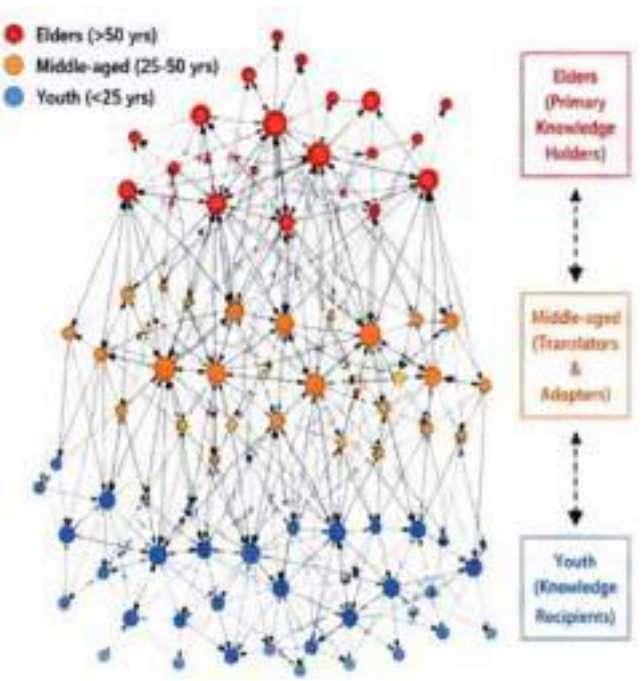


Figure 6. Temporal knowledge-flow network

Temporal, age-stratified flow

When sorted by age, there is an obvious intergenerational knowledge-transfer pathway in the community. A key role of the elders (aged 50+ years) is to be the master custodians of ecological knowledge, maintaining long-term environmental records, farming methods and cultural practices. The middle-aged (25-50 years) can be considered as a crucial link that takes the knowledge, adapts it, interprets it and passes it on to the younger generations. These exchanges are the main source of information and learning for youth (<25 years). The network is a layered one (from young to elder, from young to middle-aged and from middle-aged to elder) which emphasises the need for intermediary actors to ensure continuity and which signifies vertical and oblique cultural transmission processes.

Centrality of major knowledge holders

Table 3 illustrates that across measures, the same actors dominate. Elder Farmer A leads on every dimension (degree = 42; betweenness = 0.381; closeness = 0.612; eigenvector = 0.842), followed by Traditional Healer B (degree = 39; betweenness = 0.324; closeness = 0.584; eigenvector = 0.791), Seed Keeper C (degree = 37; betweenness = 0.287; closeness = 0.571; eigenvector = 0.765) and Farmer D (degree = 31; betweenness = 0.223; closeness = 0.539; eigenvector = 0.692), confirming that ecological memory is held by cultural repositories rather than evenly diffused.

High closeness centrality values show that the key actors have the potential to reach other actors in the network efficiently, and high eigenvector centrality values suggest that they have strong ties with other influential knowledge holders.

Table 3. Centrality measures of major knowledge holders in the transmission network

Actor	Degree	Betweenness	Closeness	Eigenvector
Elder Farmer A	42	0.381	0.612	0.842
Traditional Healer B	39	0.324	0.584	0.791
Seed Keeper C	37	0.287	0.571	0.765
Farmer D	31	0.223	0.539	0.692

DISCUSSION

The convergence of index-based and network evidence shows that ecological memory is the central adaptive asset of the Saora farming system and that its value is realised through a specific social architecture. The dominance of ecological memory in the resilience regression ($\beta = 0.61$) elevates it above conventional drivers such as landholding, consistent with evidence that flexible, knowledge-rich adaptation enhances community resilience (Petzold et al., 2024) and reinforces Berkes's concept of ecological-memory reservoirs (Berkes, 2017).

Crucially, the networks show this memory is neither evenly held nor freely circulating. It is concentrated in a core of elders, healers and seed keepers, channelled through broker pathways, organised into modular sub-cultures and transmitted along an age gradient mediated by middle-aged translators. The strong centrality–EMI correlation ($r = 0.68$) and high modularity ($Q = 0.64$) imply both strength and fragility: the system is efficient and locally robust yet acutely dependent on a few high-betweenness bridges whose loss would fragment transmission (Crona & Bodin, 2017; Singh et al., 2023).

The results of betweenness centrality were complemented by closeness and eigenvector centrality that offered additional insights into the functioning of the indigenous knowledge network. Those who were closer to other network members on average, or had higher closeness centrality, could easily access and pass on ecological knowledge. This indicates that elders, healers and seed keepers, not only served as knowledge holders, but also as efficient communicators within the network. Likewise, high eigenvector centrality values suggest that these actors also had links to other influential well connected actors, which further increased their overall influence within the knowledge system. The high closeness and eigenvectors scores of key actors then show that they are also knowledgeable and influential actors in terms of climate resilience and ecological memory.

This structural reading reframes adaptation policy. Rather than treating TEK as a diffuse cultural background, interventions can target the actors and ties that carry it, documenting elder and healer knowledge, supporting seed keepers, and strengthening the middle-aged translator layer that connects elders to youth. Identifying brokers also offers an efficient entry point for extension: engaging central actors can accelerate the diffusion of validated practices through the wider network. The findings suggest that strengthening climate resilience requires community-owned knowledge commons to preserve ecological knowledge held by elders, healers and seed keepers. Enhancing intergenerational learning, particularly through middle-aged knowledge transmitters and youth engagement, is essential. Furthermore, protecting key knowledge brokers and leveraging central actors for extension can improve the diffusion of climate-resilient practices within tribal communities.

Limitations include the single-village scope and reliance on self-reported network and memory data. Because ecological memory is a factor of CRI, the regression does not necessarily indicate any independent prediction. It would be good to develop separate indices to validate this relationship in future studies. Future work should extend the multi-layer network approach across villages and incorporate longitudinal data to observe transmission and its disruption over time.

CONCLUSION

The ecological memory plays an important role in the resilience to climate change among Saora tribal farmers and the indigenous knowledge is shared with the elders, healers and seed keepers. Social Network Analysis revealed that the knowledge network was centralized and modular with some actors exerting dominant influence in the transmission of knowledge. The betweenness centrality identified some actors that are critical bridges and thus the network is vulnerable if these actors are absent. The closeness centrality revealed some key actors who are connected to each other and can be easily reached to share ecological knowledge at a faster rate across the community whereas high eigenvector centrality highlighted strong relationships of these key actors with other key actors. There is a need for further research on similar indigenous knowledge networks in other tribal communities and to evaluate changes in transmission of indigenous knowledge over time in the era of modernization and climate change pressures.

DECLARATIONS

Ethical consideration and consent to participate: Every procedure involving human subjects was conducted in respective manner, and each participant gave their informed consent before any data was collected. Confidentiality, privacy, and voluntary involvement were all fully respected during the interview process.

Conflict of interest: The authors reported that there were no known competing financial interest and personal relationships to disclose that could have appeared to influence the work reported in this paper.

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Research Article

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Effectiveness of Community Approaches for Millet-based Entrepreneurial Promotion in Odisha, India

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HIGHLIGHTS

- The community approach has the potential to foster millet based entrepreneurship. Stakeholders have a positive perception towards the community engagement.
- KMO value (0.934) and Bartlett's test (χ^2=1324.788, p<0.001) showed that the dataset were suitable for Principal Component Analysis.
- PCA extracted major indicators are leadership ability, fund management and risk orientation in the study.
- Targeted capacity building interventions in financial management and leadership development are need to be addressed for entrepreneurial development.

ARTICLE INFO

Keywords: Millet entrepreneurship, Community approach, Rural development, Effectiveness, Milletpreneurs, PCA.

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ABSTRACT

Millets are emerging as a powerful solution for tackling malnutrition and promoting economic development in rural communities. Milletpreneurship is a key to reduce poverty, sustaining livelihoods and fostering agricultural resilience. Community approaches are critical for promoting milletpreneurship, yet empirical evidence on their effectiveness remains limited. This study addresses how diverse stakeholders' interactions influence entrepreneurial outcomes in the millet value chain. 120 purposively selected milletpreneurs engaged in millet production and enterprises across the value chain of high millet producing areas of Odisha were interviewed in the year 2024. Thirteen effectiveness indicators were developed through expert judgement using a normalization method. Principal Component Analysis (PCA) technique was used, validated through Kaiser-Mayer-Olkin (KMO=0.934) and Bartlett's test (χ^2=1324.788, p<0.001), revealed that individual entrepreneurial competencies like leadership ability, fund management and risk orientation drove 64.1% of the variance in perceived effectiveness. While 41.7% perceived moderate effectiveness and 26.6% high effectiveness, 72.1% cumulative variance suggested heterogeneous community profiles. Results indicated deficiencies in social media exposure and marketing channels. Policymakers need to intervene through capacity building in financial management and leadership development, multidimensional support integrating infrastructure, finance and market linkage and differentiated interventions acknowledging diverse operational realities rather than uniform approaches.

INTRODUCTION

Millet is a group of small-grain cereals that are emerging as a powerful solution for tackling malnutrition and promoting economic development, particularly in rural communities (Deevi et al., 2024). India's population has topped the world, and the responsibility of food growers has increased as they need to produce more on a shrinking patch of land every subsequent year. Thus, policymakers'

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attention is towards sustainability. The resurgence of millets is driven not only by their nutritional and environmental benefits but also by a growing awareness of their potential to contribute to sustainable livelihoods. Household demand for bajra, jowar, ragi and minor millets is 2.65, 2.55, 1.06 and 0.09 million tons (mt) respectively, which is expected to rise by 5-10%, leading to 2.8-2.9, 2.7-2.8, 1.11-1.7 and 0.1 mt, respectively, by 2029, creating a demand-supply gap (Sreekala et al., 2022). Driven by health-conscious and gluten-free trends, the millet-based snacks market is projected to grow from US$43.52 million in 2023 to US$ 85.91 million by 2030 at a 10.2% CAGR (Dole, 2026). Empowering entrepreneurs to create value-added millet products is essential for reducing poverty, generating sustainable rural livelihoods and fostering a resilient agricultural economy (Ranjan & Jahan, 2023; Dzingirai, 2021; Fortunato & Alter, 2015). Fostering milletpreneurship requires structured channels like Farmer Producer Companies (FPCs) to provide collective action and facilitate necessary market development around underutilized crops (Pani et al., 2023; Notaro et al., 2017).

Community approaches are key to unlocking the potential with the involvement of local cultures (Lawrence et al., 2021) and there is a need to make national policies to support group approaches (Mhembwe & Dube, 2017). Government initiatives promote millets through incentives, awareness campaigns, PDS inclusion for food security, export promotion and cultural integration like temple *prasadam* (Prasad, 2023; Srivastava, 2023). The Odisha Millet Mission, which is renamed as Shree Anna Abhiyan, works in a group approach to provide snacks to preschoolers (Fortunato & Alter, 2015). This approach also highlights the success and improvement of the livelihood of persons involved in the SHGs (Patel et al., 2014).

The millet production in Odisha had a decreasing trend between 2013 and 2022 from 201 thousand ha to 187 thousand ha, respectively; but the productivity has increased from 819 kg/ha to 964 kg/ha (Mandal et al., 2023). These challenges can be addressed by a collaborative community approach involving government agencies, private companies, NGOs and local farmers. A critical knowledge gap exists regarding the effectiveness of these diverse stakeholders in executing promotional initiatives. It is essential to understand the factors influencing farmers' millet choices, as there are insufficient empirical data capturing the specific perceptions of milletpreneurs and associated partners concerning their mutual support and interaction (Ojha et al., 2025). Without structured insight into these stakeholders' perceptions (Vattekkad et al., 2025), systematic bottlenecks and misalignment remain hidden, which hinders the ability to address operational constraints, optimize community extension approaches and build a robust, scalable framework for sustainable milletpreneurial promotion. Therefore, the study will delineate various enabling factors that are effective for promotion of milletpreneurship through community initiatives.

METHODOLOGY

The data collection was done in Rayagada and Sundargarh districts, where people have been engaged in a community approach for many years, as well as has a high millet production. The interview was conducted in 2024. Total sample size was 120, consisting of millet growers or people engaged in millet-based business, as well as the people engaged in enterprises across the millet value chain, who were selected purposively and these people are termed as milletpreneurs. The interview varied in duration from 45 minutes to 60 minutes per respondent. All the respondents were actively involved during the interview and prior consent was taken. The interview schedule was designed based on the literature review and pilot study. The thirteen indicators under the effectiveness index were developed based on 130 expert judgement relevance weightage under a three-point continuum.

$$\text{Relevancy weightage (RW)} = \frac{\text{Most Relevant x 3 + Relevant x 2 + Irrelevant x 1}}{\text{Max possible score}}$$

Indicators having weightage below 0.75 were excluded, resulting in the selection of thirteen indicators. After data collection, the indicator values were normalized using the max-min method to bring all indicators to a comparable range using formula:

$$\text{Normalization } X_{ij} = \frac{X_{ij} - \text{Min } X_i}{\text{Max } X_i - \text{Min } X_j}$$

Where, X_{ij} is the value of indicator 'j' corresponding to respondent 'i'

Before applying Principal Component Analysis (PCA) the suitability of the data set was measured using the Kaiser-Meyer-Olkin (KMO) value and spherical testing of Bartlett's K-Square ($p<0.05$). PCA was used to derive the communality value, and the weights of each indicator was obtained by using factor loadings of the rotated component matrix and multiply with their respective eigen values. Further, the sum of the normalized value of extracted indicators was divided by the grand total weight to obtain the index value. The index value came within '0' to '1' as normalized data were used.

RESULTS

PCA suitability measure

The sufficiency of the dataset for principal component analysis was confirmed through the KMO and Bartlett's test (Table 1). The KMO value of 0.934 exceeded the threshold of 0.90, indicating exceptionally high sampling adequacy and a compact correlation structure among the thirteen indicators.

Table 1. KMO and Bartlett's Test for PCA Suitability

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.934
Bartlett's Test of Sphericity	Approx. Chi-Square (χ^2)	1324.788
	df	78
	Sig.	.000

The Bartlett's test of sphericity was highly significant (χ^2 = 1324.788, df=78, $p<0.001$), confirming that the indicators were sufficiently intercorrelated to justify factor extraction. These results validate the appropriateness of PCA and confirm that effectiveness is a multidimensional construct.

Interpretation of the variance of components

PCA extracted two components with eigenvalues exceeding the KMO of 1.0 (Table 2). The first two components recorded an

Table 2. Total variance explained by extracted components

Component	Initial Eigenvalue	Extraction Sums of Squared Loadings % of Variance	Rotation Sum of Squared Loadings % of Variance
1	8.331	64.084	39.138
2	1.046	8.048	32.994
3	0.691	.	.
4	0.608	.	.
5	0.407	.	.
6	0.382	.	.
7	0.335	.	.
8	0.300	.	.
9	0.246	.	.
10	0.223	.	.
11	0.169	.	.
12	0.155	.	.
13	0.107	.	.

eigenvalue of 8.831 and 1.046, explaining 64.084 and 8.048% variance, respectively. The remaining eleven components, with eigenvalues between 0.107 and 0.691, were excluded as they explained less variance than a single original variable.

The scree plot (Figure 1) visually confirms this pattern through a sharp elbow after Component 1, reflecting that the effectiveness of community-based millet development initiatives is governed by an integrated framework rather than isolated factors. This dominance reflects the convergence of multiple stakeholder interactions into a unified influence on entrepreneurial development.

The biplot (Figure 2) illustrates that both components together account for 72.1% of the variance, with indicators positioned closer together representing higher mutual correlation. Leadership ability, fund management, risk orientation, achievement motivation and attitude towards group action cluster tightly, indicating they move together across respondents as a single underlying construct of internal entrepreneurial competence. Social media exposure, marketing channels and marketing efficiency occupy a distinct region, separated from the core cluster, signalling that marketing and digital dimensions form a separate, secondary axis of effectiveness.

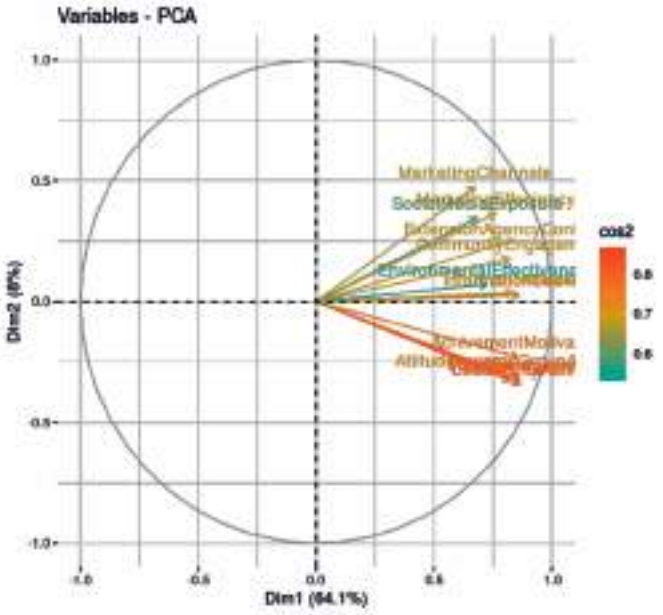


Figure 2. PCA Biplot

In Table 3 the rotated solution of community engagement, information seeking, risk orientation, attitude towards group action, leadership ability, achievement motivation, fund management and innovativeness load more strongly on Component 1, representing internal entrepreneurial competencies, whereas social media exposure, marketing channels, marketing efficiency load more strongly on Component 2, representing external market interface. Leadership ability recorded the highest communality (h^2= 0.863) and highest weight (7.610), confirming it as the most influential and best-represented construct in the framework, with a mean perceived effectiveness of 0.600 reflecting moderate to high confidence among milletpreneurs. Fund management followed as the second highest weight (7.532) and a high communality (0.850), yet its mean score was comparatively low (0.388), revealing a gap between its recognised importance and respondents' actual financial management capacity. Risk orientation ranked third in weight (7.284, communality= 0.788, mean= 0.509), reflecting a generally favourable

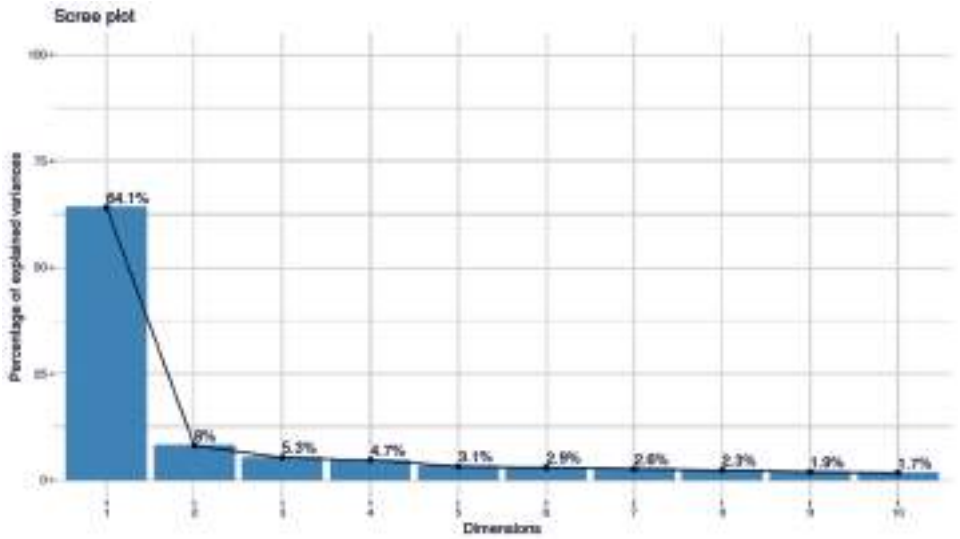


Figure 1. Scree plot showing variance in components

Table 3. Effectiveness indicators with their component variance, communality, weightage, and mean

Indicators	Component Matrix		Rotated Component Matrix		Communality Extraction value (h^2)	Weight of indicators	Mean
	Component		Component				
	1	2	1	2			
Effectiveness indicator							
Community Engagement (COENG)	0.823	0.178	0.494	0.682	0.709	4.885	0.444
Marketing Efficiency (MAREY)	0.762	0.366	0.323	0.780	0.722	3.524	0.412
Information Seeking (INFSE)	0.863	0.027	0.625	0.596	0.762	6.509	0.322
Risk Orientation (RSKOR)	0.825	-0.328	0.833	0.306	0.788	7.284	0.509
Attitude towards Group Action (ATGAN)	0.804	-0.303	0.801	0.311	0.731	6.953	0.471
Leadership Ability (LEDAB)	0.866	-0.341	0.872	0.324	0.863	7.610	0.600
Achievement Motivation (ACHMO)	0.855	-0.228	0.789	0.400	0.779	6.999	0.451
Fund Management (FNDMT)	0.863	-0.320	0.857	0.337	0.850	7.532	0.388
Innovativeness (INNVO)	0.835	0.037	0.597	0.585	0.695	5.669	0.285
Social Media Exposure (SOMEX)	0.683	0.347	0.277	0.714	0.575	3.260	0.042
Marketing Channels (MRCNL)	0.674	0.474	0.186	0.803	0.692	2.405	0.307
Extension Agency Connect (EXAGC)	0.794	0.242	0.430	0.710	0.692	4.277	0.351
Environmental Effectiveness (ENVEF)	0.727	0.072	0.494	0.539	0.532	4.683	0.292

disposition towards calculated risk-taking, consistent with evidence linking risk orientation to entrepreneurial pursuit of innovative ventures (Markowska et al., 2019). Achievement motivation and attitude towards group action followed closely, both exhibiting communalities above 0.73 and moderate mean scores (0.451 and 0.471).

In contrast, social media exposure recorded the lowest mean score (0.042). Despite moderate communality (0.575), pointing towards a severe digital divide rather than measurement weakness. Marketing channels showed both the lowest weight (2.405) and the lowest mean (0.307), suggesting an issue in the marketing channel. Marketing efficiency, although weighted moderately (3.524), had a relatively higher mean (0.412). Community engagement showed a moderate to high distribution (mean= 0.444). Environmental effectiveness recorded the lowest communality (0.532) and a low mean (0.292), suggesting this dimension reflects factors external to individual competence.

Distribution of the respondents based on indicators

The scatter plots (Figure 3a to 3m) represent heterogeneity in individual responses of milletpreneurs under each indicator. Community engagement, information seeking, risk orientation, leadership ability, achievement motivation and innovativeness showed moderate to high, fairly consistent distributions, while fund management displayed a markedly scattered pattern reflecting mixed financial management capacity. Social media exposure, marketing channels and environmental effectiveness clustered towards the lower end of the distribution, confirming these as the weakest dimensions and priority targeted intervention.

The Figure 4 represents the analysis, which reveals a high degree of heterogeneity among respondents with normalised scores generally ranging from 0.100 to 0.850. As illustrated by the multivariate radar chart, there is substantial variance and overlap in key attributes such as community engagement, leadership ability and achievement motivation. While a few individuals exhibit distinctiveness in specific areas like risk orientation or market efficiency, the overarching trend is a uniform profile across the sample. Instead, the data set demonstrates a complex distribution where most subjects display moderate baseline scores, punctuated by highly individualised strengths. Consequently, this multidimensional variability suggests that the target population operates with high diverse, non-monolithic behavioural and operational profile.

In case of the differential level of perceived overall effectiveness (Figure 5), a majority of the respondents have a moderate level of perception that the community approach is effective in promoting entrepreneurship, while 26.6% have a high perception of the approach.

DISCUSSION

The analysis reveals that there is emerging frameworks in rural entrepreneurship literature and simultaneously challenging view points towards certain assumptions regarding community engagement in milletpreneurship. Unlike a generic descriptive study of community development initiatives, the findings provide an empirically grounded analysis of how diverse entrepreneurial capacity within rural communities either disables or enables the effectiveness of the collective action in the agricultural value chain. The heterogeneity observed in the sample, with 41.7% perceived moderate effectiveness and only 26.6% perceived it as high effectiveness (Figure 5). Similarly, the diversity of the responses can be seen in the scatter plot (Figure 3.a – 3.m), suggesting that community-based approaches can operate as a transformative mechanism. The success depends critically on underlying entrepreneurial capacities within the population.

The findings reframe the relationship between individual entrepreneurial attributes and collective action, diverging from previous conceptualisations that treat community approaches and individual competence as separate. Prior research on community-based rural development (Mhembwe & Dube, 2017; Fortunato & Alter, 2015) has predominantly emphasised institutional and

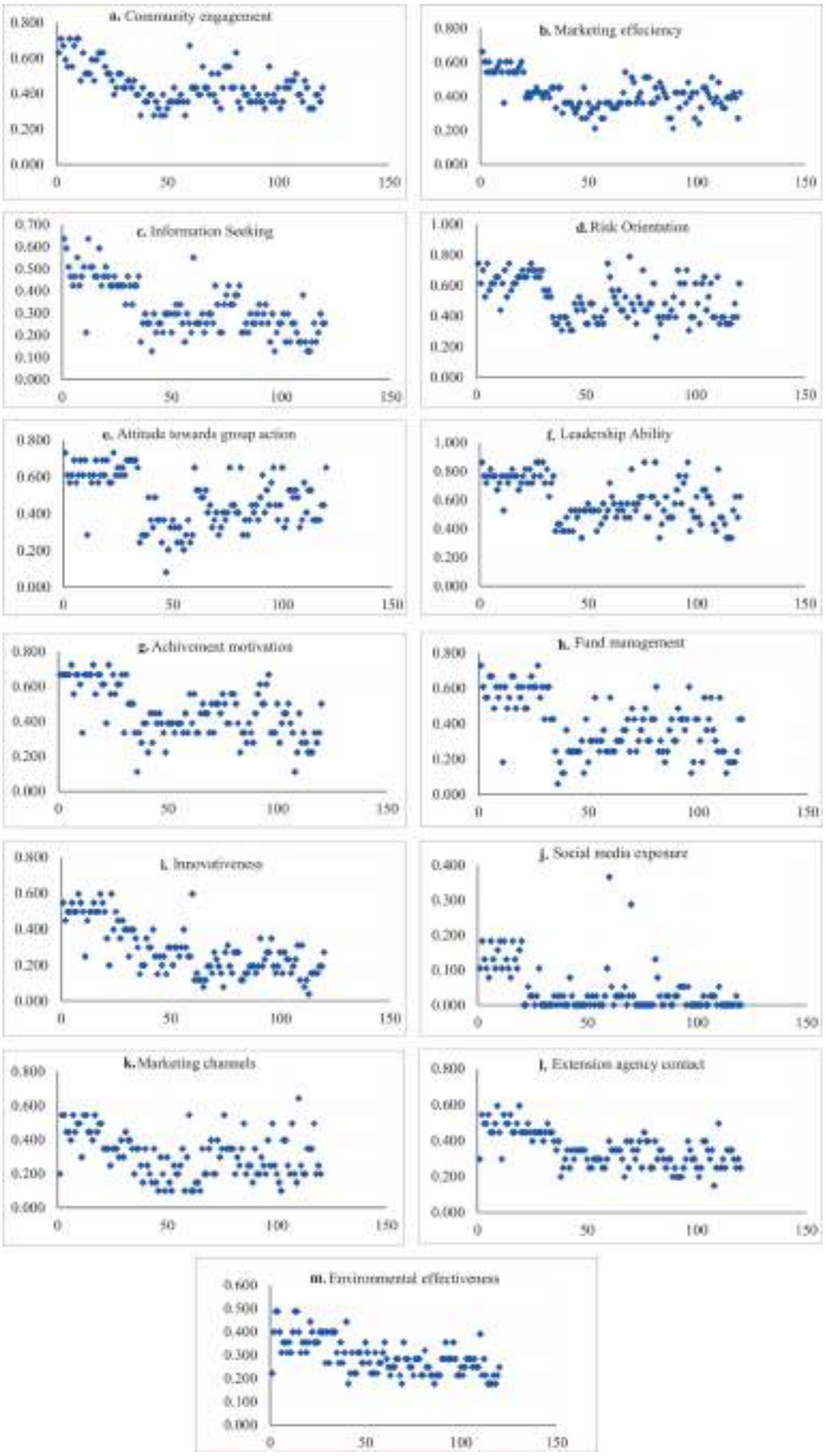


Figure 3. Distribution of respondents based on the indicators

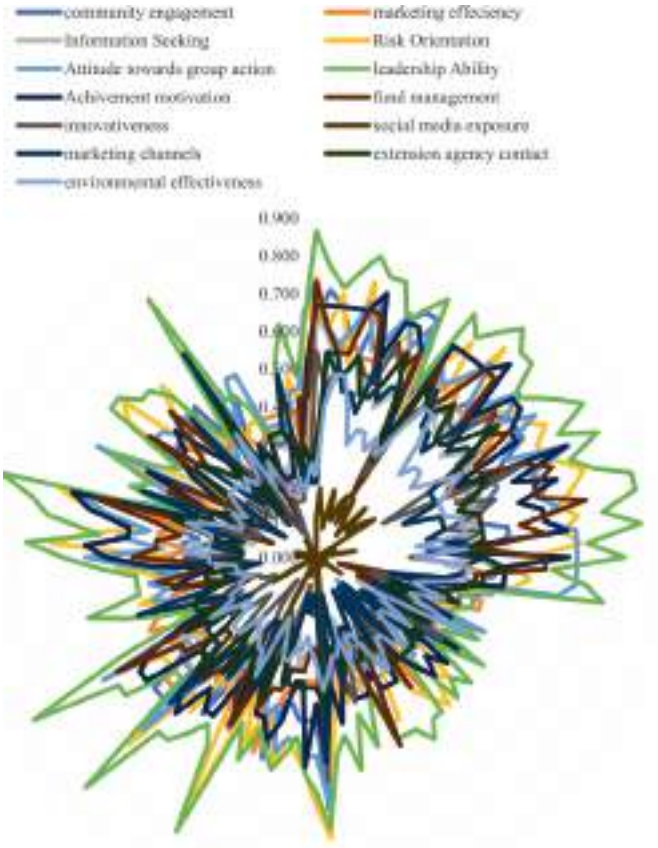


Figure 4. Distribution of effectiveness of the community approach

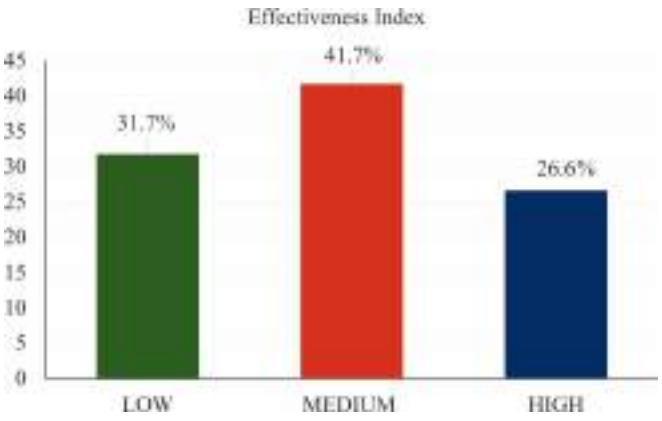


Figure 5. Distribution of the respondents based on the differential level of perceived effectiveness

systematic factors, arguing that the mere existence of cooperative structures or community initiatives drives entrepreneurial outcomes. However, the PCA result demonstrates that 64.1% of the variance in perceived effectiveness is driven by a single integrated dimension comprising individual attributes such as leadership ability (communality=0.863), fund management (communality=0.850), and risk orientation (communality=0.788). This shows that a community's effectiveness is fundamentally driven by individual entrepreneurial competencies (Sinha et al., 2021).

The recent studies on the extension system in India highlight that technological information alone doesn't translate to entrepreneurial success (Pani et al., 2023; Nain et al., 2024). In contrast to that, the findings demonstrate empirically that the gap between moderate and high effectiveness is not primarily bridged by policy interventions at the institutional level, but rather by investment in developing specific entrepreneurial capacities, particularly financial management and marketing efficiency (mean= 0.388, 0.412, respectively), indicating that despite the community framework, many milletpreneurs lack foundational competencies in financial decision-making and market positioning.

In the case of indicators like community engagement, it is evident that a majority of people have a medium to high level of effectiveness. A parallel study on health and care services also emphasises that community engagement is vital for improving health services by involving citizens (De Weger et al., 2018). This shows that milletpreneurs have a good understanding that a collective approach makes a goal more achievable. It is also found that in the case of marketing efficiency (Figure 3.b), the majority have a high level of responses (mean= 0.412), which signifies that milletpreneurs are getting good returns for their produce/products after selling. It plays a crucial role in boosting industrial development by optimizing the sale of industrial products as well as crop production (Ilyash, 2021; Park et al., 2014). The information seeking also has a medium level of distribution, which shows the milletpreneurs have an interest in being informed. A similar study shows that information seeking is crucial for entrepreneurs to understand market needs (Joshi & Anand, 2018). Risk orientation also plays a crucial role in milletpreneurship, which also has a moderate level of effectiveness. High-risk orientation enables individuals to embrace uncertainty, make calculated decisions, and seize opportunities. A similar finding was observed in a study on nascent entrepreneurs, which emphasised that risk orientation fosters entrepreneurship and encourages the pursuit of innovative ventures (Markowska et al., 2019).

Attitude towards group action is also a contributing factor for millet entrepreneurship promotion (mean=0.471). Fostering collective action accelerates entrepreneurial success by leveraging shared resources and diverse viewpoints to solve complex problems and drive innovation (Gielnik et al., 2013; Flores Anaya et al., 2023). But it can also be interpreted that a diverse viewpoint creates heterogeneity, thus only 26.6% perceived it effective (Figure 5), likely the people who have personal entrepreneurial attributes, rather than 41.7% who perceived it moderately effective, which may represent specific capacity building gaps which are not addressed yet. The moderate level of perception towards leadership ability, which is affecting the regional development and the success of the enterprise. Similarly, for entrepreneurial promotion, respondents have a moderate level of perception towards achievement motivation. Higher achievement motivation drives greater innovation, productivity and overall success by enhancing organizational capabilities and performance (Modak et al., 2018; Tanjung & Musa, 2021).

Fund management shows a quite scattered response, which means milletpreneurs have a quite mixed response towards it. A significant portion of the milletpreneurs perceived adequate financial management capabilities, which is important for entrepreneurship development. People who are well trained, educated are more

efficient in dealing with funds, making investments, take steps for their economic well-being, rather than those who are not. Regions with higher fund management skills might experience better financial outcomes and greater economic stability. In case of innovativeness, a significant number of responses have been recorded where the majority of respondents have a moderate level of perceived effectiveness, which shows milletpreneurs are interested in learning and becoming part of newer practices. Areas with higher levels of innovativeness might experience greater economic growth, innovation, and competitiveness. This can be taken into consideration that innovativeness can be further enhanced by stakeholder convergence (Schut et al., 2015).

In the studied location, milletpreneurs have a lower perception towards social media engagement, which also represents the weakest dimension (mean=0.042, communality=0.575). Regions with lower digital literacy rates and limited internet access often exhibit lower engagement in social media among rural populations. Rural communities frequently face challenges in accessing digital and social media platforms because of poor internet connectivity and difficulties in utilizing the technology. It can also be interpreted that the problem is not just about access to digital technology, but that the community as a whole hasn't grasped that digital marketing is a useful tool for milletpreneurial development. In the case of the marketing channel, milletpreneurs comparatively have a negative perception towards milletprenurship, as the respondents were still unaware of all possible channels to sell their products or produce, but it is an essential factor as it helps in creating awareness, generating interest, and facilitating sales, ultimately contributing to the success of an entrepreneurial venture.

Engaging frequently with extension agencies is a key factor in entrepreneurial success by providing valuable guidance, resources, and support throughout the business development process. This can include assistance with market research, business planning, financing, and networking opportunities, ultimately increasing the chances of entrepreneurial ventures thriving. A study with a similar context supports that extension contact improves business planning and market access. Environmental effectiveness has one of the lowest perceptions towards effectiveness.

A majority of the respondents (41.7%) perceived the community approach as moderately effective, while only 26.6% viewed it as highly effective. This distribution suggests that many milletpreneurs have not yet been exposed to the full spectrum of benefits this approach offers. However, this gap represents a clear strategic opportunity. Establishing effective linkages through a multidimensional approach strictly focuses on infrastructure development, financial support, capacity building and proper market linkage, can bridge this divide (Gudla et al., 2026). Ultimately, the evidence strongly supports that a well-supported community approach is highly active in building and sustaining local entrepreneurial skills.

It was found that there is pronounced behavioural and socioeconomic heterogeneity observed among respondents, which strongly suggests that uniform one-size-fits-all extension or marketing strategies will likely be ineffective. Instead, the presence of distinct individualized strengths, such as leadership or risk orientation, points to the necessity for targeted differentiated interventions. Leveraging this specific local capacity rather than assuming a monolithic community profile, policymakers and extension agencies can foster more resilient and adaptive group dynamics. Recognizing this multidimensional diversity is crucial for designing customized capacity-building programmes that align with the actual varied operational realities of the targeted population.

CONCLUSION

The study reveals that community-based milletpreneruship effectiveness is fundamentally driven by individual entrepreneurial capacities rather than institutional structures alone. The 64.1% variance explained by a single integrated dimension comprising leadership ability, management and risk orientation challenges traditional assumptions that treat community approaches and individual competencies separately. The heterogeneous distribution (41.7% moderate, 26.6% high effectiveness perception) demonstrates that one-size-fits-all extension strategies are ineffective. Rather than institutional policy interventions, bridging the moderate-to-high effectiveness gap requires strategic investments in targeted entrepreneurial skill development. The pronounced behavioural and socioeconomic diversity necessitates customized, differentiated capacity-building programs aligned with actual operational realities. Therefore, addressing gaps in social media exposure, marketing channels and fund management through stakeholders' convergence can enhance community resilience. This empirically grounded analysis provides policymakers and extension agencies with evidence to design context-responsive, locally adaptive interventions supporting sustainable milletpreneurship.

DECLARATIONS

Ethics approval and informed consent: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional committee of Siksha 'O' Anusandhan Deemed to be University. Verbal consent was taken before conducting the interview from the respondents. Verbal modality is used to include all the participants with low literacy levels while keeping an equal approach for all participants.

Competing interests: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that during the preparation of the work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

Conflict of interest: The authors declare no conflict of interest.

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Research Article

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Exploring Transformative Dimensions of Leadership and Life Skills Initiatives among Female Students in Higher Education Institution: A Qualitative Inquiry

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HIGHLIGHTS

- Female students perceived leadership as influencing, guiding, and empowering others through teamwork and effective decision-making.
- Themes from this study align with national higher education priorities established in the NEP 2020.
- Participants showed a preference for interactive and hands-on approaches, emphasizing the importance of active engagement in learning.

ARTICLE INFO

Keywords: Leadership, Life skills, Motivational factors, Programs, College girls, University.

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ABSTRACT

Leadership and life skills development programs play an important role in sculpting empowered, confident, and socially responsible women leaders in higher education. This qualitative study investigated how female undergraduate and postgraduate students at MMV, BHU, perceive these initiatives, examining program choices, information sources, motivational factors, perceived benefits, and barriers to participation. The study was conducted between February 2023 and July 2025. Using a purposive sampling approach, in-depth semi-structured interviews were conducted across two phases. Braun and Clarke's theme framework was used in the data analysis, supported by NVivo. The analysis revealed six prominent themes: interpretations of leadership, information sources, workshop types, motivation determinants, perceived benefits, and perceived barriers, each encompassing multiple subthemes. Findings demonstrate that leadership and life skills initiatives exert a significant and positive influence on students' personal growth, self-confidence, communication abilities, and leadership orientation. Participants highlighted enhanced self-awareness, goal clarity, and preparedness for professional and community engagement, while also identifying structural and personal constraints that limited full participation. Findings underscore the critical need for flexible, inclusive, and student-centred leadership development programs within women's colleges to effectively nurture future leaders capable of driving meaningful social and professional change.

INTRODUCTION

As the world continues to change rapidly, it is increasingly important that the younger generation be outfitted with necessary life skills (Haerani & Sari, 2024). In the 21st century interconnected and ever-changing world, universities' traditional knowledge is no longer enough (Haerani & Sari, 2024) but is expected to do more than just teach students about their fields of study. It should also help them grow as people by teaching them leadership skills and important life skills (Tawil & Locatelli, 2015; Yadav & Vatta, 2026).

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Education is crucial to developing the information, skills, attitudes, and values needed to contribute to and benefit from an inclusive and sustainable future (Incirci et al., 2018).

A key aspect of higher education is student leadership, which emphasizes the growth of students' capacity to interact, influence, and make constructive contributions to their communities and institutions (Komives et al., 2009). Leadership is now considered as a relational and dynamic process that all students, regardless of their roles, may acquire and practice rather than just as a formal position of power (Fletcher, 2012).

In the Indian context, higher education plays a crucial role in molding socially responsible and competent citizens capable of contributing to national development (Tilak, 2015). However, challenges related to holistic development remain particularly significant for female students. In India, the changes in National Education Policy (NEP, 2020) and curriculum have focused on adding life skills and leadership training to college programs (Pathak, 2023). The University Grants Commission (UGC) has launched the Life Skills 2.0 (Jeevan Kaushal) Curriculum and Guidelines (Pathak, 2023). This curriculum has been crafted with NEP 2020 accordance and is intended to be flexible enough to suit the specific needs of various institutions. It sets forth goals, learning outcomes, and hands-on learning activities aimed at equipping students with skills such as effective communication, teamwork, problem-solving, and leadership capabilities (UGC, 2023). The Government of India's youth development programs, like Mera Yuva Bharat (MY Bharat) and the National Service Scheme (NSS), help young people aged 18 to 29 years become better leaders, get involved in their communities, and learn through experience outside of school (Ministry of Youth Affairs & Sports, 2025).

Empirical research suggests that life skills training plays a crucial role in enhancing leadership potential by improving one's ability to solve problems, adapt to new situations, and interact effectively with others (Karagianni & Montgomery, 2018). Women are the essential other half, and their empowerment is crucial to the advancement of society as a whole (Yadav et al., 2023). The leadership and life skills should be integrated as complementary elements of a student's holistic development rather than being treated as distinct and separate areas. Studies have indicated that participating in project-based learning and leadership workshops can substantially boost women's leadership skills (Dasgupta & Stout, 2014; Coluccio et al., 2024). In recent years, Banaras Hindu University (BHU) introduced structured initiatives, including workshops, mentorship programs, interactive sessions, and counseling support systems, aimed at strengthening student leadership and life skills. (Varanasi: Bid to develop leadership qualities in Mahila Mahavidyalaya students, 2022; Banaras Hindu University: Better life skills help remain balanced, 2023).

METHODOLOGY

The investigation used a qualitative research design that was guided by the social constructivist paradigm (Sandelowski, 2000; Creswell, 2021). Mezirow's Transformative Learning Theory serves as the foundation for this qualitative research (Mezirow, 1991). All aspects of the research protocol were comprehensively reported in accordance with the Consolidated Criteria for Reporting Qualitative Research (COREQ) guidelines (Tong et al., 2007) (Supplementary file S1). The study was conducted at Mahila Mahavidyalaya (MMV), BHU, Varanasi. This setting offered a relevant and informative context for investigating the effects on female students. The sample comprised female students enrolled at MMV, BHU, Varanasi, who had participated in student leadership and life skills initiatives (workshops). The sample included students from 2 academic sessions (2023-2024 & 2024-2025) with different programs and years of study.

Purposive sampling strategies were employed to recruit the study sample, who have completed any workshop that is implemented under the umbrella of 'Student Leadership & Life Skill Initiatives.' Subsequently, a clear language statement describing the research guidelines along with the consent form was delivered to all the interested participants in person. An in-depth, semi-structured interview guide comprising seven open-ended questions (Supplementary file S2) was developed to gather data, which was pilot tested with five students for refinement. No revisions were needed in the interview guide, as the respondent was able to answer. Apart from the open-ended question, some socio-demographic information was also obtained from the participants, which included age, course & employment status. The interviews were carried out in two phases: the first phase took place from February 29 to April 25, 2024, and the second phase occurred between March 29 and July 4, 2025, as two sessions were deemed necessary to assess the transformative outcomes.

Data were obtained from 48 students in a closed classroom environment, ensuring that no faculty members or familiar batchmates were present during the interview recording process. All interviews were face-to-face and audio recorded., in either Hindi or English, according to the interviewee's preference, till the 48th interview, as saturation was reached at this number. The first 38 interviews were conducted in phase I of the study, and the other 10 were conducted in phase II. The average duration of the interviews was 15 min 20 sec.

Using Braun and Clarke's six-phase thematic analysis framework (Braun & Clarke, 2006), an inductive thematic analysis was carried out simultaneously with the interviews to ensure a balanced approach to data collection and analysis (Sandelowski, 2000). The coding process utilized NVivo (Version 15, Lumivero 2024) software. These codes were further categorized into potential themes, which were thoroughly reviewed and refined, and in the final phase, each theme was clearly defined and described in detail.

Program description

In pursuance of the vision of holistic student development and in alignment with the university's broader objectives, the Leadership and Life Skills Development Initiative was launched in July 2022 on a pilot basis, which was further extended into other departments and faculties of the university, witnessing the successful implementation of the initiative in MMV (Varanasi: Bid to develop leadership qualities in Mahila Mahavidyalaya students, 2022; Banaras Hindu University: Better life skills help remain balanced, 2023). The initiative was conceived with the objective of nurturing leadership qualities and essential life skills among students, enabling them to become confident, self-aware, socially responsible, and

future-ready individuals capable of meeting academic, professional, and societal challenges (Nurturing future leaders: BHU trains over 800 students under FLY, 2024). To ensure effective implementation, a structured Leadership and Life Skills Committee was constituted at MMV, comprising one coordinator supported by an appropriate number of faculty members drawn from different disciplines (Varanasi: Bid to develop leadership qualities in Mahila Mahavidyalaya students, 2022).

Under this initiative, the MMV Student Clubs were established; the clubs aimed to create an enabling and agile institutional culture that would allow students to explore, experience, and strengthen their leadership traits and life skills. To operationalize these goals, five student clubs were formed, namely the Communication Club, Cultural Club, Creativity Club, Sports Club, and Open Mic Club. Each club addressed specific dimensions of leadership and life skills development, ranging from communication and creative expression to physical wellness, teamwork, confidence building, and direct audience engagement, thereby providing diverse platforms for experiential learning and holistic growth.

Supplementary file S3 offers a comprehensive overview of the activities carried out by the Leadership and Life Skills Development Initiative during the 2023–2024 and 2024–2025 academic years. Each activity is detailed with its name, stated goal, and the total number of student participants. This information was sourced from institutional archives, official event reports, and verified attendance records. The dataset was meticulously compiled and cross-checked to ensure the accuracy and transparency of the data.

RESULTS

Six major themes were identified through analysis of 48 interviews associated with the role of students participating in the Student Leadership and Life Skills Initiatives programs: (i) Interpretations of Leadership, (ii) Information Source, (iii) Workshop Types, (iv) Motivation Determinants, (v) Benefits, and (vi) Perceived Barriers.

As shown in Figure 1, a word frequency analysis was conducted in NVivo 15 software. After removing stop words and performing basic text cleaning, a word cloud was generated to visually represent the most frequently occurring terms.



Figure 1. Word cloud representing frequently used keywords by students in their qualitative responses.

DISCUSSION

This qualitative study delved into the impact of the Leadership and Life Skill Development Program at MMV, BHU, through an in-depth examination of students' lived experiences and perceptions. The study derived major themes and subthemes by analyzing how participants constructed meaning from their experiences. Analysis of interview data indicates that the program had a meaningful and positive influence on students' personal and leadership development. The themes have contributed to understanding the study's primary aims. These aims closely correspond with the University Grants Commission's Life Skills 2.0 (Jeevan Kaushal) Curriculum, which emphasizes leadership and managerial skills, communication competence, ethical values, and holistic student development as fundamental objectives of undergraduate education in India (Pathak, 2023).

Subsequently, the themes arising from this study coincide with national higher education targets specified under the NEP 2020, as expressed in UGC policy documents and scholarly discussions published by the Association of Indian Universities (Association of Indian Universities, 2025). These documents underline the need for universities to go beyond academic instruction and promote students' holistic development by strengthening life skills, leadership potential, ethical values, and social responsibility, enabling graduates to respond effectively to personal, professional, and societal challenges (Association of Indian Universities, 2025). The

Table 1. THEME-1 Interpretations of Leadership

Sub-themes	Quotes
Leading Quality	"Leadership is… the ability to lead others…by guiding, managing, and directing people to effectively perform their duties." (P2, 22 years, PG) "…It is about leading others, guiding them, and yes, of course, motivating them when they need support." (P14, 21 years, UG) "Leadership means one person leading while others follow…" (P47, 23 years, PG)
Teamwork	"A leader is someone who moves ahead and takes others along… right… this quality can be referred to as leadership." (P42, 24 years, PG) "Umm… It means taking initiative to guide a team clearly, stay focused on goals, and help others move forward." (P43, 20 years, UG) "True leadership means moving forward together as a team." (P47, 23 years, PG)
Leadership is taking initiative	"Leadership is… taking the initiative to bring the change we want to see in society." (P39, 23 years, PG) "Leadership is not all about becoming a leader; it is about being able to take initiative, even in the small aspects of our lives." (P8, 20 years, UG)

Table 2. THEME-2 Information Sources

Sub-themes	Quotes
WhatsApp Group	"There is a college WhatsApp group where information keeps coming in… that's how we get to know about the workshop." (P18, 20 years, UG) "We got the information through the WhatsApp group." (P25, 25 years, PG) "Yeah… so, there is a common WhatsApp group; I joined it… and get all information from there only." (P38, 19 years, UG)
Peer	"I received the information through my seniors and batchmates." (P6, 18 years, UG) "I came to know about the workshop through my classmates." (P9, 21 years, UG) "…I have friends, and they usually tell me about these workshops…" (P13, 20 years, UG)
Faculty	"…also, our professors keep telling us about these workshops." (P39, 23 years, PG) "When I came to class, Ma'am used to tell me about it." (P13, 20 years, UG)

Table 3. THEME-3 Workshop Type Preference

Sub-themes	Quotes
FLY (Finding the Leader in You)	"I chose the FLY workshop, um… there were many activities; we got to learn a lot of new things from it." (P39, 23 years, PG) "I preferred FLY, because it was very practical…we had one-to-one interaction with professors and included interesting games, which made it more engaging and effective." (P6, 18 years, UG) "I chose the Fly workshop because it improves personality and skills. I lacked confidence, and Fly helped me build it." (P37, 25 years, PG)
Self-Defense	"Self-defense means… gaining confidence and… learning to handle situations, which is why I give more importance to the self-defense workshop." (P7, 24 years, PG) "Because… it's very relevant in today's scenario. Everyone should learn it, regardless of gender." (P13, 20 years, UG) "I found the self-defense part very useful, and that is the main reason I chose this workshop." (P47, 23 years, PG) "Self-defense is crucial for girls so we can protect ourselves when no one else is around." (P1, 19 years, UG)
Calligraphy	"I enjoyed the calligraphy workshop… because it helped me improve my handwriting and express my creativity in a calm and focused way." (P18, 20 years, UG) "The calligraphy workshop was very productive for me, and it is something I can use in other areas as well." (P43, 20 years, UG) "I took the calligraphy workshop because the timing was convenient, and I definitely found it interesting." (P42, 24 years, PG)
Writing Skills Workshop	"…from all I enjoyed the Writing Skills workshop… umm, we learned prose on the first day, then poetry, and how to create short fiction on the final day… It was a great experience." (P41, 21 years, UG) "I, uhh…, went for the Writing Skills workshop because… like self-defense matters, but my own interest is more towards writing." (P48, 25 years, PG) "I chose it because, umm, it focuses on basics like essay writing and handwriting, which really help in academics. We did one, and it was really useful." (P43, 20 years, UG) "I enjoyed the Writing Skills workshop the most. We learned poetry and jingles, and the mentor was really good." (P46, 21 years, UG)

Table 4. THEME-4 Motivation Determinants

Sub-themes	Quotes
Topic of Interest	"I already had an interest in writing…so I was curious to learn, which drew me to the creative writing workshop." (P41, 21 years, UG) "…motivation is…like I go for that workshop, which I found interesting, like…the calligraphy one." (P39, 23 years, PG)
Personality Development	"I felt that, umm… If I attended these workshops, some qualities would develop in me, which would, you know, really help my personality." (P8, 20 years, UG) "While attending the workshop, I didn't realize much, but afterwards I could see a positive change in myself." (P47, 23 years, PG) "I found leadership traits in myself through the FLY workshop, which improved my personality." (P28, 20 years, UG)
Life Skills	"I felt that, umm… doing these workshops would help me improve the qualities that I, you know, don't really have." (P21, 19 years, UG) "Because… these workshops teach skills that are really important for life." (P17, 22 years, PG) "I thought that, like… by joining these workshops, I would pick up some life skills and learn something new, something not part of my everyday routine." (P4, 21 years, UG)

Table 5. THEME-5 Benefits

Sub-themes	Quotes
Problem Solving	"Actually, umm… self-defense helps us to tackle difficult situations. Like, when we are outside and don't know what might happen, we have to think quickly and decide what to do on our own." (P18, 20 years, UG) "...workshops give girls a place to learn how to contribute to society, solve problems, and deal with their own issues." (P7, 24 years, PG) "Yeah, like… if in the future I go for a job interview and my communication isn't good, that becomes a problem. So, umm… workshops help us think, communicate, and solve real-life problems instead of just following book language." (P3, 20 years, UG)
Decision Making	"We gained real benefits from these workshops, like learning how to make decisions quickly. These decision-making skills are useful and can be applied in our day-to-day life." (P26, 18 years, UG) "Now I make decisions for my own happiness… my family's happiness, and my career, which makes these workshops very beneficial for my future…" (P6, 18 years, UG) "…these workshops helped us learn how to make decisions in life; this can be counted as a benefit…" (P33, 20 years, UG)
Taking Initiatives	"After attending the workshop… I felt motivated to take initiative and, yeahhh, face my fear of failure." (P33, 20 years, UG) "Through the FLY workshop, … umm … I learned about taking initiative, one of the five pillars, and … yeahhh … for me, it felt important and beneficial." (P39, 23 years, PG) "In the workshop, … umm … I heard about the importance of taking initiative, and it will help me in the future." (P14, 21 years, UG)
Cultivate New Skills	"We get chances to learn new skills, umm, like … aaa … the vertical gardening workshop, which I had never tried before…" (P41, 21 years, UG) "It helps us learn new skills, like writing and … (thinking) … clay modeling." (P48, 25 years, PG)
Being Innovative	"…I started trying different and innovative ways, and I feel it's becoming part of my daily life now." (P1, 19 years, UG) "I feel more open to experimenting and trying different ideas…" (P15, 23 years, PG) "In the future, umm, at work I feel these new ideas will help me, and, yeahhh, I can work in more innovative ways." (P36, 18 years, UG)
Boost Confidence	"The workshop helped me to feel more confident…" (P35, 22 years, PG) "It, umm…boosted my confidence; now I can handle tough situations too." (P38, 19 years, UG)

program's results also align with the Government of India's overarching youth-development strategy, which emphasizes the importance of life skills, civic participation, leadership, and motivation in enabling young adults to make significant contributions to society (Verma & Chauhan, 2022).

The study further stated that faculty, peers, and social media platforms (WhatsApp) served as key sources of information regarding leadership and life skills workshops. The significance of institutional channels supports the findings of Dugan and Komives (2010), who underlined the crucial role of higher education institutions in building leadership awareness and participation among students. Young adults' growing use of social media reflects changing information transmission patterns, requiring program organizers to use both traditional and digital methods. These findings

Table 6. THEME-6 Perceived Barriers

Sub-themes	Quotes
Time Management	"…time…due to exams, managing time for workshops becomes difficult." (P10, 22 years, PG) "One thing I dislike is…the timing…uhhh…which often becomes a challenge to all of us." (P43, 20 years, UG) "For us…balancing workshops with regular classes becomes difficult when both are scheduled at the same time." (P13, 20 years, UG) "Barrier...(thinking)…missing our class… When workshops are at different hours, we end up missing classes." (P42, 24 years, PG)
Dialect	"I remember in some workshops…language was a barrier; it was in English only." (P39, 23 years, PG) "In the last workshop… the instructor spoke in a Bengali accent, and even though I understood it, I couldn't interact much." (P42, 24 years, PG) "…Since many students weren't from an English background and the sir wasn't comfortable in Hindi, it became difficult for both ends." (P20, 24 years, PG)
Lack of Resources	"Yes, limited space, I think, … you know … sitting comfortably was difficult in a few workshops." (P39, 23 years, PG) "During the calligraphy workshop, there were not enough tools for all the students. It should be an appropriate quantity…" (P21, 19 years, UG).
Duration of Workshops	"Like the recent five-day workshop, umm, it was hard to attend all the days." (P48, 25 years, PG) "Yeah...Workshops are scheduled back-to-back for months, and then there are very few in other months...which makes the schedule uneven." (P47, 23 years, PG) "In the calligraphy workshop… I felt that the time was too short, as we learned only basic letters and wanted to explore more styles…" (P39, 23 years, PG)

coincide with Pandey et al. (2020), who reported that college students utilized social media significantly, notably WhatsApp and Facebook, and spent plenty of time on such platforms (Gupta & Vatta, 2025). Moreover, participants also demonstrated a preference for an interactive and hands-on approach, underscoring the relevance of active engagement in learning. This finding is similar to Jenkins and Owen (2016), who highlighted that experiential and high-impact educational techniques play a significant role in supporting students' leadership development. Students preferred FLY, self-defense, calligraphy, and writing skills workshops over others, which clearly shows their interest in programs that help them with both personal growth and leadership development, which was also mentioned by another study (Caza et al., 2010).

Another significant discovery has to do with identity formation and empowerment. This study corresponds with Transformative Learning Theory (Mezirow, 1978, 1990, 2000), which indicates that critical reflection can lead to important adjustments in views, attitudes, and actions. Gray et al. (2019) observed that training improved women's self-efficacy and self-confidence, and Ferrari (2022) identified a significant but minor improvement in confidence after training. Despite these advantages, female students identified challenges such as time constraints, academic loads, lack of resources, and language. Rosch and Stephens identified similar issues, indicating that barriers frequently limit students' engagement in leadership development activities (Rosch & Stephens, 2017). Overall, our findings emphasize the need for developing accessible, adaptable, and student-centered leadership programs that may effectively support female students' personal and professional development.

CONCLUSION

The study demonstrates that the Leadership and Life Skills Development workshops at MMV, BHU, effectively foster essential leadership qualities and life skills among students. The programs strengthened critical thinking, communication, decision-making, innovation, and self-confidence while encouraging students to view leadership as a quality-driven, participatory process rather than a position of authority. By motivating students to step beyond their comfort zones, the workshops promoted academic, personal, and social development, resulting in more confident, responsible, and socially aware individuals. The findings highlight the importance of mentorship, aptitude development, and structured student leadership roles in enhancing ownership, peer learning, and the long-term sustainability of such initiatives. Establishing dedicated spaces for leadership activities and clearly defining student responsibilities can further improve engagement and implementation. The study advocates for flexible, inclusive, and student-centred leadership development frameworks in higher education to nurture adaptable, socially responsible leaders capable of driving positive change in their professions and communities.

DECLARATIONS

Ethical approval: The research protocol for this inquiry was approved by the Ethics Committee of the Institute of Medical Science, Banaras Hindu University (IMS/IEC/November/2025/30).

Conflict of interest: The authors declare no conflict of interest.

Authors' contribution: Five investigators were involved in implementing this qualitative inquiry. The study was conceptualized by senior female author LV having expertise in extension & communication, and the methodology was cooperatively designed by all authors. Two authors SP (a female doctoral scholar of food & nutrition) and JJ (pursuing a postgraduate degree in extension and communication), did the review of literature, gathered the data, and carried out the data analysis. Before data collection, the postgraduate student (JJ) as well as the doctoral scholar (SP) received formal training in conducting in-depth qualitative interviews and coding. The manuscript was prepared, edited, and structured

collaboratively by LV, SB (a senior female author having expertise in geography & gender studies), and SP. Three authors, LV, SB, and PR (a mid-career female researcher and pediatric cardiologist), offered guidance throughout the research process, validated the methodology, interpreted the findings, and critically reviewed the manuscript. All authors involved with the discussion of the results, contributed to the revision of the manuscript, and approved the final version for submission.

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Research Article

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Support Mechanisms and Challenges of Human Charitable Organizations: Exploring Perception and Practices Regarding Community's Discarded Goods

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HIGHLIGHTS

- Multidimensional nature of Human charitable organisations needs facilities related to health, education, clothing, and overall well-being of residents.
- Key themes include charitable organisation's support system, external needs and expectations of the organisation, challenges faced due to lack of funding and staffing.
- Donation of external communities' discarded goods may support the better livelihood of charitable communities.
- Digital app may create a bridge between external communities and human charitable organisations for the donation of discarded goods.

ARTICLE INFO

Keywords: Discarded goods, Donation, Human charitable Organization, Social welfare, Underprivileged groups.

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ABSTRACT

Human charitable organizations play an important role in satisfying the needs of underprivileged groups. Despite their significant contribution, they confront several obstacles, such as unstable finances, ineffective operations, and trouble obtaining external community support. The main objective of this study is to explore the support system, needs and challenges faced by the human charitable organization in Varanasi district, Uttar Pradesh, India. A qualitative in-depth interview guide was designed to collect data for the study to understand the surroundings, needs, and challenges faced by the organization management and its beneficiaries. The study was conducted in 2025 using a purposive and stratified sampling technique to choose participants who could offer pertinent insights and were actively involved in the operation of these organizations. The findings indicate that the donation of discarded goods is a significant way for charitable communities to fulfil their common needs. It was found that most of the charitable organizations are performing well, however they are facing some challenges such as lack of fulfilled requirements of necessities, education promoting things and health issues. The research also highlighted the necessity of capacity building infrastructure, long-term funding plans, and increased cooperation with external society people through digital or another convenient platform.

INTRODUCTION

Indian charitable organizations, also known as non-profit organizations, are supporting the advancement of education, alleviating poverty, empowering women economically, supporting migrant workers, and facilitating technology integration in underprivileged communities (Plerhoples, 2017). Charitable organizations are non-profit entities dedicated to providing support, resources, and services that enhance the well-being of individuals, communities, or targeted causes. These organizations depend on donations, grants, and volunteer contributions to address a range of social, educational, health, environmental, and humanitarian challenges. Their principal objective is to generate social impact rather than financial profit, and they are increasingly adopting digital

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tools to improve communication, mobilize support, and reinforce advocacy initiatives. In the digital era, non-governmental organizations (NGOs) must determine not only which digital platforms to utilize but also whether to delegate decision-making authority to their supporters (Hall et al., 2019). The acceleration of digitization, particularly following initiatives like Digital India, has further transformed the sector (Yadav et al., 2026). Non-profit organizations serve as institutions of democratic thought, cultivating citizens who are prepared to engage in civic life and promoting internal organizational processes that foster democracy within the sector itself (King & Griffin, 2019). Charitable organizations serve an important function within society; however, they frequently encounter challenges that threaten their long-term sustainability. A primary concern is financial instability. These organizations rely on external funding sources, including grants, donations, and gifts, all of which are susceptible to economic fluctuations (Shevchenko et al., 2024). In addition, these organizations encounter challenges related to organizational capacity, limited access to evidence-based practices, volunteer leadership, and staffing constraints (Despard, 2016). Nonprofit organizations often struggle with governance, fundraising, performance, and the balance between daily operations and their social mission. As social, political, and economic uncertainties increase, it has become more important for these organizations to build capacity and adapt to stay sustainable and serve their communities well. (Waerder et al., 2021). Charitable organizations provide used clothing to individuals in need, offering both immediate relief and sustained assistance in economically disadvantaged regions (Sumo et al., 2023). To enhance fundraising efforts and organizational distinctiveness, management scholars recommend fostering innovation and adopting creative strategies (Svensson et al., 2019). Changing lifestyle and the rise of fast fashion have led to more reusable items like clothes, books, toys, furniture, and household goods being thrown away. At the same time, charities that help vulnerable groups often lack enough resources. Even though many people are willing to donate, a lack of awareness and inefficient redistribution systems make it harder for donations to reach those in need. While most research looks at the welfare work of charities, there is less focus on how donated goods are collected, managed, and distributed. Previous studies have not explored much about how charitable organizations in India, especially in Varanasi, collect, manage, and redistribute reusable goods. This research examines how charities help extend the use of discarded but still useful items to support people in need and encourage sustainable consumption. It also considers how a digital platform could help connect donors and charities and offers practical suggestions to improve resource sharing, social welfare, and environmental sustainability.

METHODOLOG

An exploratory-descriptive qualitative research design was employed to examine the support systems, work environments, and challenges faced by human charitable organizations, as well as their perceptions and practices regarding community donations and reusable goods in the Varanasi district, Uttar Pradesh, India. This study received ethics approval from the Ethical Committee, Institute of Science, Banaras Hindu University (I.Sc./ECM-XX/2025-26). The Consolidated Criteria for Reporting Qualitative Research checklist served as the study's guidance (Tong et al., 2007). This study uses a qualitative interpretative approach (Climent-Sanz et al., 2020). Data were collected between February and May 2025 from 17 charitable organizations, including 9 old-age homes and 8 orphanages as shown in Figure 1 and 2. The Varanasi district comprises eight blocks: Pindra, Rajatalab, Baragaon, Chiraigaon, Cholapur, Harhua, Kashividyapeeth, and Sewapuri. To ensure geographical representation, organizations were selected from different blocks, with two organizations surveyed from each block and three from one block. Purposive sampling was used to select organizations actively engaged in welfare services and possessing relevant knowledge, while stratified sampling ensured representation from various geographical areas. Both government and private-sector organizations were included to provide a comprehensive understanding of their roles, operational approaches, and needs within the charitable sector.

The study targeted charitable organizations in the Varanasi district that provide welfare services to vulnerable groups, including orphaned children, elderly individuals, women, persons with disabilities, slum children, and economically disadvantaged populations. Participants comprised key staff members such as founders, managers, coordinators, and other knowledgeable personnel. Participation was voluntary, and informed consent was obtained from all respondents. Organizations that were inactive, temporarily closed, no longer operating during the study period, located outside Varanasi, or not engaged in human welfare were excluded.

Data collection was conducted through in-person, in-depth interviews using an open-ended interview guide designed to elicit detailed information and enable participants to share their experiences, perspectives, and challenges. The interview schedule, validated by two subject-matter experts, addressed four primary areas: the working environment and support systems of charitable organizations; needs and expectations regarding community donations of reusable goods; opinions and suggestions on utilizing digital platforms to support sustainable development; and the main challenges encountered in Varanasi. Each interview lasted approximately 30 to 45 minutes and was conducted flexibly, with follow-up questions used to explore emerging topics and deepen understanding. Data collection continued until thematic saturation was achieved to guarantee the reliability, validity, and transparency of the qualitative data following the study of Chaturvedi and Vatta (2026). All interviews were digitally recorded and manually transcribed. Field notes were taken to supplement the transcripts and capture non-verbal responses. To maintain confidentiality, each organization and respondent was assigned a coded label, such as R-1, R-2 and as more. The data were analysed following a six-step methodology: familiarization with the data, generation of initial codes, identification of themes, review of themes, definition and naming of themes, and reporting of findings (Braun et al., 2022). Data were manually coded and organized using NVivo Version 15 (Lumivero, 2024). Themes and sub-themes were developed from the main topics in each area and grouped by similar meaning to form broader categories.

RESULTS

The identified themes and sub-themes illustrate how charitable organizations promote the well-being and empowerment of vulnerable populations. The thematic framework developed from the analysis highlights the varied roles and practices adopted by Charitable organizations in addressing organizational environments, needs, and expectations from external communities. These include aspects such as donations, the necessity of digital platforms, and associated challenges. The following sections provide a detailed discussion of the themes and sub-themes.

Theme-1 Organisation's environment and support mechanism for beneficiaries

These outcomes addressed basic needs, health care, emotional support, educational access, skill development, and leisure opportunities to enhance the livelihood of charitable populations, and facilitate their integration into society.

Provision of essential needs and daily services for beneficiaries

Result found that organizations support vulnerable people by ensuring what they have what they need to survive, stay safe, and live with dignity. They provide food, clothing, shelter, and daily care and many charitable organizations created safe, caring spaces for older adults, orphaned or abandoned children, women facing challenges, people with disabilities, and others often left out. These services are essential for the well-being and protection of those they support. "We always try to offer a caring and supportive place for people who are alone or separated from their families." (R-3)

Encouragement of physical health and healthcare access

Healthcare support has become a primary priority for many charitable organizations, helping make medical services easier to access by organizing health camps, doctor visits, vaccination campaigns, distributing medicine, and providing emergency care. These efforts improve physical health and help reduce healthcare gaps for people in need. "Many of the beneficiaries come from situations where healthcare is either unavailable or too expensive. Our organization places a special emphasis on health and well-being." (R-2)

Access to education, development of skills and independence

Many organizations provided literacy programs, educational support, and opportunities for both formal and informal learning, especially for underprivileged children and adults. When people take part in vocational training in areas like computer literacy, tailoring, or handicrafts, they gain practical skills that make it easier to find jobs and become financially independent. "We always aim to improve reading, writing, and basic math skills for both adults and children through our literacy programs and school support courses." (R-13)

Recreation, social inclusion and individual Growth

Organizations support personal growth by offering social, cultural, and recreational activities that make life better. Sports, yoga, outdoor adventures, music, art, and crafts give people ways to exercise, be creative, express themselves, and connect with others. These activities help build confidence, friendships, and a sense of belonging, while also bringing happiness and comfort.

Charitable groups provide more than basic support. They help people in need build long-term health, resilience, and personal growth through these activities. "Vocational training programs in areas such as computer skills, tailoring, and handicraft making provide people with practical ways to earn a living." (R-10)



Figure 1. Orphanage homes with their target area



Figure 2. Elder care/old age centres with their target area

Theme 2- External needs and expectations of charitable organizations

The findings showed that nonprofits mainly depend on outside funding to keep their services running and reach more people in need. Even though these organizations are committed to offering full support, many cannot keep up with the growing needs of their communities because they lack resources. To keep their work going and stay sustainable, they look for financial help, donations, and partnerships with others in the community. These outside contributions not only help provide support but also encourage more people and groups to get involved in welfare efforts.

Demand for material support and essential goods

Organizations said they always need donations of basic items such as clothing, shoes, school supplies, bedding, food, and household goods. These donations help lower their costs and directly support people's daily needs. Respondents' states that organization builds a cycle of responsibility and kindness by passing on used items to people who need them most. "Every item we give reflects compassion and ensures nothing valuable is missed that could change someone's life." (R-1)

Acceptance and repurposing of throwaway to useful material

Many organizations accept gently used items that are still in good working order. Donate these items is a practical way to help people in need and make the most of available resources. When reusable goods are shared, it shows a commitment to caring for the community, protecting the environment, and acting responsibly. Organizations usually take items that donors no longer need, although they are in excellent condition. This method helps organizations reach their goals. By giving these items to those who need them, organizations encourage generosity and responsibility. Every donation shows empathy and helps keep useful things out of landfills. "Our organization creates a loop of responsibility and kindness by redistributing such as used things to those who need them the most". (R-3)

Provision of educational and developmental materials

Several organizations have highlighted the need for educational supplies such as school bags, study tables, notebooks, stationery, and books. For children and teenagers from underprivileged backgrounds, these materials are vital to supporting their education and providing better learning opportunities. "If anyone want to donate willingly (study materials) we can accept because it may slight helpful for beneficiaries". (R-5)

Theme 3 Digital platforms as a catalyst in social impact and resource mobilization

The findings indicate that charitable organizations expressed significant interest in utilizing digital platforms to streamline the collection, management, and distribution of donated resources. Participants identified digital technology as an effective tool for enhancing organizational efficiency and connecting contributors with beneficiaries. Organizations reported that a unified digital platform could simplify donation processes, improve access to resources, foster community engagement, and strengthen the sustainability of support initiatives.

Enhancing accessibility to donations and resources

A primary expectation was that digital platforms would facilitate easier access to donated goods and services. Organizations

indicated that these platforms enable geographic interaction with potential contributors and expedite the identification of available resources. This increased accessibility was considered particularly advantageous for organizations with limited financial and logistical capacity. “Yes, digital platform may be easier for donors who want to help but they have no idea that where they to donate, as per my point of view it may be good.” (R-2)

Facilitating connections between donors and beneficiaries through digital technology

Participants highlighted that digital platforms enable direct and effective interaction between donors and nonprofit organizations. These platforms were regarded as mechanisms to ensure that donated goods reach beneficiaries more efficiently by reducing communication barriers and supporting real-time engagement. “Yes, I think it will be good. Building a digital relationship between donors and beneficiaries is now essential for our charitable organization to run smoothly in today’s connected world.” (R-13)

Promoting efficient redistribution of valuable resources

Organizations report that digital channels can facilitate the transfer of functional yet surplus items such as furniture, clothing, shoes, household goods, and educational materials.

These platforms enhance the social value of donated resources and reduce waste by employing systematic listing and matching processes. The online platform ensures that resources reach individuals and communities in need by enabling donors to list and share surplus yet valuable items without temporal or geographic limitations. “Not bad if the customer’s used items may be useful for our organisation’s beneficiaries, then it will be best solutions.” (R-10)

Promoting volunteerism and community engagement through digital platforms

Participants suggested that increasing the visibility and accessibility of charitable initiatives through digital platforms may facilitate broader community involvement. Such platforms can raise awareness of social issues and organizational needs, thereby attracting additional volunteers, contributors, and supporters. Maintaining charitable activities and fostering a culture of social responsibility were identified as essential components. “It can make a strong bridge between external community and our organisation and people will be aware about charitable organisation purpose.” (R-7)

Strengthening collaborative partnerships and community engagement

Organizations have emphasized the importance of building strong relationships with government and private funders, volunteers, community members, businesses, and other benefactors who support charities. These partnerships help raise public awareness, secure funding, and make philanthropic efforts more effective and sustainable.

Strategies for innovation and future development

Many organizations are adopting digital tools to streamline communication, donation management, resource tracking, and engagement with both donors and beneficiaries. Respondents also report efforts to expand services to reach vulnerable populations and underserved communities. To address limited resources, organizations are implementing more efficient methods for collecting and distributing donations. Additionally, there is a recognized need for funding models that ensure consistent support, enabling programs to operate sustainably rather than relying on irregular donations. “I hope this unique idea will create a sustainable future for charitable communities as well as external community donors.” (R-9)

Theme 4: Organizational challenges affecting sustainable services and maintenance

Charitable organizations face numerous challenges that limit their capacity to deliver services efficiently and sustainably, despite

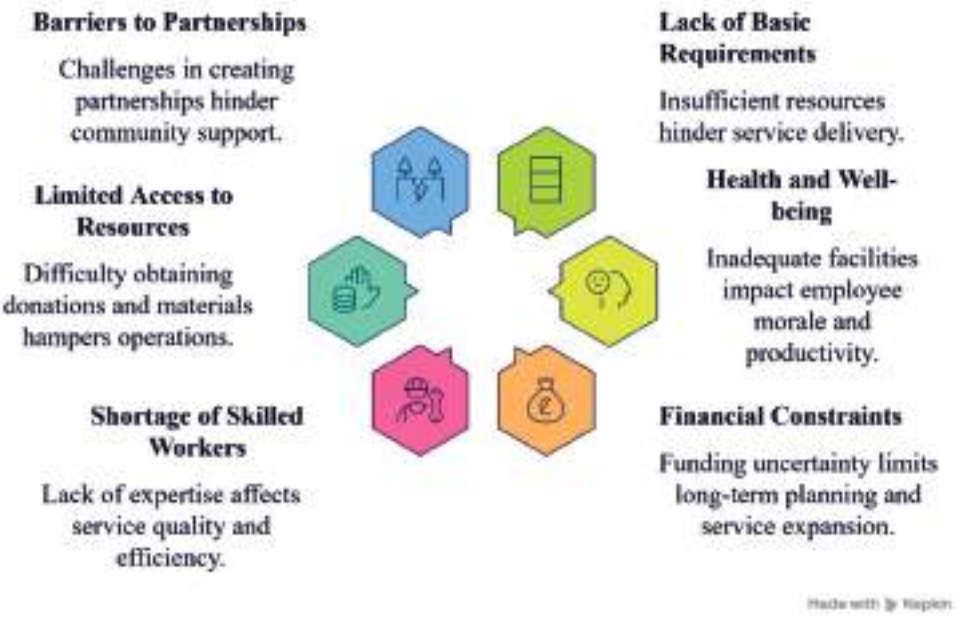


Figure 3. Challenges faced by Human Charitable Organizations

their significant contributions to the welfare of vulnerable population. Financial limitations, insufficient human resources, organizational difficulties, and technological barriers often hinder efforts to provide holistic care, healthcare support, education, resource redistribution, and social inclusion initiatives.

Lack of basic requirement

Some common needs, such as clothing, come with unique challenges. Even though many donations are received, problems can arise with sorting, keeping items clean, and making sure the right products go to the right people. While donors mean well, these gaps sometimes leave beneficiaries with unmet needs. One participant explained, "Beneficiaries greatly like the secure dorms (bedding). We maintain the seasonal gear we supply, such as blankets in the winter and lighter clothing in the summer. But still, it is insufficient sometimes." (R- 6)

Insufficient health and wellbeing facilities

Many charity organizations encounter challenges in providing beneficiaries with adequate facilities to support their health and well-being. Beneficiaries have frequently reported dissatisfaction with medical care, citing restricted access to regular checkups, shortages of essential medications, and insufficient specialist treatment for chronic conditions or psychological concerns. Due to an absence of qualified health educators, preventive health education sessions are not frequently conducted, and many recipients are still ignorant of topics like reproductive and mental health. Another significant obstacle is access to healthcare services, as doctor visits and medical camps are irregular and largely depend on volunteer availability and external funding.

"Even though our organization values health and well-being, there are a number of obstacles that restrict what we can offer". (R-16)

Financial constraints and funding uncertainty

A primary challenge faced by nonprofit organizations is inadequate and unreliable funding. Many organizations struggle to cover operating expenses, maintain infrastructure, procure essential supplies, and expand their services. Insufficient funding often restricts the number of beneficiaries who can be assisted and undermines the long-term sustainability of welfare programs. Securing enough funding to continue and expand our services for those in need is our biggest challenge. "Financial instability makes long-term planning particularly difficult, compelling organizations to prioritize immediate needs over sustainable growth." (R-12)

Shortage of skilled workers and human resources

Many organizations report difficulties in recruiting and retaining volunteers, social workers, healthcare professionals, and skilled employees. This shortage of human resources limits the organization's ability to deliver specialized services, manage programs, and respond effectively to growing community needs. Additionally, it increases the workload for existing staff members. "The shortage of qualified professionals is particularly challenging when addressing complex issues such as mental health support, healthcare services, and educational development." (R-17)

Limited access to financial donations and material resources

Although organizations rely significantly on donations of food, clothing, educational materials, and other essential items, these resources are frequently unavailable. Fluctuations in donations can hinder service delivery and create difficulties in consistently meeting the needs of beneficiaries. Securing adequate and high-quality resources to support disadvantaged populations remains a persistent challenge for organizations. "Whenever we want to organise any training programmes and some other activities for their wellbeing then we face some financial challenges although enough." (R-11)

Barriers to create sustainable partnerships and securing community support

Many organizations face real difficulties building lasting partnerships with businesses, government agencies, donors, and local communities. Low public awareness and uneven donor involvement make it harder for these groups to grow and gather the resources they need.

Building stronger coalitions is key to helping organizations last, reach more people, and make a bigger difference in their communities. "Limited meeting with external society's organisation always faces obstacle regarding donation problems because people are not aware about charitable communities." (R-16)

DISCUSSION

This discussion highlights how complex support systems of charitable organizations work, especially in areas like health, clothing, education, and social support. To understand how these systems work and what they mean, it is important to look at organizational relationships and evidence-based approaches to generosity. Charitable organizations offer a variety of services, such as educational, medical, rehabilitation, and social-pedagogical programs. The sustainability of diversified funding sources depends on expanding donation streams, such as individual giving, community support, and foundation grants. Studies of activity and culture nonprofits indicate that organizational characteristics shape both the composition and scale of charitable contributions, allowing organizations to more effectively target fundraising strategies and strengthen resilience to funding volatility (Krawczyk et al., 2017).

Studies show that these organizations make health services like primary care and mental health support more accessible, directly meeting the needs of underserved communities (Latief, 2010). Besides healthcare, they often give out clothing and educational materials, helping people meet basic needs and encouraging learning and skill development. These actions can help reduce poverty and social exclusion, and educational support fits with wider social goals. Non-profits can become more effective and sustainable by focusing on social connections and motivation (Speckbacher, 2013). While this study offers a different view from Smith-Carrier (2020), it is clear that charitable systems can create power imbalances, as providers often have more control than recipients because of the focus on direct aid. Addressing only the symptoms of social problems, instead of their root causes, can lead to ongoing dependency rather than real empowerment (McAllum, 2018).

Nonprofits are also using social media more to engage communities and develop services together (Namisango et al., 2021). Social media is a fast-growing group of online platforms where people participate and share (Pandey et al., 2020). Tools like WhatsApp are now widely used (Mishra & Kumari, 2024). Using new ways to communicate through social media improves traditional information technologies and helps promote wellness (Vedel et al., 2020). Humanitarian organizations mainly serve people in need and play an important role in meeting basic needs like healthcare, clothing, education, and social support. They usually combine community involvement, direct aid, and advocacy for broader change as their main ways of providing support (Kamimura et al., 2013).

However, donors, governments, and the public are asking more from charitable organizations in terms of accountability, transparency, and showing how effective they are. Because human behaviour is complex and the people served are so diverse, it is difficult to use standard ways of measuring performance methods usually made for public or for-profit organizations in nonprofit human services (Carnochan et al., 2013). The generation of reusable discarded goods, driven by fast fashion and consumerism, and the unmet material needs of charitable organizations highlight a significant opportunity for sustainable resource redistribution. Charitable organizations can play a vital intermediary role in extending the life cycle of reusable products, supporting vulnerable populations, reducing waste, and promoting circular economy practices through effective and digitally enabled redistribution mechanisms.

CONCLUSION

This study emphasizing the significance of an organization's environment and the role of donations and its operations. According to the findings charitable organizations are aiding vulnerable populations, such as the old person and orphaned children, not only offering immediate assistance but also promoting long-term self-sufficiency. Still these charitable institutions face numerous challenges, despite the historical and cultural richness of Varanasi, by proactively identify and tackling obstacles of charities could be improved their operation, strength their relationship with donors. Future contributions in areas like education, skill enhancement, healthcare, and social integration significantly aid in sustainable social progress. However, the ongoing success and efficacy of these efforts are heavily reliant on steady donations and external support. Consequently, it is essential for individuals, organizations, and government to actively provide resources and support, allowing charitable organizations to amplify their impact and continue to work effectively toward the overall improvement of society.

DECLARATIONS

Ethical consideration and consent to participate: All data were managed in compliance with institutional and international ethical requirements, and no identifiable information has been revealed. Participants were made aware that they might leave at any time without facing any repercussions. Every procedure involving human subjects was conducted in respective manner, and each participant gave their informed consent before any data was collected. Confidentiality, privacy, and voluntary involvement were all fully respected during the interview process.

Authors contribution: IY designed the study, developed the research design, conducted fieldwork, collected qualitative data, finalized theme analysis and data transcription, and drafted the first report with the help of SB. PS and LV monitored the whole scholarly program, contributed to the formulation of the study plan and interview guide, and critically analysed the work for intellectual content including reading and approving the final text of the article.

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Research Article

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Socio-economic Impact of *Pradhan Mantri Jan Dhan Yojana* on Financial Inclusion among Beneficiaries in Haryana

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HIGHLIGHTS

- PMJDY significantly improved financial inclusion and socio-economic conditions among beneficiaries in Haryana.
- Beneficiaries reported improved financial security, savings habits, and access to formal banking services.
- PMJDY reduced dependence on informal credit sources and strengthened direct benefit transfers.
- Annual income significantly influenced the ease of opening and operating PMJDY accounts however, low and irregular incomes limited active utilization.

ARTICLE INFO

Keywords: Banking accessibility, Economic empowerment, Financial security, Poverty alleviation, Rural development.

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ABSTRACT

The Indian government introduced the *Pradhan Mantri Jan Dhan Yojana* (PMJDY) in 2014, to advance financial inclusion. The current study examined its socioeconomic effects in Haryana from 2024 to 2025. A semi-structured questionnaire was used to collect primary data from 500 respondents from eight districts, which was then corroborated by suitable secondary data sources. Changes in important variables such as income, education, living standards, social interactions and resource access were the main focus of the study. This study aimed to examine the socio-economic impact of PMJDY on its beneficiaries in Haryana. Data were analyzed using ANOVA and factor analysis. The ANOVA results showed that annual income significantly influenced the ease of opening a PMJDY account ($p < 0.001$), while availability shows marginal significance ($p = 0.066$). Factor analysis confirms data adequacy with KMO = 0.810 and a significant Bartlett's test ($p < 0.001$), extracting eight factors, with the highest loading (0.775) on the perception that PMJDY reduces poverty and improves living standards. The findings indicate that while PMJDY has improved financial access, low-income beneficiaries still face challenges in regular usage. The study suggested that policy efforts should focus on enhancing financial literacy and encouraging active utilization of accounts.

INTRODUCTION

Financial inclusion began in India over a century ago (Shah, 2011) but it is now in the twenty-first century that targeted government initiatives are giving it the utmost priority. Prime Minister Sri. Narendra Modi's flagship initiative, *Pradhan Mantri Jan Dhan Yojana* (PMJDY), has been highlighted in his Independence Day speech. The scheme's tagline, *"Mera Khata-Bhagya Vidhata,"* basically implies that an individual's fate would be connected to their account (Jain & Jain, 2017). It is a National

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Mission that uses an integrated strategy to ensure that every household in the nation has complete financial inclusion (Minakshi et al., 2025). Affordable access to financial services, such as banking and savings, deposit accounts, remittances, credit, insurance, and pensions, is guaranteed by the PMJDY program (Kalawat et al., 2025; Raj & Narayan, 2025). Any bank or post office branch can open a PMJDY account (Gupta, 2023). In order to meet the demands of Below Poverty Line (BPL) clients, PMJDY allows for the opening of *"no frills"* zero balance accounts with straightforward Know Your Customer (KYC) criteria. This feature of PMJDY can be viewed as an expansion of the Basic Saving Bank Deposit Account (BBSDA) opening provision, which has been in effect since 2010 (Thakur, 2022). With a significant emphasis on rural and semi-urban regions and women beneficiaries, the program has developed into one of the biggest global efforts for financial inclusion, with over 55 crore by mid-2025 (Chougala & Angadi, 2026). The PMJDY can be viewed through several connected theories that show how financial access supports socio-economic development. Financial Inclusion theory highlights that universal access to affordable financial services is essential for inclusive growth. Expanding financial access not only boosts economic participation but also assists households in managing risk and improving living standards (Demirgüc-Kunt & Klapper, 2013). Financial inclusion is not only about access to banking services but also represents the growth of people's capacities, and allowing them to seek and realize the sorts of lives they value (Sen, 1999). According to (Schumpeter, 1934), formal financial institutions have been acknowledged as a stimulant for entrepreneurship, innovation, and productivity enhancement. District and state level studies on PMJDY have been conducted across various districts of Haryana, primarily focussing on financial inclusion outcomes, access and usage gaps, and the socio-economic impact. As seen in the research study carried out in Sonipat, Panchkula and Rohtak, the use of banking services is better due to the scheme but there are disparities in the level of banking service accessibility for different socio-economic groups (Rani, 2016; Dixit, 2019; Arunkumar et al., 2023; Mishra & Mahipal, 2026). Further, there are significant variations in the level of financial inclusion through recent secondary data analysis in various districts of Haryana. Most of the existing research, however, is confined to particular districts. There is still limited use of more advanced multivariate techniques such as factor analysis to more structurally capture the dimensions of financial inclusion. The aim of the present study is to assess socio-economic impact of the PMJDY on its beneficiaries.

METHODOLOGY

The study was conducted in Haryana during 2024-2025 using both primary and secondary data. Haryana was purposively selected due to its diverse socio-economic characteristics, comprising 400 rural and 100 urban beneficiaries, varying income levels, and differences in access to financial services across districts. The state also represents an important setting for assessing the socio-economic impact of the Pradhan Mantri Jan Dhan Yojana (PMJDY). A multistage sampling procedure was adopted for the study. Based on geographical dispersion, Haryana was divided into four zones: based on geographic distribution: north, south, east, and west. Ambala and Kaithal were chosen from the northern zone, and Bhiwani and Rewari were chosen from the southern zone. Hisar and Fatehabad were chosen from the western zone, while Karnal and Panipat represented the eastern zone, were purposively selected to ensure representation of the state's diverse socio-economic and regional characteristics. A total of 500 PMJDY beneficiaries were surveyed through convenience sampling from both rural and urban areas. The district-wise distribution of respondents was Ambala (87), Kaithal (22), Bhiwani (100), Rewari (84), Hisar (100), Fatehabad (20), Karnal (50), and Panipat (37). The effect was thoroughly evaluated by a five-point Likert scale. This measure was helpful in grouping the respondents on the basis of the extent of the benefits of the PMJDY that had improved their socioeconomic condition. It made it possible to determine whether the participants of the programs indicated significant or minor changes in their socio-economic status. Ordinal data obtained from the five-point Likert scale were quantified and entered into SPSS for statistical analysis. Factor analysis was used to determine the underlying dimensions of financial inclusion and One-way ANOVA used to determine whether significant differences exist between socio demographic groups on the financial inclusion dimensions. One-way ANOVA analysis was conducted only for education and annual income because they were the only variables that showed statistically significant differences in the financial inclusion perception of respondents in the preliminary analysis. Thus, they were all chosen for additional scrutiny of differences in means across groups.

RESULTS

The objective of the analysis was to identify the socio-economic impact of the *Pradhan Mantri Jan Dhan Yojana* (PMJDY) among the respondents. This analysis aimed to examine the underlying structure of the socio-economic statements and identify the key components that explained the scheme's impact.

Table 1. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.810
Bartlett's Test of Sphericity	Approx. Chi-Square	5647.398
	df	465
	Sig.	0.000
Cronbach's Alpha		0.821
Number of Items		30

The data in the Table 1 shows that Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was found to be 0.810, indicating that the sample size was adequate for conducting factor analysis. Additionally, the findings of the Bartlett's Test of Sphericity generated a significant chi-square value ($\chi^2 = 5647.398$, $df = 465$, $p < 0.001$), representing that the variables in the dataset were correlated, justifying the use of factor analysis. Furthermore, Cronbach's Alpha coefficient was figured to be 0.821 signifying high internal reliability among the statements included in the analysis.

Exploratory factor analysis of socio-economic impact of the scheme

Table 3 presents the exploratory factor analysis of the socio-economic impact of the PMJDY scheme. The first factor, labeled

Table 2. The cumulative total variance explained

Extraction Sums of Squared Loadings			
Components	Total	% of Variance	Cumulative %
1	6.091	19.650	19.650
2	3.421	11.037	30.686
3	2.435	7.855	38.542
4	1.970	6.355	44.897
5	1.595	5.146	50.043
6	1.574	5.077	55.120
7	1.089	3.514	58.634
8	1.063	3.429	62.063

"PMJDY benefits/upliftment of society," explained the maximum variance at 19.65 percent with an Eigen value of 6.091 and a Cronbach's alpha of 0.70. This indicated a good level of internal consistency and suggested that this factor was the most important among all the other factors. The PMJDY's wide-ranging socio-economic impact was demonstrated by this factor, which explained the greatest percentage of the overall variance. The statement "People believe that PMJDY has reduced poverty and uplifted every household" had the greatest factor loading (0.775), indicating that the program was widely regarded as a successful tool for reducing poverty and uplifting households. Similar to this, PMJDY's significant influence on financial resilience and general living

Table 3. Exploratory factor analysis of socio-economic impact of the scheme in Haryana

Statements	Factor Loading	Cronbach's Alpha	Variance Explained	Eigen values
PMJDY benefits/Upliftment of society				
People believe that PMJDY has reduced poverty and uplifted every household	0.775	0.70	19.650	6.091
PMJDY has contributed to social and economic development	0.767			
PMJDY helps in handling emergencies and financial crises	0.672			
Swavalamban pension benefits have boosted economic well-being	0.600			
Satisfied with the overall impact of PMJDY on our life	0.515			
Accidental insurance cover under PMJDY provides financial security	0.422			
Financial Security				
Opening a PMJDY account encouraged to save money regularly	0.759	0.77	11.037	3.421
PMJDY reduced reliance on moneylenders and informal credit sources	0.654			
PMJDY improved financial planning and budgeting skills	0.614			
PMJDY helped to access formal financial services which were previously unavailable	0.603			
Financially secured after enrolling in PMJDY	0.493			
PMJDY enabled family members to open bank accounts	0.435			
PMJDY helped to access social security schemes like PMSBY and PMJJBY	0.354			
Privileges and hassle-free transactions				
PMJDY helps in availing benefits from other financial schemes	0.687	0.55	7.855	2.435
PMJDY helped in securing timely disbursal of government benefits	0.644			
PMJDY helped in avoiding high-interest loans from informal sources	0.571			
PMJDY increased creditworthiness with banks	0.555			
Experienced faster and hassle-free transactions due to PMJDY account	0.541			
PMJDY enables you to receive government subsidies and benefits directly	0.514			
Accessibility				
Zero-balance feature of PMJDY made banking services more accessible	0.823	0.62	6.355	1.970
PMJDY enabled to open a bank account for the first time	0.741			
Digitally enabled				
PMJDY made it easier to participate in government welfare schemes	0.743	0.62	5.146	1.595
PMJDY enabled to make cashless payments and digital transactions	0.631			
PMJDY enabled family to access subsidized LPG cylinders	0.527			
Usefulness of PMJDY				
RuPay Debit Card provided through PMJDY been useful for smoothly financial transactions	0.737	0.61	5.077	1.574
PMJDY helped in improving quality of life	0.560			
Overdraft facility under PMJDY useful in times of need	0.536			
Increased savings				
PMJDY promoted a saving habit among family members	0.768	0.51	3.514	1.089
People experienced an increase in savings and investments due to PMJDY	0.674			
PMJDY built more confident managing finances	0.363			
Micro insurance and pension schemes				
PMJDY helped to avail micro-insurance and pension schemes	0.742	-	3.429	1.063

standards was demonstrated by large loadings for its contribution to social and economic development (0.767) and its role in assisting households during emergencies and financial crises (0.672). The program significantly improved quality of life, strengthened financial protection, and fostered social advancement among beneficiary households, according to moderate loadings for benefits like the *Swavalamban* pension contributing to improved well-being (0.600), overall satisfaction with PMJDY's impact (.515), and accidental insurance coverage enhancing financial security (0.422). Having been considered, this factor demonstrated PMJDY's important contribution to wider socio-economic advancement.

With an Eigen value of 3.421 and a Cronbach's alpha value of 0.77, the second factor, "financial security," accounted for 11.037 percent of the total variance, demonstrating a good degree of internal consistency. The statement about encouraging regular saving had the highest factor loading (0.759), indicating that the PMJDY had significantly influenced account users' savings-oriented financial behavior. Loadings for reduced reliance on moneylenders (0.654), improved financial planning and budgeting skills (0.614) and access to previously unavailable financial services (0.603) demonstrate that the scheme can be crucial in reducing financial exclusion and decreasing dependence on unauthorized credit providers. Other indicators, such as financial security after enrolling (0.493), family members being able to open accounts (0.435) and access to social security schemes (0.354), validated that PMJDY can strengthen household security and broaden financial inclusion.

The third factor, "privileges and hassle-free transactions," was better understood through data. With an average degree of consistency, this factor explained 7.855 percent of the variance, with an Eigen value of 2.435 and a Cronbach's alpha of 0.55 indicated a weak reliability. Assistance in obtaining benefits from other financial schemes showed a substantial factor loading (0.687), followed by prompt government benefit disbursement (0.644). Moderate factor loadings were found in statements indicating reduced reliance on high-interest informal borrowing (0.571), improved creditworthiness with formal banking institutions (0.555) and quicker, more convenient financial transactions (0.541). It was found that the PMJDY reduced the barriers to transactions and hence, improved access to formal banking services. The loading associated with the direct receipt of government subsidies (0.514) also showed the improved efficiency and transparency of the scheme. Overall, this feature echoed the beneficiaries' increased trust in the official financial system, as they considered PMJDY a reliable and accessible platform for accessing financial and governmental services without the need for middlemen.

The fourth factor namely "accessibility" showed a good internal consistency. This factor accounted for 6.355 percent of the total variance with Eigen value of 1.970 and Cronbach's alpha of 0.62. Factor loading on the claim that the zero-balance provision made banking services more accessible was particularly high (0.823), indicating that the absence of a minimum balance requirement had a major impact on beneficiaries decision to enroll in the program. Similarly high loading of first time account opening (0.741) indicated the success of PMJDY in reaching the unbanked. These findings indicated that the PMJDY had substantially enhanced financial services access and lowered entry barriers to the formal banking system, particularly for economically and socially disadvantaged households.

The fifth factor, "digitally enabled", contributed 5.146 percent to the total variance with an Eigen value of 1.595 and a Cronbach's alpha score of 0.62, indicating adequate internal consistency. The ease of participation in government welfare initiatives had the highest factor loading (0.743) followed by the convenience of digital transactions and cashless payments (0.631). The integration of financial services with home welfare support was further demonstrated by a moderate loading (0.527) for access to subsidized LPG benefits. All of these results indicated that beneficiaries were motivated to interact with a more open, effective, and inclusive financial system via digital accessibility and easier access to welfare benefits.

The sixth factor, "usefulness of PMJDY," explained a variance of 5.077 percent, with an Eigen value of 1.574 and a Cronbach's alpha of 0.61, showing a good level of internal consistency. Convenient payment methods are crucial for promoting financial inclusion, shown by the RuPay Debit Card's substantial factor loading (0.737). Furthermore, the PMJDY not only guaranteed access to basic banking services but also offered a financial safety net and opportunities for socio-economic improvement, as evidenced by the emphasis on improving quality of life (0.560) and the value of the overdraft facility during financial emergencies (0.536). All things considered, the program provided both basic financial services and more extensive assistance for socioeconomic advancement.

The seventh factor, "increased savings," explained a variance of 3.514 percent, with an Eigen value of 1.089 and a Cronbach's alpha of 0.51, showed weak reliability. The promotion of savings behavior among family members had the highest factor loading (0.768), followed by an increase in investment and savings behavior (0.674). A moderate loading for confidence in financial management (0.363) suggested that beneficiaries' behavior had changed as a result of the program. Overall, these results indicated that the PMJDY supported long-term socio-economic upliftment by acting as a catalyst for sustainable financial practices in addition to serving as a mechanism for financial access.

The final factor, "micro insurance and pension schemes," explained a variance of 3.429 percent, with an Eigen value of 1.063. This factor showed a weak preference for the PMJDY's micro insurance and pension-related benefits, due to one statement loading on this factor. Although this factor contains a single item, it was retained because access to micro-insurance and pension schemes is a distinct objective of PMJDY. The factor loading of the item was acceptable (0.742), indicating the item is theoretically relevant.

Effects on financial inclusion due to socio-economic variables

H_{01}: There is no significant difference on financial inclusion due to education of respondents

The data presented in Table 4 about effects on financial inclusion due to socio-economic variables. The analysis showed that the education of respondents did not significantly affect any aspect of financial inclusion. The p-values for availability ($p = 0.248$), ease of use ($p = 0.334$), trust ($p = 0.592$), and empowerment ($p = 0.928$)

Table 4. Effects on financial inclusion due to education

Socio-economic Variable	Financial Inclusion Dimension	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Education of respondents	Availability	Between Groups	4.519	6	0.753	1.316	0.248
		Within Groups	282.767	494	0.572	-	-
		Total	287.285	500	-	-	-
	Easy to use	Between Groups	5.223	6	0.871	1.147	0.334
		Within Groups	375.016	494	0.759	-	-
		Total	380.240	500	-	-	-
	Trust	Between Groups	4.125	6	0.687	0.772	0.592
		Within Groups	440.031	494	0.891	-	-
		Total	444.156	500	-	-	-
	Empowerment	Between Groups	7.990	6	1.332	0.317	0.928
		Within Groups	2074.780	494	4.200	-	-
		Total	2082.770	500	-	-	-

Table 5. Effects on financial inclusion due to annual income

Socio-economic Variable	Financial Inclusion Dimension	Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Annual Income	Availability	Between Groups	24.773	31	0.799	1.428	0.066
		Within Groups	262.513	469	0.560	-	-
		Total	287.285	500	-	-	-
	Easy to open account	Between Groups	64.532	31	2.082	3.092	0.000*
		Within Groups	315.708	469	0.673	-	-
		Total	380.240	500	-	-	-
	Trust	Between Groups	32.687	31	1.054	1.202	0.213
		Within Groups	411.469	469	0.877	-	-
		Total	444.156	500	-	-	-
	Empowerment	Between Groups	149.713	31	4.829	1.172	0.244
		Within Groups	1933.058	469	4.122		
		Total	2082.770	500			

were all greater than 0.05. This suggested that differences in education levels among respondents did not significantly influence their views on financial inclusion. Therefore, the null hypothesis (H_{01}) was accepted in the context of education.

H_{02}: There is no significant difference on financial inclusion due to annual income of respondents

The results (Table 5) indicated that annual income significantly impacted the ease of opening an account aspect of financial inclusion ($p = 0.000 < 0.05$), suggesting variation across income groups. However, no statistically significant effect was found for availability ($p = 0.066$), trust ($p = 0.244$), and empowerment ($p = 0.213$) at the 5% level. The p-value of 0.066 for availability indicates weak or marginal significance at the 10% level, suggesting a possible but not strong relationship between income and perceived availability of financial inclusion services. The analysis of variance test showed that there was a significant difference among the means for the dimension "Ease of Opening Account" ($F = 3.092$, $p < 0.001$); however, Tukey's HSD post hoc test was not possible due to the number of groups with annual incomes that were large and too few observations were found in several groups, which violated the assumptions of the test for reliable pairwise comparisons. Thus, specific group differences were not able to be discerned.

DISCUSSION

The results indicate that PMJDY has substantially improved financial inclusion by expanding access to formal banking services across diverse socio-economic groups. The factor analysis shows that beneficiaries primarily associate the scheme with poverty reduction, financial security, and overall socio-economic improvement. This suggests that the benefits of PMJDY extend beyond account ownership and contribute to broader social and economic well-being. The absence of significant differences across educational groups indicates that educational attainment is not a major determinant of beneficiaries' perceptions of financial inclusion under PMJDY. Annual income influenced only the ease of opening a bank account, whereas no significant differences were observed for availability, trust, or empowerment. This indicates that although procedural differences may exist during account opening, income has a limited influence on the overall benefits received under PMJDY. Earlier studies also found that cumbersome procedures, ease of availability of credit from non-institutional sources and lack of financial literacy were the major constrains of financial inclusion (Arunkumar et al., 2025). The findings therefore suggest that the scheme has narrowed economic disparities in access to formal financial services and has promoted more equitable financial

participation. Ruchi et al. (2024) have also highlighted the importance of financial participation and decision-making in enhancing socio-economic empowerment among people. The findings of the present study is consistent with Yadav et al. (2024a) where satisfactory KMO values and a statistically significant Bartlett's Test of Sphericity confirmed sample adequacy and established the suitability of the dataset for factor analysis. Furthermore, the methodological framework corresponds with Yadav et al., (2023) and Yadav et al. (2024b). The results are consistent with Sharma and Kukreja (2013), who pointed out that programs like PMJDY helps households escape poverty by connecting them to the formal financial system. Kapoor (2020) noted that the scheme made it easier for government subsidies to reach people and reduced their reliance on informal moneylenders. This change led to improvements in financial security at the household level. Singh and Naik (2018) mentioned that PMJDY positively impacted rural livelihoods. Better access to finance opened more opportunities for entrepreneurship, education, and healthcare spending. The findings of the present study are also supported by Bagar and Sijeriya (2020) and Kar et al. (2025), reported that PMJDY enhances financial inclusion and improves socio-economic conditions through improved availability of banking services. The results emphasize the role of PMJDY in enhancing access to formal financial services and reducing the barriers to financial inclusion. There is no significant variation across the educational groups indicating that the scheme has been successful in reaching out to the beneficiaries irrespective of their educational background. Besides, the limited influence of income on most dimensions of financial inclusion suggests that PMJDY has improved equitable access to the banking services which has helped in the creation of financial security and inclusive socio-economic development. Collectively, these findings reinforce the broader literature suggesting that PMJDY has played a transformative role in promoting inclusive growth and reducing financial exclusion in India.

CONCLUSION

The present study concludes that the *Pradhan Mantri Jan Dhan Yojana* has a noticeable positive influence on the socio-economic conditions of the respondents. The most prominent factor, identified as "benefits/upliftment of society," reflects improvements in access to formal financial services, a growing inclination toward saving, and a perceived decline in poverty levels. Supported by strong factor loadings and acceptable reliability, these results indicate that PMJDY has enhanced financial security and facilitated the inclusion of previously unbanked households. Nevertheless, the socio-economic benefits are not uniformly experienced. The persistence of low and irregular income limit the effective utilization of financial services. Therefore, income generation opportunities should be complemented with financial literacy programmes, and stronger convergence with livelihood schemes such as MGNREGS to maximize their impact. Future research may adopt longitudinal approaches or cross-state comparative studies to examine the long-term socio-economic effects of PMJDY and gain deeper insights into its implementation and outcomes.

DECLARATIONS

Research ethics statement(s): Informed consent of the respondents

Conflict of interest: The authors declare no conflict of interest.

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Consumer Demand and Market Requirements for Sustainable Goat Production in Vietnam: Implications for Extension Education

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HIGHLIGHTS

- Restaurants are the principal channel for goat meat consumption in Vietnam.
- Domestic goats account for most goat meat supplied to restaurants.
- Consumer demand is influenced by food safety, origin and traceability.
- Market-oriented extension is essential for sustainable goat sector development.

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ABSTRACT

The study examined consumer demand, restaurant purchasing preferences, and market requirements for goat meat in Vietnam and discussed implications for market-oriented extension. Data were collected from 86 goat meat restaurant owners/managers and 509 consumers across ten provinces and cities in Northern and Central Vietnam. Descriptive statistics and Pearson's Chi-square tests were used for data analysis. The goat meat consumption was strongly associated with restaurant-based dining. Significant relationships were found between consumption frequency and place of consumption ($\chi^2 = 17.476$, $p = 0.002$) and between consumption frequency and preferred product form ($\chi^2 = 26.934$, $p < 0.001$). More than half of consumers (54.8%) preferred processed goat meat dishes, while food safety, product origin, and traceability were identified as the most important purchasing attributes. Restaurants consumed an average of 98.8 goats per month and relied mainly on traders (67.2%) for supply. Restaurant owners preferred Vietnamese Co goats (a type of indigenous goat breed), Vietnamese crossbred goats and animals weighing 20–30 kg. The findings from this study highlight the need for market-oriented extension programmes that integrate technical husbandry training, food safety standards, market information, entrepreneurship development and value-chain linkages to improve the competitiveness and sustainability of goat production in Vietnam.

INTRODUCTION

Goat production is an important livelihood activity for smallholder farmers in many developing countries because of its contribution to food security, income generation, and poverty reduction. Goats require relatively low investment, adapt well to diverse agroecological conditions, and efficiently utilize locally available feed resources, making them particularly suitable for resource-poor households (FAO, 2011; Olmo et al., 2024). In Vietnam, goat farming plays an important role in mountainous and upland areas, where alternative livestock production opportunities are often limited (Nguyen et al., 2021; Don et al., 2023).

The goat sector in Vietnam has expanded steadily during the past decade. The national goat population increased from

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approximately 2.68 million head in 2018 to nearly 2.95 million head in 2024, reflecting the growing importance of goat production within the livestock sector (Livestock & Veterinary Information Center, 2024). Rising household incomes, urbanization and changing dietary preferences have stimulated demand for high-quality animal-source foods. Consumers are increasingly concerned about food safety, product quality, and traceability, while the rapid expansion of goat meat restaurants has further strengthened market demand (Phuong et al., 2014; Olmo et al., 2024). Previous studies have shown that restaurants constitute an important marketing channel for goat meat in Vietnam, creating strong linkages among producers, traders, and food service enterprises (Gray et al., 2019; Nguyen et al., 2023).

Despite favourable market prospects, goat production remains constrained by small-scale production systems, limited technical knowledge, weak market coordination, and poor integration into formal value chains (Gunaseelan & Singh, 2018; Don et al., 2023). Information gaps related to breeding, feeding, animal health, and marketing further reduce farmers' ability to respond effectively to changing market requirements (Sinha et al., 2017). These challenges highlight the need for extension services that provide not only technical advice but also market information and business-oriented support. Credit linked Production and Procurement Model and on door procurement models have gained importance to handle marketing issues (Kumari et al., 2022).

Market-oriented extension has emerged as an important approach for improving the competitiveness and sustainability of livestock production. Unlike conventional production-focused extension, this approach integrates consumer preferences, market requirements, value-chain coordination, and entrepreneurship into advisory services, enabling farmers to make production decisions that better respond to market opportunities. Such an approach is particularly relevant to goat production, where consumer demand increasingly emphasizes food safety, product origin, and traceability.

Although previous studies have examined goat production systems and value chains in Vietnam, empirical evidence on consumer demand, restaurant purchasing preferences and market requirements remains limited. Such information is essential for developing market-oriented extension programmes and strengthening value-chain linkages. Therefore, this study aimed examine consumer demand, restaurant purchasing preferences, and market requirements for goat meat in Vietnam and discuss their implications for market-oriented extension programmes supporting sustainable goat production.

METHODOLOGY

The study was conducted in ten provinces and cities in Northern and Central Vietnam, including Son La, Hoa Binh, Dien Bien, Hanoi, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Da Nang, and Thua Thien Hue. These locations were purposively selected because they represent major goat-producing and goat meat-consuming areas and have relatively developed goat marketing networks. The study targeted two key stakeholder groups within the goat value chain: (i) goat meat restaurant owners/managers and (ii) goat meat consumers. Restaurant respondents were selected purposively based on their specialization in goat meat products and a minimum of three years of business operation. Consumer respondents were randomly interviewed at restaurants, traditional markets, supermarkets, residential areas, and other public locations to ensure diversity in consumption patterns and socio-economic backgrounds. A total of 86 restaurant owners/managers and 509 consumers participated in the survey. Primary data were collected by using structured questionnaires and face-to-face interviews conducted by trained enumerators. Separate questionnaires were designed for restaurant owners and consumers. The restaurant survey collected information on goat procurement practices, supply sources, purchasing frequency, preferred goat breeds and slaughter weights, perceptions of market trends, and quality requirements for goat meat products. The consumer survey focused on goat meat consumption behaviour, preferred product attributes, food safety concerns, product origin, and traceability requirements. Respondents' perceptions of quality-related attributes were assessed using a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree.

The study examined consumer demand and market requirements for sustainable goat production. Key variables included consumption frequency, place of consumption, preferred product forms, goat procurement patterns, preferred goat breeds, preferred slaughter weights, perceived market trends, and consumer evaluations of goat meat quality attributes.

Descriptive statistics, including means, standard deviations, and percentages were used to summarize consumption patterns, purchasing behaviour, market trends, and quality preferences. Mean scores were employed to assess the relative importance of quality attributes such as food safety, product origin, traceability, freshness, and organic production. Pearson's Chi-square tests were used to examine associations between consumption frequency and place of consumption, and between consumption frequency and preferred product forms. The findings were interpreted to identify market-oriented extension implications for sustainable goat production and value chain development in Vietnam. Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 26.0.

RESULTS

Goat meat consumption behaviour of consumers

The results presented in Table 1 show that goat meat was consumed relatively infrequently by most respondents. Approximately 90.4% of consumers reported consuming goat meat less than once per month, indicating occasional rather than regular consumption, while 8.8% consumed goat meat one to two times per month and only 0.8% consumed it three or more times per month. It should be noted that respondents in the less than once per month category were occasional consumers rather than non-consumers, as all survey participants had previous experience consuming goat meat. These findings suggest that goat meat remains a niche livestock product and is typically consumed on special occasions or when dining out, rather than as a routine source of animal protein in most households. Regarding product preferences, more than half of the respondents (54.8%) preferred processed goat meat dishes, whereas 28.5% preferred fresh goat meat for home preparation. A further 16.7% reported consuming both fresh and

Table 1. Goat meat consumption behaviour among surveyed consumers (n = 509)

Indicator	Category	Value (%)
Frequency of consumption	Less than once/month	90.4
	1–2 times/month	8.8
	≥3 times/month	0.8
Preferred product form	Fresh goat meat	28.5
	Processed goat meat dishes	54.8
	Both	16.7

processed goat meat products. The preference for processed goat meat dishes suggests that convenience and restaurant-based consumption play important roles in shaping consumer demand.

Table 2 presents the distribution of place of consumption within each consumption frequency category (row percentages), whereas Table 1 summarizes the overall distribution of respondents by consumption frequency. The relationship between consumption frequency and place of consumption is presented in Table 2. The Chi-square test revealed a significant association between these variables ($\chi^2 = 17.476$, $p = 0.002$). Restaurants were the primary venue for goat meat consumption across all consumer groups. Among respondents who consumed goat meat less than once per month, 67.8% reported consuming it mainly at restaurants, compared with 61.3% among those consuming goat meat one to two times per month and 52.6% among frequent consumers. Consumers with higher consumption frequency were relatively more likely to consume goat meat both at home and in restaurants.

Findings from this study suggest that restaurant-based consumption plays a dominant role in the goat meat market and constitutes an important driver of consumer demand.

The results presented in Table 3 showed a significant association between goat meat consumption frequency and preferred product form ($\chi^2 = 26.934$, $p < 0.001$). Processed goat meat dishes were the most preferred product form across all consumption groups, accounting for 67.7% of consumers who consumed goat meat less than once per month, 61.3% of those consuming goat meat one to two times per month, and 52.6% of frequent consumers.

In contrast, preference for both fresh and processed goat meat products was more common among consumers with higher consumption frequency. It accounted for 12.5% respondents consuming goat meat less than once per month, 25.8% of those consuming goat meat one to two times per month, and 47.4% of respondents consuming goat meat three or more times per month.

Table 2. Association between consumption frequency and place of consumption (Row percentages, n = 509)

Consumption frequency	Home (%)	Restaurant (%)	Both (home and restaurant) (%)
< 1 time/month	19.7	67.8	12.5
1–2 times/month	13.4	61.3	25.3
≥ 3 times/month	31.6	52.6	15.8
χ^2 value	17.476		
p-value	0.002		

Note: Percentages are row percentages calculated within each consumption frequency category and may differ from the overall percentages presented in Table 1.

Preference for fresh goat meat alone remained relatively low across all groups and was not reported among consumers who consumed goat meat three or more times per month. These findings suggest that consumption frequency is associated with consumer preferences for goat meat products. Consumers with lower consumption frequency tended to prefer processed goat meat dishes, which are commonly consumed in restaurants, whereas more frequent consumers exhibited more diversified preferences, including both fresh and processed goat meat products. The results further highlight the important role of restaurant-based goat meat dishes in stimulating consumer demand and shaping consumption behaviour in Vietnam.

Table 3. Association between consumption frequency and preferred product form (Row percentages)

Consumption frequency	Fresh goat meat (%)	Processed goat meat dishes (%)	Both (Fresh and Processed goat meat) (%)
< 1 time/month	19.8	67.7	12.5
1–2 times/month	12.9	61.3	25.8
≥ 3 times/month	0	52.6	47.4
χ^2 value	26.934		
p-value	0.000		

Note: Percentages are row percentages calculated within each consumption frequency category.

Consumer perceptions of goat meat quality

Consumer evaluations of goat meat quality attributes are presented in Table 4. Food safety received the highest mean score (M= 4.4), followed by product origin, traceability, and organic production practices (M = 4.1 for each attribute). In contrast, freshness received the lowest mean score (M=3.5), although it remained above the midpoint of the scale. These findings suggest that consumers place considerable importance on food safety, product origin, traceability, and production practices when purchasing goat meat. The relatively low standard deviations (SD=0.5-0.7) indicate a high degree of agreement among respondents regarding the importance of these quality attributes.

Goat meat consumption and supply sources in surveyed restaurants

Table 5 presents the purchasing frequency and supply sources of goat meat among the surveyed restaurants. More than 65% of

Table 4. Consumer evaluation of goat meat quality (n = 509)

Criteria	Mean (M)	Standard Deviation (SD)
Freshness	3.5	0.6
Product origin	4.1	0.6
Food safety	4.4	0.5
Traceability	4.1	0.6
Organic production	4.1	0.7

Note: Perceptions of goat meat quality criteria were measured using a five-point Likert scale, where 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree.

Table 5. Goat purchasing frequency and supply sources among surveyed restaurants (n = 86)

Frequency and Supply Sources	Category	Value (%)
Frequency of goat purchasing	Daily	65.1
	Every few days	31.4
	Weekly	2.3
	Every two weeks	1.2
Form of goat meat purchasing	Live goats	47.7
	Slaughtered goats	39.5
	Both forms	12.8
Sources of goat meat supply	Smallholder farmers	19.6
	Traders	67.2
	Slaughterhouses	13.2

restaurants purchased goats daily, while 31.4% purchased goats every few days, which is approximately one-third. Only a small proportion of restaurants purchased goats weekly or less frequently. Live goats were the most common form of purchase, accounting for 47.7% of respondents, followed by slaughtered goats (39.5%), while 12.8% purchased both live and slaughtered goats. Traders were the primary suppliers of goats, accounting for 67.2% of purchases, followed by smallholder farmers (19.6%) and slaughterhouses (13.2%).

Origin and sources of goats consumed in restaurants

The origin of goats consumed by surveyed restaurants is presented in Table 6. On average, each restaurant consumed approximately 98.8 goats per month, indicating substantial demand for goat meat among restaurant-based markets. Vietnamese crossbred goats accounted for the largest share of total consumption, with an average of 50.1 heads per restaurant per month, representing 50.7% of all goats consumed. Indigenous Vietnamese Co goats ranked second, with an average consumption of 27.5 heads per month (27.8%), followed by goats imported from Laos, which accounted for 20.5 heads per month (20.7%). Goats imported from other countries contributed only a negligible proportion of total consumption (0.8%).

Table 6. Origin of goats consumed by surveyed restaurants

Goat origin	Mean (Heads/ month)	Standard Deviation (SD)	Percentage (%)
Vietnamese crossbred goats	50.1	45.6	50.7
Vietnamese Co goats	27.5	39.1	27.8
Lao goats	20.5	45.9	20.7
Imported goats from other countries	0.7	6.3	0.8
Total	98.8	11.2	100

The relatively high standard deviations observed for Vietnamese crossbred goats (SD = 45.6), Vietnamese Co goats (SD = 39.1), and Lao goats (SD = 45.9) indicate considerable variation in sourcing patterns among restaurants. This variation may reflect differences in restaurant size, customer demand, local supply availability, and procurement strategies. Overall, domestic goats accounted for approximately 78.5% of total goat consumption, demonstrating that local production remains the primary source of supply for the restaurant sector. Nevertheless, the substantial contribution of Lao goats highlights the growing role of cross-border trade in meeting increasing market demand. The predominance of Vietnamese crossbred and indigenous Co goats suggests that these goat types are highly preferred by restaurant operators and constitute the principal sources of goat meat supplied to consumers in Vietnam.

Restaurant preferences for goat meat quality

The preferred characteristics of goats used by restaurants are presented in Figure 1. Indigenous Vietnamese Co goats were the most preferred breed, accounting for 65.1% of respondents. Lao goats and Vietnamese crossbred goats were preferred by 16.3% and 15.2% of respondents, respectively, while only a small proportion (3.5%) preferred other breeds such as Boer goats. Restaurant owners generally preferred medium-sized goats. The most preferred weight category was 20–25 kg/head (38.4%), followed by over 30 kg/head (27.9%) and 25-30 kg/head (23.3%). Only 8.1% of respondents preferred goats weighing less than 20 kg/head. These findings suggest that restaurant owners generally favor indigenous goat breeds and goats weighing between 20 and 30 kg live weight, which together accounted for 61.7% of responses.

Perceived market trends in the goat meat sector

The perceptions of restaurant owners regarding recent changes in the goat meat market are presented in Table 7. More than one-

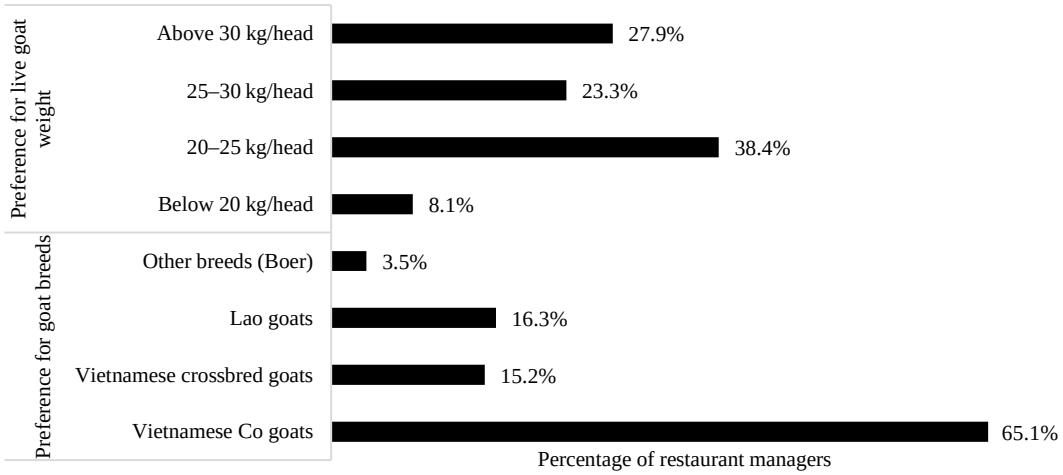


Figure 1. Preferred characteristics of meat goats by restaurants

Table 7. Perceived market trends in the goat meat sector according to restaurant owners (%)

Indicator	Unchanged	Increased	Decreased	Do not know
Live goat price	51.2	39.5	5.8	3.5
Goat supply	66.3	9.3	19.8	4.6
Number of goat meat restaurants	47.7	27.9	20.9	3.5
Consumer demand for goat meat	32.6	24.4	32.6	10.4

third of the respondents (39.5%) reported that live goat prices had increased in recent years, while 51.2% perceived prices as relatively stable. Only 5.8% believed that goat prices had decreased. These findings suggest that live goat prices have generally remained stable or increased over time. Two-thirds of the restaurant owners (66.3%) indicated that goat availability had remained relatively unchanged, whereas 19.8% reported a decline in supply. Only 9.3% observed an increase in goat availability. This suggests that respondents generally perceived goat supply as stable, although some concerns regarding supply constraints were reported. Restaurant owners also perceived mixed trends in the development of the goat meat sector. Nearly 28% reported an increase in the number of goat meat restaurants, while about 48% considered the number relatively stable. Similarly, 24.4% of respondents observed increasing consumer demand for goat meat, whereas 32.6% perceived demand as stable and an equal proportion reported declining demand. Overall, the results indicate that restaurant owners generally perceived the goat meat market as relatively stable, particularly with respect to prices, supply, and the number of goat meat restaurants. However, perceptions regarding consumer demand were more varied, suggesting differing experiences across locations and market segments.

DISCUSSION

The findings suggest that goat meat consumption in Vietnam is strongly associated with the expansion of food service establishments and changing consumer preferences. The average consumption of approximately 99 goats per restaurant per month highlights the substantial commercial importance of the goat sector. This result supports previous studies reporting that demand for goat meat in Vietnam has increased steadily in recent years and is expanding faster than domestic production capacity (Olmo et al., 2024). Similar patterns have been observed in many developing countries where rising incomes, urbanization, and dietary diversification have stimulated demand for high-value animal-source foods (FAO, 2011).

The predominance of restaurant-based consumption observed in this study reflects ongoing changes in food consumption behaviour in Vietnam. The Chi-square analysis revealed a significant association between goat meat consumption frequency and place of consumption ($\chi^2 = 17.476$, $p = 0.002$), indicating that restaurants constitute the primary venue for goat meat consumption across different consumer groups. More than half of the respondents in all consumption-frequency categories reported consuming goat meat mainly at restaurants, highlighting the central role of food service establishments in the goat meat market. This finding suggests that goat meat is increasingly perceived as a specialty food consumed in social and dining-out settings rather than as a routine household food item.

The growing importance of restaurant-based consumption is consistent with broader changes in dietary patterns associated with urbanization, rising incomes, and increasing demand for convenience foods. Similar observations were reported by Nguyen et al. (2023), who identified restaurants as the principal marketing channel for goat meat in Central Vietnam. Likewise, Phuong et al. (2014) noted that eating outside the home has become increasingly common among Vietnamese consumers as lifestyles and food preferences continue to evolve. The predominance of processed goat meat dishes preferred by consumers further reinforces the importance of restaurants in shaping market demand and consumption patterns.

From a market development perspective, the continued expansion of goat meat restaurants represents an important driver of demand growth and creates opportunities for producers, traders, and other actors along the goat value chain. The findings imply that extension programmes and livestock development initiatives should not only focus on improving farm-level productivity but also strengthen farmers' capacity to meet the quality, consistency, and food safety requirements of restaurant-based markets. Enhancing linkages between producers and restaurant operators could improve market access, support value addition, and contribute to the sustainable development of the goat sector in Vietnam.

The study also revealed a strong preference among restaurant owners for indigenous Vietnamese goats and Vietnamese crossbred goats. These breeds may be preferred because of their perceived meat quality attributes, although further research is needed to identify the specific characteristics influencing consumer and restaurant preferences. Previous studies have likewise reported that local goat breeds are often associated with natural grazing systems and superior eating quality (Gray et al., 2019; Hung et al., 2014). This preference highlights the importance of maintaining and improving local genetic resources while enhancing productivity through better feeding and management practices.

Consumer evaluations further indicate that food safety, product origin, and traceability are key determinants of purchasing decisions. The high ratings assigned to these attributes suggest that consumer preferences are gradually shifting from quantity-based consumption toward quality-oriented consumption. Similar trends have been reported by Don et al. (2023), who observed increasing consumer concern regarding product quality, food safety, and traceability within Vietnam's goat meat market. These findings are also consistent with broader international evidence showing that urban consumers increasingly demand safe and transparently sourced livestock products (FAO, 2011).

The perceived market trends reported by restaurant owners further support the existence of favorable market conditions for goat production. A substantial proportion of respondents indicated increasing goat prices and growing numbers of goat meat restaurants, while demand was generally perceived as stable or increasing. While many respondents perceived goat supply as stable and relatively few respondents reported increases in supply, perceptions regarding consumer demand were more varied. Nevertheless, the findings may

indicate concerns about the ability of domestic production systems to respond to changing market conditions. Similar observations were reported by Olmo et al. (2024), who highlighted the widening gap between goat meat demand and domestic supply in Vietnam.

From an extension education perspective, these findings emphasize the importance of strengthening market-oriented advisory services for goat producers. Sustainable livestock development increasingly requires farmers to understand not only production technologies but also consumer preferences, quality requirements, and market opportunities. Sinha et al. (2017) reported that goat farmers expressed substantial information needs regarding breeding, feeding, disease management, and marketing practices, while access to reliable information remained limited. Likewise, Gunaseelan and Singh (2018) identified technical knowledge gaps, marketing constraints, and inadequate institutional support as major challenges affecting commercial goat farming enterprises. The results of the present study suggest that extension programmes should integrate market information, quality standards, food safety practices, and value chain development into farmer training activities.

The findings also highlight opportunities for entrepreneurship and value chain development in the goat sector. Growing consumer demand creates potential for smallholder farmers and rural youth to engage in goat production, fattening, trading, and other value-added enterprises. Sharma and Singh (2023) demonstrated that entrepreneurship-oriented training programmes improved managerial skills and enterprise development capacities among livestock farmers. In addition, the heavy reliance of restaurants on traders for goat procurement indicates that marketing channels remain fragmented. Similar challenges have been reported in livestock value chains across developing countries, where weak coordination among value chain actors often limits product quality control and market efficiency (Gray et al., 2019; Namonje-Kapembwa et al., 2022). Strengthening linkages among producers, traders, processors, and restaurant operators could therefore improve traceability, market access, and economic returns for smallholder goat farmers.

Overall, the findings suggest that the sustainable development of goat production in Vietnam will depend on improving production efficiency while simultaneously responding to evolving market requirements. Extension services can contribute significantly by facilitating access to technical and market information, strengthening farmer capacities, and supporting the development of more integrated and market-responsive goat value chains.

CONCLUSION

The study assessed consumer demand and market requirements for sustainable goat production in Vietnam. The goat meat restaurants are the principal marketing channel and an important driver of market demand. Surveyed restaurants preferred Vietnamese crossbred goats, indigenous Co goats, and animals weighing 20–30 kg raised under semi-grazing and natural grazing systems. Consumers placed high importance on food safety, product origin, and traceability, reflecting increasing demand for quality-assured goat meat products. There were considerable market opportunities for the goat sector but also constrained related to small-scale production, fragmented marketing channels, weak value chain coordination, and limited traceability systems. From an extension education perspective, market-oriented extension programmes should integrate technical husbandry training with market information, food safety standards, entrepreneurship development, and value chain strengthening. Improving farmer access to advisory services and strengthening producer–market linkages would enhance product quality, market responsiveness, long-term sustainability and competitiveness of goat production systems in Vietnam.

DECLARATIONS

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Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: This study was conducted in accordance with ethical standards. Informed consent was obtained from all respondents prior to data collection.

Data availability: The data used in this study are available from the corresponding author upon reasonable request.

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Research Article

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Socioeconomic Determinants of Farmers' Attitudes toward Climate Adaptation Practices in Northern Bangladesh

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HIGHLIGHTS

- The majority (72.4%) of farmers exhibited a moderately favorable attitude toward climate change adaptation practices in northern Bangladesh.
- Bivariate analysis showed that farmers' attitudes were significantly and positively associated with education, farm size, household income, organizational participation, and access to information.
- In the multiple regression analysis, education and access to extension information emerged as significant predictors of farmers' attitudes, and the final model explained 29.8% of the total variation.

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Keywords: Climate change adaptation, Education level, Information dissemination, Agricultural attitudes, Regression analysis.

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ABSTRACT

The objective of the study was to determine the factors contributing to farmers' attitudes toward climate adaptation practices. Data were collected during 2024 through face-to-face interviews with 98 sampled farmers in the Dinajpur district of northern Bangladesh. Descriptive statistics, Pearson's product-moment correlation, and stepwise multiple regression analysis were used for data analysis. The results indicated that most farmers (72.4%) had a moderately favorable attitude toward climate adaptation practices. Pearson's correlation analysis showed that education, farm size, household income, organizational participation, and information access had significant positive relationships with farmers' attitudes toward climate adaptation practices. Multiple regression analysis revealed that education and information access were the most significant determinants of farmers' attitudes, explaining 36.6% of the variation. In the stepwise regression model, only education and information access emerged as significant predictors, jointly explaining 29.8% of the variation in farmers' attitudes toward climate change adaptation practices. Education alone explained 25.5% of the variation, while the inclusion of information access contributed an additional 4.3%. The findings suggest that improving non-formal education and strengthening extension services through farm and home visits, mass media campaigns, and ICT-based information dissemination can enhance farmers' adaptive attitudes and promote climate-resilient agricultural practices in Bangladesh.

INTRODUCTION

Agriculture plays a significant role in the development of Bangladesh, contributing 11.2% to the national GDP in fiscal year 2024–2025. This sector remains a vital source of employment, engaging about 35% to 40% of the country's labour force (Bangladesh Bureau of Statistics [BBS], 2025). Despite this importance, Bangladesh faces major challenges in achieving sustainable agriculture. The country has a population of over 160 million, projected to increase to around 265 million by 2050, creating

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increasing pressure on limited natural resources and food security (BBS, 2024). Bangladesh ranks 85th in the Global Hunger Index (GHI), indicating serious levels of hunger and food insecurity (Concern Worldwide, Welthungerhilfe, & Institute for International Law of Peace and Armed Conflict, 2025). In addition, Bangladesh is considered one of the most climate-vulnerable countries in the world (Karim & Thiel, 2017; Mamun et al., 2021; Ali et al., 2021). Due to its geographical location, the southern region is highly prone to cyclones, while the northwest frequently experiences drought (Ministry of Environment and Forests [MOEF], 2009). Climate change poses a serious threat to agriculture, particularly in Bangladesh (Food and Agriculture Organization [FAO], 2014), where the sector is among the most affected (Roy et al., 2013).

The Intergovernmental Panel on Climate Change (IPCC) predicts that global temperatures may increase by 1.8°C to 4.0°C by the end of the 21st century, increasing climate variability and the frequency of extreme weather events (Coumou et al., 2014). Consequently, climate change is expected to alter regional food production systems and technological innovations (Karim, 2015), affecting food security both directly and indirectly.

Bangladesh adopted Green Revolution technologies in the 1960s to meet growing food demand through improved crop varieties, irrigation, and chemical fertilizers and pesticides. Although these technologies significantly increased cereal production, excessive use of chemical inputs has caused land degradation, reduced soil microbial activity, and groundwater contamination (Roy et al., 2013). Therefore, climate-resilient farming practices such as drought-tolerant varieties, vermicompost, crop diversification, intercropping, pheromone traps, and perching for insect control are essential for addressing climate change impacts and ensuring long-term agricultural sustainability (Morand & Barzman, 2006).

Previous studies showed that socio-economic characteristics significantly influence farmers' attitudes toward agricultural practices (Haque et al., 2007; Rahman et al., 2020). Following the successful achievement of the Millennium Development Goals (MDGs), Bangladesh promoted climate adaptation practices in line with the Sustainable Development Goals (SDGs). The agricultural sector, particularly through the Department of Agricultural Extension (DAE), plays a key role in promoting climate adaptation practices aligned with SDG 2 (Zero Hunger) and SDG 13 (Climate Action).

In Bangladesh, most climate-related studies have focused on policy issues (Ali & Meisner, 2017), while limited research has examined adaptation practices (Mahashin & Roy, 2017) and climate change impacts on food security (Hasan et al., 2018). Although some studies explored farmers' attitudes toward sustainable agriculture, organic farming, and aquaculture (Haque et al., 2007; Hasan et al., 2019), very limited studies have applied econometric approaches to identify determinant factors influencing attitudes toward climate adaptation practices. Therefore, this study aims to assess farmers' attitudes toward climate adaptation practices and identify the key contributing factors.

METHODOLOGY

Biral Upazila in Dinajpur District was purposively selected for the study. The area lies between 25°31′ and 25°46′ north latitude and 88°26′ and 88°38′ east longitude. The main reason for selecting the area was its location in the Barind Tract Agro-Ecological Zone (AEZ), which is characterized by moderate to severe drought conditions that adversely affect agriculture. These geographical conditions make the northern region of Bangladesh highly vulnerable to drought impacts (Rahman et al., 2022). Subsequently, three villages out of nine villages in the sub-district were selected randomly. An updated list of farmers adopting climate adaptation practices under the DAE was prepared with the assistance of the Sub-Assistant Agricultural Officer (SAAO). The total number of farmers adopting climate adaptation practices was 265, constituting the study population. A sample size of 98 was determined using the formula of Miller and Brewer (2003):

$$n = N/\{1 + N (\alpha^2)\}$$

where N is the population, n is the required sample size, and α is the margin of error (fixed at 0.08). Data were collected through face-to-face interviews using a structured interview schedule from November to December 2024.

Based on literature review, judge rating, and questionnaire pre-testing, 10 socio-economic characteristics were selected as independent variables to explain farmers' adaptive attitudes. Farmers' attitudes toward climate adaptation practices were considered the dependent variable and measured using a five-point Likert scale developed by Likert (1932), widely used in attitude studies (Hasan et al., 2019; Rahman et al., 2020). A total of 18 statements covering insect pest control (7), water management (4), and soil management (7) were used. Among them, 11 were positive and 7 were negative statements arranged randomly to minimize response bias. Responses ranged from 5 (strongly agree) to 1 (strongly disagree) for positive statements and vice versa for negative statements. Total attitude scores ranged from 18 to 90, where lower scores indicated less favorable attitudes and higher scores indicated more favorable attitudes toward climate adaptation practices.

To identify the socio-economic factors influencing farmers' attitudes, correlation analysis, multiple linear regression, and stepwise multiple regression were employed. Similar analytical approaches were followed by Jayasingh and Mishra (2024), Shahin et al. (2024) and Rashid et al. (2026).

RESULTS

Descriptive statistics of the selected characteristics

The descriptive statistics of selected characteristics are presented in Table 1. The age of the farmers ranged from 23 to 52 years, with a mean value of 35.59 and a standard deviation of 6.662. This indicates that most of the farmers belonged to the young to middle-aged category. The mean education level of the farmers was 6.18 (SD = 3.774), indicating that most completed primary to secondary education. The average family size was 5.43, which is higher than the national average family size of 4.3 (BBS, 2025). The average farm size was 0.27 ha (SD = 0.387), indicating that most farmers belonged to marginal to small farm categories. The average annual household income was BDT 66.96 thousand. Farmers participated in training programs for an average of 2.39 days and received credit averaging BDT 26.60 thousand. The mean

Table 1. Descriptive statistics of the selected socio-economic characteristics

Characteristics	Description/Unit	Range	Mean	St. Dev.
Age	Measured in years	23-52	35.59	6.662
Education	Years of education completed	0.5-17	6.18	3.774
Family size	Number of members in the family	3-11	5.43	1.705
Farm size	Total household cultivated land in Hectare	0.01-2.40	0.27	0.387
Household income	Total annual income ('000' BDT.)	30-300	66.96	32.311
Training access	Number of days participated in training	0-5	2.39	1.231
Credit received	Amount of money received from different sources like bank or NGOs ('000' BDT)	0-200	26.60	30.082
Organizational participation	Participation in organization is measured by a score	0-5	1.40	1.00
Information access	The extent of contact with different extension sources measured in score	8-33	20.78	4.883
Farming experience	Farming engagement measured in years	2-30	8.80	4.580

organizational participation score was 1.40. Information access scores ranged from 8 to 33, with a mean of 20.78. The average farming experience was 8.80 years, with a standard deviation of 4.883.

Farmers' attitude towards climate adaptation practices

The total attitude score for individual respondents ranged from 18 to 90, while the observed scores ranged from 45 to 85, with a mean of 70.52 and a standard deviation of 5.116. Based on the observed scores, farmers were classified into three categories: "less favorable (45–58)", "moderately favorable (59–72)", and "highly favorable (73–85)". Data presented in Table 2 show that more than two-thirds (72.4%) of the farmers had moderately favorable attitudes, while 26.5% had highly favorable attitudes, and only 1.1% had less favorable attitudes toward climate adaptation practices. Therefore, it could be said that the majority of farmers showed a moderately favorable attitude toward climate adaptation practices. This finding is supported by previous studies from different perspectives (Haque et al., 2007; Hasan et al., 2019; Rahman et al., 2020).

Table 2. Categorization of farmers based on their attitude toward climate adaptation practices

Categories	Percent	Mean	SD
Less favorable (45-58)	1.1		
Moderately favorable (59-72)	72.4	70.52	5.116
Highly favorable (73-85)	26.5		

Multiple regression analysis for estimating factors contributing to farmers' attitudes

According to Nicol and Pexman (2010), the results of multiple regression analyses are typically presented using two tables: a correlation matrix for predictor and dependent variables (Table 3), and regression output tables summarizing multiple regression results. Accordingly, Pearson's Product-Moment Correlation (r) was used to examine the associations between independent variables and farmers' attitudes toward climate change adaptation practices (Table 3). Among the ten selected socioeconomic characteristics, five variables such as education, farm size, household income, organizational participation, and information access showed significant positive relationships with farmers' attitudes toward climate adaptation practices. These findings indicate that improvements in these factors are associated with more favorable attitudes toward adaptation practices.

The correlation results (Table 3) show that education ($r = 0.512$, $p < 0.01$), farm size ($r = 0.284$, $p < 0.01$), household income ($r = 0.254$, $p < 0.05$), organizational participation ($r = 0.457$, $p < 0.01$), and information access ($r = 0.357$, $p < 0.01$) were significantly and positively related to farmers' attitudes toward climate adaptation practices. Age ($r = -0.178$), family size ($r = -0.035$), training access ($r = 0.096$), credit received ($r = 0.040$), and farming experience ($r = 0.137$) were not significantly related to farmers' attitudes.

Table 3. Correlation between Farmer's attitude towards climate adaptation practices and independent variables

Independent variables	Value of 'r' with 96 d.f.
Age	-0.178
Education	0.512**
Family size	-0.035
Farm size	0.284**
Household income	0.254*
Training access	0.096
Credit received	0.040
Organizational participation	0.457**
Information access	0.357**
Farming experience	0.137

Note: *p < 0.05, **p < 0.01

However, correlation analysis only indicates the direction and strength of relationships but does not measure the magnitude of contribution. Therefore, stepwise multiple regression analysis was conducted to determine the relative contribution of significant predictor variables to farmers' attitudes toward climate change adaptation practices. The stepwise regression procedure involves entering and removing predictor variables sequentially based on statistical criteria (Karim et al., 2017). Based on the correlation results (Table 3), five significant variables were entered into the multiple regression. All assumptions for regression analysis were tested and satisfied. The normal P–P plot indicated that residuals were normally distributed, showing no significant deviation from the straight line. Since the sample size exceeds 30, the Central Limit Theorem (CLT) further supports the normality assumption.

The scatter plot indicated a linear relationship between dependent and independent variables. The Durbin–Watson statistic (2.131) confirmed the independence of residuals. Additionally, Pearson correlation coefficients were below 0.9, and Variance Inflation Factor (VIF) values were below 5 (Table 4), indicating no multicollinearity among the independent variables. The model was statistically significant ($p < 0.001$), rejecting the null hypothesis that there is no significant contribution of the selected characteristics to adaptive attitudes. This confirms a significant linear relationship between the dependent variable and at least one predictor variable. Since independent variables were measured in different units, standardized coefficients were used for meaningful comparison (Hasan et al., 2019). In multiple regression analysis, the results indicated that education and information access were statistically significant predictors contributing to farmers' attitudes, while the model explained 36.6% of the variation in farmers' attitudes toward climate change adaptation practices ($R^2 = 0.366$), indicating a good model fit (Biswas et al., 2026). Although the model explains a meaningful share of variation in farmers' attitudes, approximately 63.4% of the variance remains unexplained. This unexplained component might be reflected in institutional and social factors.

The significant two variables in multiple regression were further included in the stepwise regression analysis. In Table 5, the stepwise regression results show that the first model indicated that education alone explained 25.5% of the variation in farmers' attitudes toward climate change adaptation practices. In the second model, the inclusion of information access increased the explained variation to 29.8%, contributing an additional 4.3% explanatory power. These findings suggest that, although several variables were significantly correlated with farmers' attitudes, only two significant predictors such as education and access to information significantly emerged as strong predictors. Overall, the results underscore the critical role of non-formal education and extension-based information access in shaping farmers' attitudes toward climate change adaptation practices.

DISCUSSION

The moderately favorable attitude of most farmers toward climate change adaptation practices reflects growing awareness of climate-related risks and sustainable farming practices. This finding is consistent with previous studies (Haque et al., 2007; Hasan et al., 2019; Rahman et al., 2020), which suggest a gradual positive shift in farmers' perceptions toward climate-resilient agriculture. The results of the correlation analysis indicate that socio-economic factors such as education, farm size, income, organizational participation, and access to extension services are associated with farmers' attitudes toward climate change adaptation practices. Farm size and household income significantly influence farmers' attitudes, as farmers with larger landholdings and higher income levels generally have greater financial capacity and risk-bearing ability, enabling them to invest in new technologies and long-term adaptation strategies (Kassie et al., 2013; Shitu et al., 2018; Rahman et al., 2020). These findings are supported by Sthitaprajna and Shasani (2026), who identified economic motivation, annual income, and larger farm size as significantly correlated with adaptive capacity and attitude. Similarly, organizational participation enhances farmers' exposure to information, peer learning, and collective decision-making, which collectively contribute to more favorable attitudes toward climate adaptation (Aryal et al., 2018; Munasib & Jordan, 2011), aligning with their findings that social participation is a significant determinant of adaptive capacity.

In the multiple regression analysis, the results indicated that education and information access were the most significant determinant factors contributing to farmers' attitudes, while the model explained 36.6% of the variation in farmers' attitudes toward climate change adaptation practices, indicating a good fit (Biswas et al., 2026). The unexplained variation might reflect institutional and social determinants that were not included in the present analysis, such as communication skills and technical competence of extension officers, the quality of farmer–extension officer relationships, the extent of social capital and peer influence, and the role of local institutional structures in shaping access to extension services (Billah et al., 2025; Biswas et al., 2026).

In the stepwise regression analysis, education played a particularly important role in shaping adaptive attitudes. Educated farmers are more likely to understand climate risks, process information effectively, and adopt appropriate adaptive strategies (Haque et al., 2007; Mango et al., 2017). The contribution of education is also consistent with Sthitaprajna and Shasani (2026), who reported that education, along with scientific orientation and

Table 4. Summary of multiple linear regression analysis showing the significant variables

Independent variables	B (Un-standardized)	Std. Error	Beta (Standardized)	t	Sig.	Tolerance	VIF
Education	0.391	0.144	0.289**	2.725	0.008	0.615	1.627
Farm size	1.990	1.227	0.151	1.621	0.108	0.797	1.254
Household income	0.012	0.014	0.075	0.818	0.416	0.826	1.210
Organizational participation	1.000	0.538	0.196	1.859	0.066	0.622	1.608
Information access	0.196	0.097	0.188**	2.017	0.047	0.797	1.254

Constant (Intercept) = 61.301, R = 0.605, $R^2 = 0.366$, Adjusted $R^2 = 0.331$, F (5,92) = 10.614, $p < 0.001$, Durbin–Watson = 2.131

Table 5. Stepwise regression showing the contributing variables to adaptive attitude

Model	Variables Entered	Unstd. Coeff. (B)	Std. Coeff. (β)	Adjusted R^2	R^2 Change (Contribution %)	t-value	Sig.
1	Constant + Education	0.694	0.512	0.255	0.255 (25.5%)	5.841	0.000
2	Constant + Education + Information Access	0.245	0.234	0.298	0.043 (4.3%)	2.644	0.010

organizational participation, significantly enhances farmers' adaptive capacity. This highlights the importance of human capital in strengthening adaptive behavior. In addition, access to information through extension services emerged as another important determinant influencing farmers' attitudes. Timely access to relevant information on weather, soil, and crop management helps farmers make informed decisions under changing climatic conditions (Hasan et al., 2018; Mulwa et al., 2017), while Sthitaprajna and Shasani (2026) similarly emphasized the role of information source utilization and extension participation in enhancing adaptive capacity. This emphasizes the critical role of agricultural extension systems in supporting climate-resilient farming practices.

Overall, the stepwise regression results further confirm that education and access to extension services are the most influential determinant factors of farmers' attitudes toward climate change adaptation practices. These findings indicate that knowledge and information access play a central role in shaping adaptive attitudes (Ghanghas et al., 2015). Overall, the findings suggest that improving educational attainment and strengthening extension service delivery are key strategies for enhancing farmers' positive attitudes toward climate change adaptation practices and promoting sustainable agricultural development.

CONCLUSION

Correlation analysis revealed that education, farm size, income, organizational participation, and access to extension services were significantly associated with farmers' attitudes. However, stepwise regression results confirmed that education and access to extension information were the most important determinant contributing to farmers' attitudes. The findings highlight the importance of non-formal education and effective extension services in shaping farmers' adaptive behavior and attitudes. Therefore, these two factors should be prioritized in future climate adaptation strategies and policymaking. The study recommends strengthening government and non-government non-formal education and extension programs to promote climate change adaptation practices. ICT-based awareness campaigns should also be enhanced to promote favorable attitudes. Future research should examine the socioeconomic impacts of climate-resilient practices in different regions, as climate change effects vary across locations and contexts.

DECLARATIONS

Ethical approval and informed consent: No ethical approval is needed for this study, however, the informed consent was sought from participants.

Conflict of interest: The authors hereby declare that there is no conflict of interest.

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Research Article

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Climate Vulnerability and Sustainable Livelihood Strategies in Agriculture: A Bibliometric Analysis

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HIGHLIGHT

- Publications on Climate Vulnerability and Sustainable Livelihood rose sharply from 2020 and reached the highest level in 2025.
- Livelihood, vulnerability, agriculture and food security formed the core keyword network.
- Recent trends shifted towards adaptation, resilience and livelihood diversification.

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ABSTRACT

Rural households are increasingly vulnerable to climate-induced risks by impacting livelihoods, income, food security, access to resources and adaptive capacity. Livelihood capitals and sustainable livelihood strategies for climate vulnerability were reviewed and mapped through bibliometric analysis. Scopus-indexed journal articles published during 2017-2026 were analysed following PRISMA-based screening. Biblioshiny and VOSviewer were used to examine annual scientific production, major sources, keyword co-occurrence, thematic mapping, trend topics and conceptual structure. The findings show a steady increase in research output after 2020, with sustainability, development, climate change and disaster-risk journals contributing prominently. Keyword and thematic analyses revealed that livelihood, vulnerability, agriculture, food security, adaptation and resilience form the core knowledge structure of the field. Recent trends indicate a shift from descriptive vulnerability assessment towards solution-oriented themes such as adaptive capacity, livelihood diversification and climate-smart agriculture. However, livestock systems, gender dimensions, local institutions and extension advisory mechanisms remain weakly integrated. The study concludes that agricultural extension must move beyond crop-centred advisory services towards livelihood-based, climate-resilient extension models that emphasise vulnerability diagnosis, diversification support, institutional convergence, climate information services, and capacity building.

INTRODUCTION

Climate variability has emerged as one of the most important threats to rural livelihood security, especially in developing countries, where agriculture and other natural resource based livelihood activities continue to be the key sources of income, employment, and food security. Climate risks are not the same for all rural households, however. Vulnerability is a function of agro-ecological conditions, livelihood dependence, access to productive resources, institutional support and adaptive capacity (Morton,

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2007). Belay and Lebeza (2024) showed that livelihood vulnerability varies across different agro-ecological zones in north-western Ethiopia, indicating the need to understand the local production environment and household resource endowment to understand climate risk. Tribal, marginal, and smallholder farming households with livelihoods in climate-sensitive sectors are particularly vulnerable in India. Kumar and Mohanasundari (2025) noted significant geographical disparities in the climate vulnerability of tribal households in Central India; similarly, Hazarika et al. (2024) highlighted the roles of exposure to climatic shocks, socio-economic sensitivity, and the limited adaptive capacity of rural households. The vulnerability to climate change is not limited to environmental impacts and is a multidimensional problem in terms of livelihoods, institutional frameworks, and rural development.

The Sustainable Livelihood Framework (SLF) offers a comprehensive perspective on this relationship by describing how households are resilient in their livelihoods and across five livelihood capitals: human, social, natural, physical, and financial. These capitals affect how households diversify income sources, use agriculture strategies in the face of climate change, access finance, build social connections, and withstand climate-related shocks and stress. Natarajan et al. (2022) pointed out that SLF still has much relevance for current development research but needs to be resituated in the context of the new risks, social inequalities and environmental shifts. The dimensions of climate vulnerability, exposure, sensitivity, and adaptive capacity are commonly used to assess climate vulnerability. Hahn et al. (2009) developed the Livelihood Vulnerability Index (LVI) and LVI-IPCC to measure these three aspects, and Opiyo et al. (2024) demonstrated that households with high exposure and low adaptive capacity had significantly higher vulnerability.

While studies on climate change adaptation, resilience, livelihood diversification, and sustainable agriculture have grown significantly, the literature remains scattered across agricultural sciences, environmental studies, rural development, disaster risk reduction, and sustainable agriculture. Bibliometric analysis is a useful tool for summarising the vast body of knowledge that has accumulated over the years and for identifying the most influential authors, emerging topics, collaborations, and research gaps (Donthu et al., 2021; Chandra et al., 2026). Previous bibliometric research has largely focused on climate change, agricultural sustainability, or adaptation, without paying much attention to the interdependent linkages among livelihoods, vulnerability, and agriculture. Thus, the present study offers a thorough bibliometric analysis to capture the intellectual landscape and development of livelihood, vulnerability and agriculture research.

METHODOLOGY

The research was conducted through a systematic literature review and a bibliometric analysis of the literature on climate vulnerability and livelihood capitals/sustainable livelihood strategies. The review was carried out in a transparent and systematic way, following the PRISMA 2020 guidelines for identifying, screening and selecting relevant studies (Page et al., 2021). Science-mapping techniques were employed for bibliometric analysis to explore publication trends, influential publications, collaboration trends, thematic evolution, and research gaps (Donthu et al., 2021).

Scopus was chosen because it offers extensive coverage of high-quality, peer-reviewed literature across agriculture, environmental sciences, social sciences, and development studies. The search was conducted in English, for journal articles from 2017 to 2026 with a query of TITLE-ABS-KEY (Livelihood) AND TITLE-ABS-KEY (Vulnerability) AND TITLE-ABS-KEY (Agriculture). To ensure consistency and quality, conference papers, book chapters, reviews, editorials, and notes were not included. There were 1,449 records found. Following the deduplication and screening of titles, abstracts and metadata for theme relevance, 1,094 articles were retained for analysis. Selected records were exported in CSV format, including bibliographic data, such as author, title, abstract, keywords, source title, volume, year, affiliation and number of citations. Synonymous and closely related terms were standardised before performing co-occurrence analysis to ensure the accuracy of the co-occurrence analysis.

The Bibliometrix package (version 4.3.2) via the Biblioshiny interface and the VOSviewer (version 1.6.20) were used for bibliometric analyses. The annual production of scientific items has been analysed, the main journals, authors, institutions, countries, citation performance, as well as the thematic evolution, conceptual structure and collaboration networks have been determined (Aria & Cuccurullo, 2017). Keyword co-occurrence networks and thematic clusters were visualised using VOSviewer (Van Eck & Waltman, 2010). The results of the bibliometric analysis were analysed using the Sustainable Livelihood Framework, connecting themes that emerged with livelihood capital, climate vulnerability dimensions, and sustainable livelihood strategies, thereby highlighting research gaps and a pathway for future research on climate change and rural development.

RESULTS

Scopus was selected due to its wide range of high-quality, peer-reviewed literature across the fields of agriculture, environmental sciences, social sciences, and development studies. The search was done in English using the terms TITLE-ABS-KEY (Livelihood) AND TITLE-ABS-KEY (Vulnerability) AND TITLE-ABS-KEY (Agriculture) for journal articles published between 2017 and 2026. To maintain uniformity and quality, conference papers, book chapters, reviews, editorials, and notes were omitted. A total of 1449 records were found. After deduplication and screening of titles, abstracts, and metadata for theme relevance, 1,094 articles were retained for analysis. Selected records were exported as a CSV file comprising bibliographic information (author, title, abstract, keywords, source title, volume, year, affiliation and number of citations). Synonymous and closely related terms were standardised before performing co-occurrence analysis to ensure the accuracy of the co-occurrence analysis.

The PRISMA flow diagram (Figure 1) summarises the study selection process for this review. A total of 1,449 records from the Scopus database have been identified during the period from 2017 to 2026. 1,307 records were screened after duplicate records were removed, and a further examination excluded 113 non-relevant publications, such as book chapters, conference papers, and short

communications. Thereafter, 1,194 reports were evaluated, and 32 reports were found in non-English languages and 68 were articles that were not open access. Last, a critical literature selection procedure was followed and 1,094 studies were included in the bibliometric analysis.

Annual scientific production

The annual scientific production showed a gradual increase in publications on livelihood capitals, climate vulnerability, and livelihood strategies during 2017–2025 (Figure 2). The publication output was moderate during 2017–2019, followed by a noticeable increase from 2020 onwards. The number of publications further increased during 2021–2023, reaching its highest level in 2025, with approximately 140 publications. This signals the growing focus on climate vulnerability, livelihood resilience, adaptation and sustainable rural livelihood systems. The drop in 2026 should be viewed with caution as the data for this year was not fully available.

Most relevant sources

The source analysis identified the key journals published in this field (Figure 3). The top journal was Sustainability (Switzerland) followed by Environment, Development and Sustainability, Climatic Change, Regional Environmental Change and Climate and Development. The other substantial sources were Geo Journal, PLOS ONE, International Journal of Disaster Risk Reduction, Land Use Policy and Agricultural Systems. The spread of publications across these journals suggests that research on climate vulnerability and livelihood is multifaceted, focusing on sustainability science, development studies, environmental change, disaster risk reduction, land-use systems and agricultural resilience.

Keyword co-occurrence network

The co-occurrence analysis of keywords showed the main thematic connections in these publications (Figure 4). The keywords that stood out were livelihood, vulnerability, and agriculture and food security, suggesting that these are the key themes of the research area. There were four major clusters. The first cluster was related to livelihood, smallholders, food security and coping mechanisms. The second cluster related to agriculture, ecosystems, climate and land use. The third cluster pertained to drought, disasters, adaptation strategies and India, emphasising the need for hazard and region-specific studies. The fourth was associated with

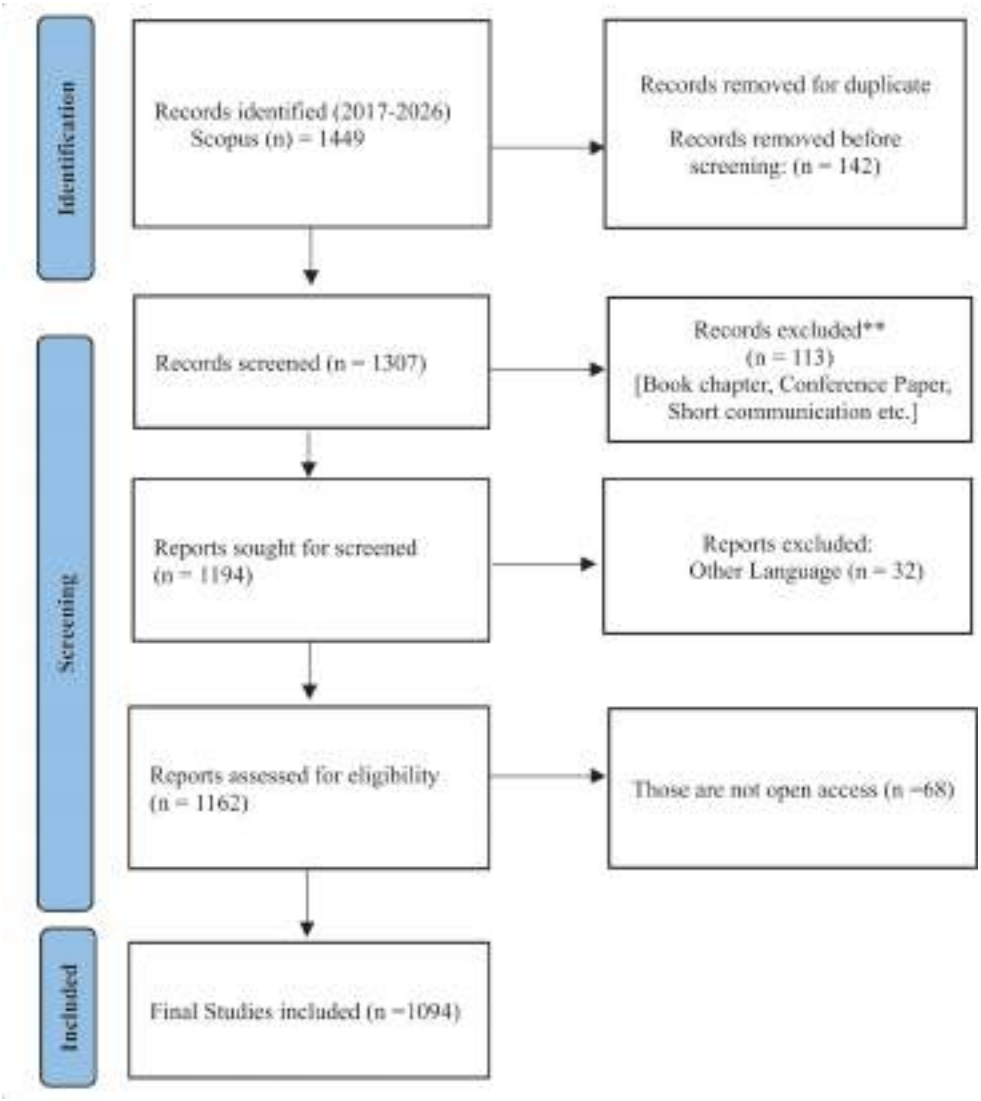


Figure 1. PRISMA flow chat

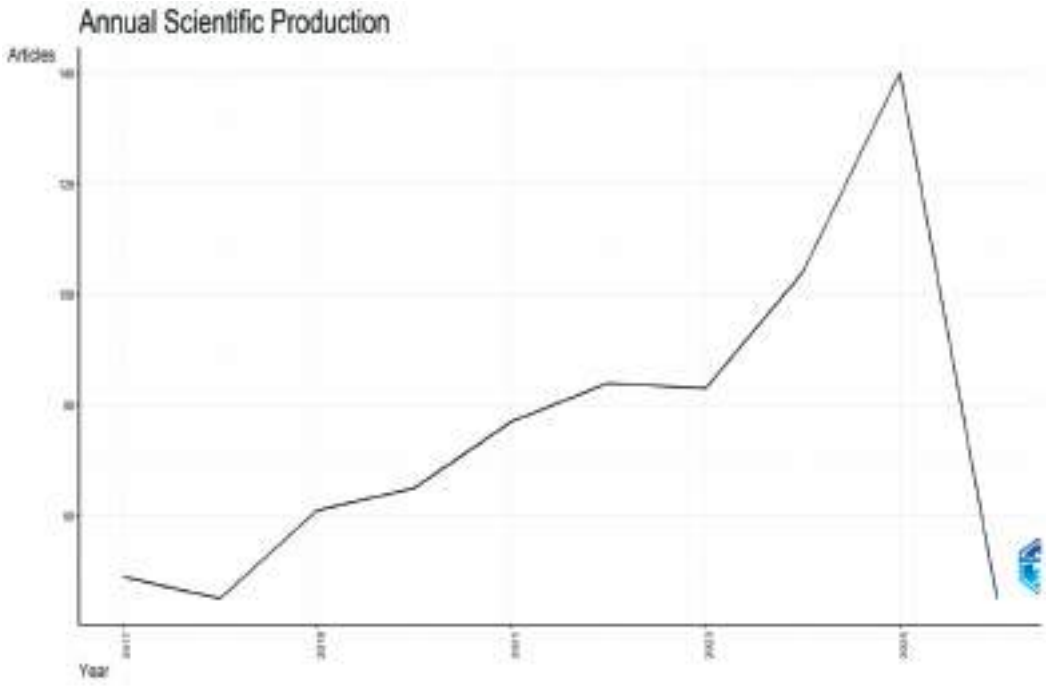


Figure 2. Annual scientific production

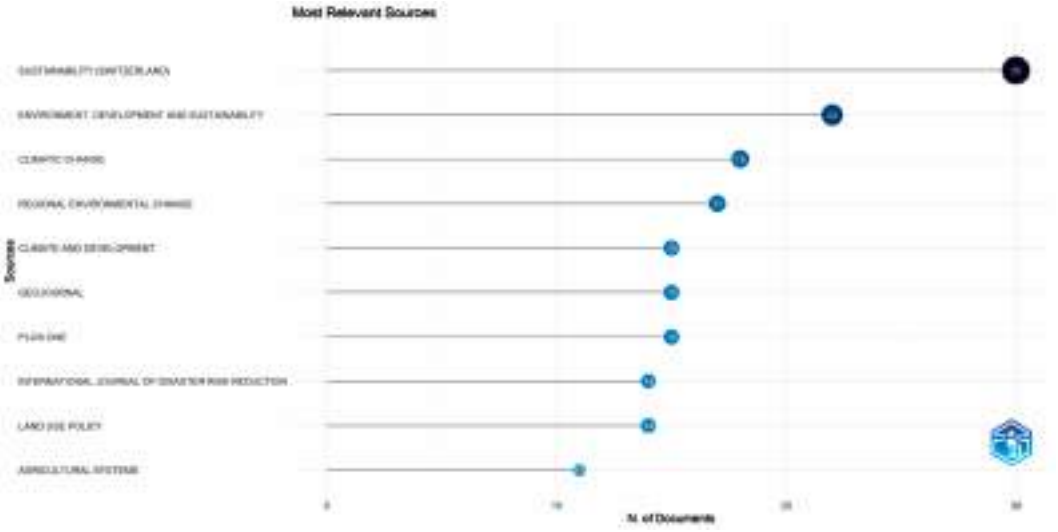


Figure 3. Most relevant source

farmers, households, humans, and income. The inclusion of concepts such as exposure, sensitivity, and adaptive capacity suggests that the literature is heavily influenced by existing climate vulnerability assessment literature.

Thematic map

The thematic map categorised research themes into centrality and density (Figure 5). Vulnerability, climate change and livelihoods were significant themes, highlighting their prominence. These themes were highly relevant but immature in their own development. Agriculture, human and article appeared as motor themes, suggesting that they were highly developed and well connected with other themes. Sustainability, sustainable development, and economics appeared as niche themes, indicating they were relatively mature but probably less well connected to other themes. Risk assessment, decision-making, and Bangladesh were present in the emerging or declining quadrant, suggesting that these topics might be worth exploring, particularly in studies of site-specific and decision-support research.

Trend topics

The trend topic analysis revealed a gradual shift in research from vulnerability assessment to adaptation- and resilience-focused themes (Figure 6). Terms such as vulnerability, climate change and livelihood were consistent over the years and demonstrated their ongoing relevance. Recently, the keywords climate adaptation, livelihood resilience, livelihood diversification, and adaptive capacity have become more prominent. This suggests a research focus on finding solutions. Middle period themes like drought, agricultural production and risk assessment were more prevalent, whereas recent trends show a growing focus on sustainable development, resilience and climate responsive livelihoods.

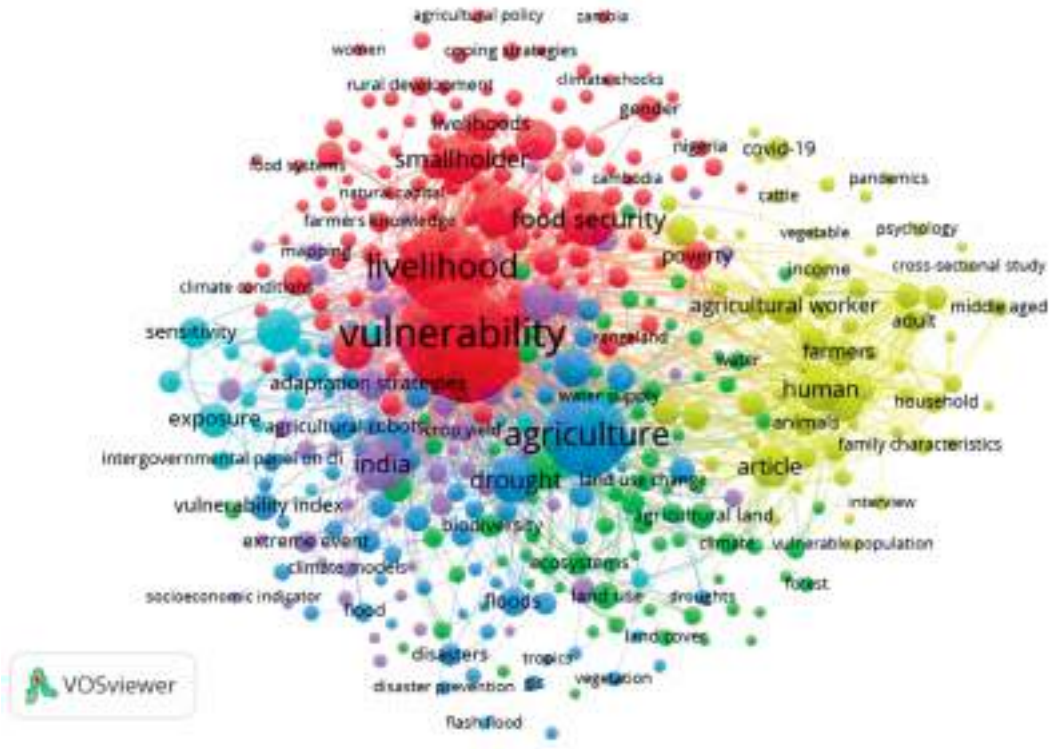


Figure 4. Co-occurrence with index keywords

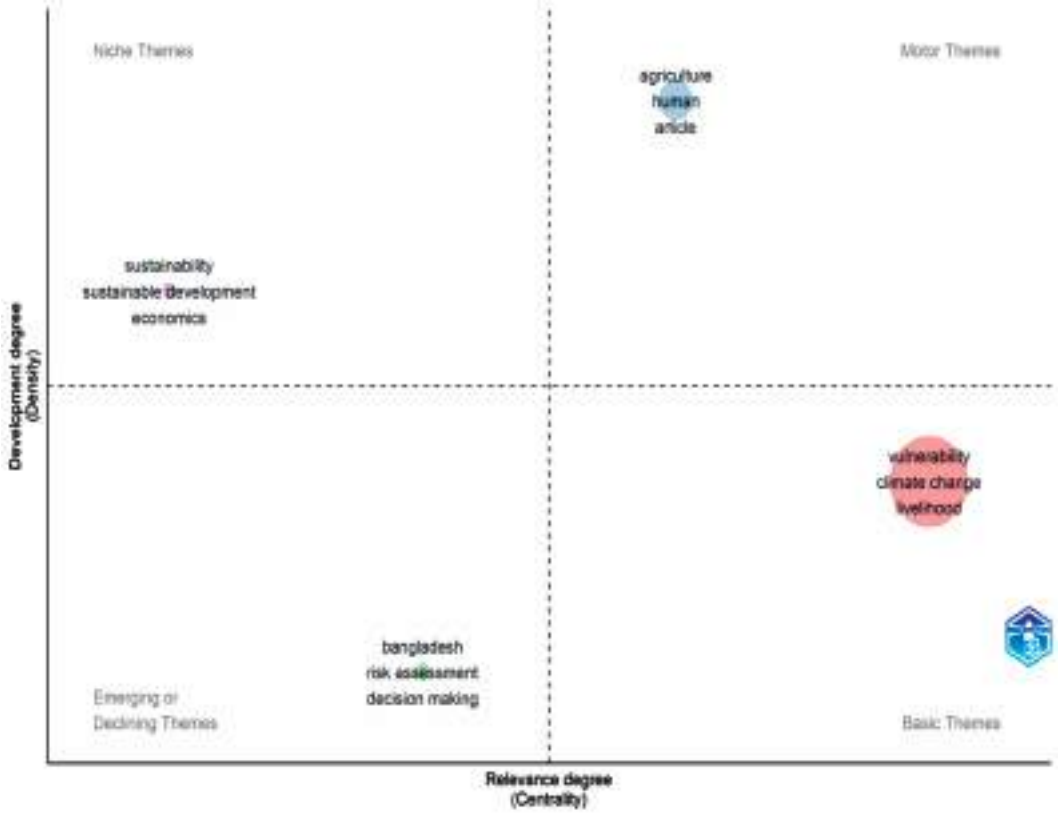


Figure 5. Thematic map

Factorial map

The factorial map obtained from the Multiple Correspondence Analysis illustrated the conceptual organisation of the research topic (Figure 7). The central cluster of terms (climate change, agriculture, smallholder farmers, food security, and risk assessment) was close to the centre of the map, suggesting a high degree of conceptual inter-relationship. Vulnerability, resilience, adaptation, adaptive capacity and livelihoods were also grouped together, revealing the link between climate risk and livelihoods. Geographical markets such as India, Bangladesh, Ethiopia, and Ghana highlighted the significance of

Figure 6. Trend topics

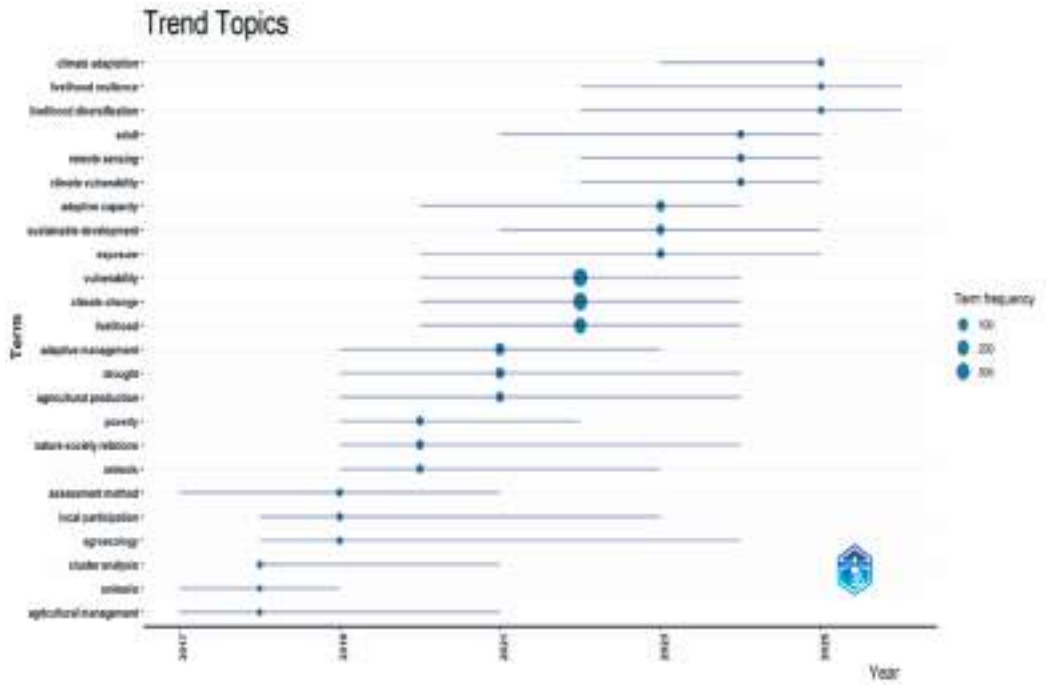
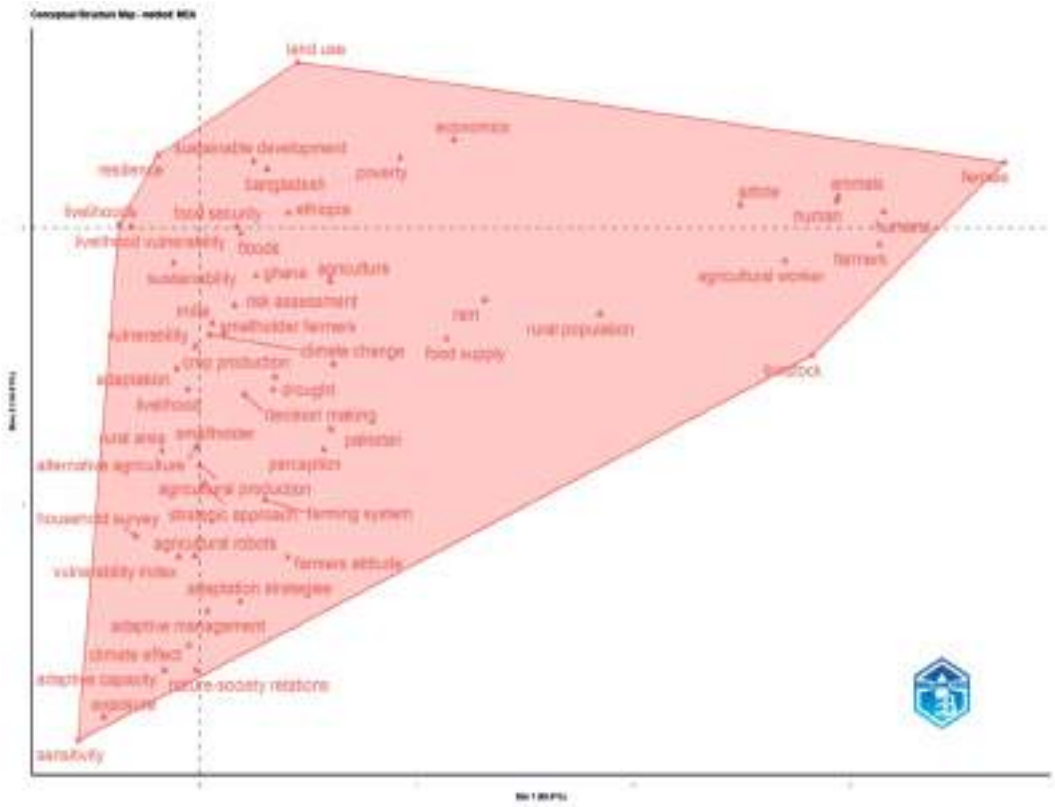


Figure 7. Factorial map



developing country settings in this research field. Outlier themes, including livestock, farmers, and animals, were relatively separate from the core theme, indicating that research on these topics is not as well connected within the field of livelihood vulnerability.

DISCUSSION

Livelihood capitals and climate vulnerability have evolved from descriptive vulnerability studies towards resilience and solution-oriented studies. This is important for extension because vulnerability to climate change is no longer just a crop production risk issue; it's a livelihood systems issue. The keywords "livelihood", "vulnerability", "agriculture" and "food security" in the network indicate that extension strategies should be framed around households' livelihood portfolios rather than agricultural production. This aligns with the Sustainable Livelihood Framework, which posits that human, social, natural, physical, and financial

capitals drive rural households' responses to shocks (Natarajan et al., 2022; Roy et al., 2025).

The rising trend in publications since 2020 reflects the increased research and policy focus on climate-resilient livelihoods. The challenge with this increase is not only the number of publications, but also how they are translated into field-level advisory approaches. The approach of extension is still technology transfer focused, with climate vulnerability needing diagnostic, participatory and site-specific advisory models. Mallappa and Gadde (2025) developed a tool to measure livelihood vulnerability of climate-sensitive farming communities, reinforcing the need for extension agencies to use locally valid vulnerability indicators before recommending interventions.

The co-occurrence of agriculture, food security, smallholders, coping strategies, and adaptive capacity indicates that vulnerability is closely linked to farmers' ability to reorganise their livelihood choices. Therefore, adaptation should not be treated as a single practice, such as the introduction of drought-tolerant varieties or irrigation improvements. Rather, it should be framed as a bundle of decisions involving crop choice, income diversification, credit access, risk information, insurance, collective action and institutional linkage. Evidence from Bundelkhand showed that farmers' adaptation behaviour was influenced by access to institutional credit, weather information, and crop insurance, indicating that adaptation depends strongly on enabling services rather than farmer awareness alone (Jatav & Singh, 2023). Shitu and Nain (2025) suggested that agencies and stakeholders assisting farmers in scaling up the adoption of climate smart agricultural practices, like precision conservation agriculture, should develop a shared understanding and strategy for promoting these cutting-edge technologies within farming communities.

The emergence of livelihood diversification and livelihood resilience as recent trend topics is particularly relevant for extension science. Diversification reduces livelihood sensitivity by spreading risk across farm, off-farm and non-farm activities. Pal et al (2017) recommended to diversify their activities to reduce the livelihood vulnerability in this age of climate change. In Odisha, occupational diversification among farmers was influenced by education, non-farm engagement, achievement motivation and management orientation, explaining substantial variation in diversification behaviour (Jayasingh & Mishra, 2024). Extension services should include training in entrepreneurship, skills, market information, and enterprise facilitation, not just crop advisory.

The thematic map also reveals that sustainability and economics are relatively mature but less connected with the mainstream vulnerability literature. This is a gap because farmers judge adaptation based on ecological and non-ecological value, including cost, labour, profit, risk and social acceptability. Climate-smart agriculture studies also support this argument (Mishra et al., 2024). Mishra et al. (2025) observed that improving farmers' knowledge and economic capacity could strengthen adoption of climate-smart agricultural practices, suggesting that technical recommendations require strong extension mediation for adoption among vulnerable smallholders.

The factorial map indicates that livestock, animals and farmers remain relatively peripheral in the broader livelihood vulnerability literature. This is a concern because livestock often functions as a buffer asset during climate and income shocks, especially for smallholders and rainfed farmers (Verma et al., 2025). Similarly, the limited visibility of gender, local institutions and extension advisory systems points to a conceptual gap. Climate vulnerability is experienced differently across gender, caste, resource ownership and institutional access, and ignoring these differences can make adaptation programmes technically sound but socially ineffective (Pundir et al., 2025). This requires vulnerability diagnosis, capital-specific interventions, farmer collectives, institutional convergence, digital climate services, local adaptation planning and continuous feedback-based extension (Lalu et al., 2025; Saha et al., 2026). The bibliometric study signals the need for a new extension architecture that can strengthen adaptive capacity and sustainable livelihood resilience in the face of climate vulnerability.

CONCLUSION

The study reveals a clear shift in research from vulnerability assessment towards resilience-oriented and livelihood-focused approaches, with strong emphasis on livelihood capitals, adaptation and diversification. The findings highlight that vulnerability is not solely determined by climate exposure but by the strength of human, social, financial, physical and natural capitals. The growing prominence of livelihood diversification, adaptive capacity and climate-smart practices indicates a transition towards solution-driven research; however, gaps remain in integrating livestock systems, gender dimensions and local institutional mechanisms. The study implies the need to move beyond production-centric advisory towards livelihood-based extension models. Extension systems should prioritise vulnerability assessment, diversification support, climate information services, institutional linkage and capacity building. Strengthening farmer collectives, promoting rural enterprises and integrating crop-livestock systems will be critical for enhancing adaptive capacity and ensuring sustainable, climate-resilient rural livelihoods.

DECLARATIONS

Ethical consideration and consent to participate: The study was conducted through the Bibliometrix package (version 4.3.2) via the Biblioshiny interface and the VOSviewer (version 1.6.20) for bibliometric analyses of the data fetched from Scopus database. Hence, ethical issues were not involved.

Conflict of interest: The authors reported that there were no known competing financial interest and personal relationships to disclose that could have appeared to influence the work reported in this paper.

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Research Article

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Mapping Global Research on Farmers' Climate Resilience and Agricultural Extension: A Bibliometric Analysis

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HIGHLIGHTS

- Global research on farmers' resilience and agricultural extension grew 40.62% annually, increasing nearly fifty-fold from 2015-2026.
- Keyword mapping reveals 2 clusters, with agricultural extension viewed as one adaptation strategy rather than a standalone research field.
- Author collaboration remains regionally concentrated, with limited cross-regional links, highlighting opportunities for broader international partnerships.
- Ethiopian universities dominate institutional output, while recent research increasingly emphasizes household survey based studies over extension theory.

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Keywords: Agricultural extension, Bibliometric analysis, Biblioshiny, Climate change adaptation, Farmers' resilience, Mapping research, Sustainable agriculture.

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ABSTRACT

The study mapped global research on farmers' climate resilience and agricultural extension through a bibliometric analysis of 353 Scopus-indexed publications published between 2015 and 2026. Bibliometric data were analysed using Biblioshiny in the Bibliometrix package. The results revealed rapid publication growth, with an annual growth rate of 40.62%, increasing from two documents in 2015 to 100 in 2025. The literature received an average of 17.86 citations per document, indicating growing scholarly interest. Research output was concentrated in Ethiopia, India, China, the United States, Ghana, and the United Kingdom, while Ethiopian universities accounted for five of the ten most productive institutions. Author keyword analysis identified two dominant thematic clusters centred on climate adaptation, resilience, and agricultural systems. Thematic evolution showed a shift from livelihood-oriented studies toward resilience and adoption-focused research. Although collaboration networks remained fragmented, publication output continued to expand. A key finding was that agricultural extension remained conceptually embedded within broader climate adaptation and resilience research rather than emerging as an independent thematic domain. The study provided future research directions for strengthening the theoretical and empirical integration of agricultural extension interventions to enhance farmers' resilience under changing climatic conditions, particularly in Southeast Asia and Latin America.

INTRODUCTION

Climate change has stimulated rapid growth in research on farmers' resilience, adaptive capacity, vulnerability, and climate adaptation over the past decade. Following the adoption of the Paris Agreement and the Food and Agriculture Organisation's Climate Smart Agriculture (CSA) framework in 2015, scholarly attention has increasingly focused on understanding how farming households

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respond to climate-related risks through technological innovation, institutional support, and livelihood adaptation. Agricultural extension has emerged as a central mechanism for strengthening farmers' adaptive capacity by facilitating knowledge exchange, providing climate information services, and disseminating innovations. Raghuvanshi and Ansari (2020) demonstrated that farmers' vulnerability is closely associated with awareness, adaptive capacity, and extension support. Evidence from Pathak et al. (2024) indicates that farmers who actively accessed extension services and climate-related information were generally better prepared to respond to climate change. This underscores the continuing role of agricultural extension in supporting farmers' adaptation and resilience.

The rapid expansion of this literature has produced a highly fragmented and multidisciplinary knowledge base spanning agricultural extension, rural sociology, agricultural economics, climate science, sustainability, disaster risk reduction, and development studies. Although this diversity has enriched resilience research, it has also made it increasingly difficult to obtain a comprehensive understanding of the field's intellectual structure, collaboration patterns, and thematic evolution. Conventional narrative and systematic reviews provide valuable syntheses of empirical evidence but offer limited insights into the dynamics of scientific knowledge production and the evolution of research domains.

Bibliometric analysis has become an established approach for systematically mapping scientific knowledge through publication trends, citation performance, collaboration networks, and thematic evolution (Aria & Cuccurullo, 2017; Donthu et al., 2021). Baraj et al. (2024) mapped the literature on climate change, resilience, adaptation, and sustainable agriculture in India, revealing rapid scientific growth and evolving thematic structures. Similarly, Mukherjee et al. (2025) analysed global research on ICT-based agricultural extension and advisory services, highlighting the increasing prominence of digital extension and knowledge-sharing systems. However, these studies focused on specific research domains and did not examine the broader intellectual relationship between agricultural extension and farmers' climate resilience. Roy et al. (2024) while analysing Indian Journal of Extension Education, identified several intervention areas, a further improvement in those will enable this only Scopus-indexed journal on Agricultural Extension from Indian origin to provide Extension Researchers with a strong global platform. Thus, the findings not only confirm existing knowledge but also uncover unique situations, providing researchers and stakeholders with valuable perspectives for future exploration and engagement in extension education and related fields.

More importantly, no previous bibliometric study has explicitly investigated the position of agricultural extension within the global knowledge structure of farmers' climate resilience. As resilience research has expanded beyond technological adaptation to encompass adaptive capacity, institutional support, social learning, livelihood resilience, climate information services, and disaster preparedness, agricultural extension has become an increasingly important component of resilience-building. Nevertheless, it remains unclear whether agricultural extension has evolved into an independent research domain or continues to function primarily as a supporting theme within resilience research. Addressing this gap is essential for clarifying the intellectual development of agricultural extension and identifying future research priorities.

METHODOLOGY

Bibliographic data were retrieved from the Elsevier Scopus database, with the search conducted on 5 May 2026. Scopus was selected because of its broad multidisciplinary coverage, comprehensive citation indexing, and extensive representation of agricultural, environmental, and social science journals. Consistent with recent bibliometric studies in agricultural extension (Chandra et al., 2026), a single database was used to ensure dataset consistency, avoid duplicate records, and harmonise metadata associated with merging multiple databases. The search was performed in the TITLE-ABS-KEY field using three concept groups representing farmers, climate resilience, and agricultural extension: TITLE-ABS-KEY ((“farmer” OR “smallholder” OR “agriculture”) AND (“resilience” OR “climate change adaptation” OR “adaptive capacity” OR “vulnerable”) AND (“agricultural extension” OR “advisory service” OR “climate-smart agriculture”)).

The initial search retrieved 2,091 records. Following the PRISMA 2020 framework (Page et al., 2021), records were sequentially refined using predefined Scopus filters. Publications were limited to the period 2015-2026 (n = 2.017), the subject areas Agricultural and Biological Sciences and Social Sciences (n = 722), document types articles and reviews (n = 532), final publication stage (n = 510), journal sources (n = 431), and English-language publications (n = 353). As all records originated from a single database, no duplicate records were identified. Titles and abstracts of the remaining publications were subsequently checked to confirm their relevance to farmers' climate resilience and agricultural extension, resulting in a final dataset of 353 peer-reviewed publications. The complete identification and screening process is presented in Figure 1.

The bibliometric analysis was conducted using Biblioshiny, the web interface of the Bibliometrix R package (Aria & Cuccurullo, 2017), a widely adopted platform for science mapping (Donthu et al., 2021). Performance analysis included annual publication and citation trends, as well as the most productive authors, journals, institutions, and countries. The intellectual and conceptual structure of the field was explored through author keyword (DE) co-occurrence analysis, co-authorship networks, strategic thematic mapping, thematic evolution, trend-topic analysis, and word cloud visualisation. Author Keywords (DE) were selected instead of Keywords Plus (ID) because they more accurately represent the thematic focus of individual publications. Thematic evolution was examined across four time periods (2015-2016, 2017-2019, 2020-2022, and 2023-2026) to identify changes in research themes.

RESULTS

Overview of the bibliometric dataset

Table 1 summarises the principal descriptive parameters of the dataset. The 353 documents were published across 198 distinct sources, mostly peer-reviewed journals all of which are peer-reviewed Scopus-indexed journals, over the 2015-2026 timespan,

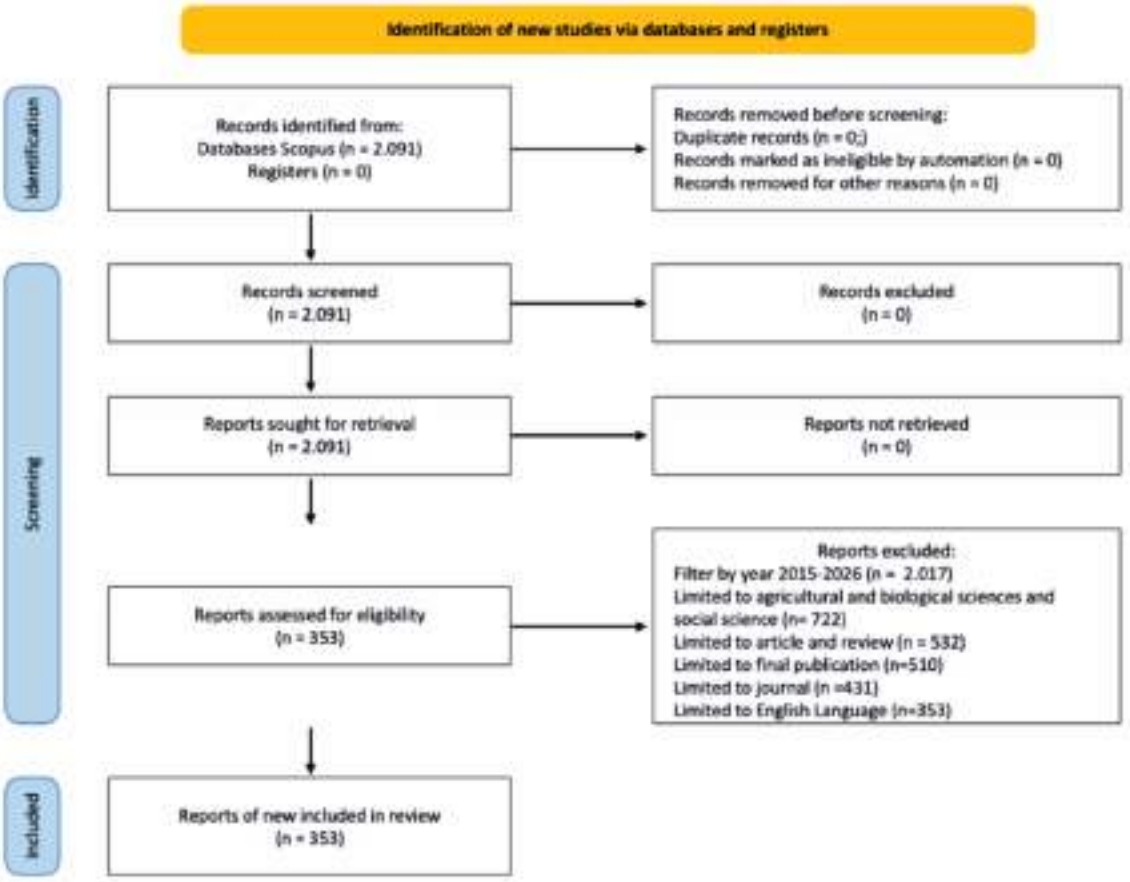


Figure 1. PRISMA flow diagram

Table 1. Main bibliometric information about the dataset (2015-2026)

Description	Result
Timespan	2015-2026
Sources (journals)	198
Documents	353
Annual growth rate (%)	40.62
Document average age (years)	2.41
Average citations per document	17.86
Keywords Plus (ID)	1,360
Author's Keywords (DE)	1,087
Authors	1,636
Authors of single-authored documents	19
Single-authored documents	20
Co-authors per document	5.07
International co-authorship (%)	43.91
Document type: Article	309 (87.5%)
Document type: Review	44 (12.5%)

comprising 309 articles (87.5%) and 44 reviews (12.5%). The annual growth rate of 40.62% indicates a rapid increase in publication output over the study period. In addition, the average document age was 2.41 years, calculated as the mean interval between each publication year and the data collection year (2026), following the descriptive bibliometric indicators implemented in the Bibliometrix package (Aria & Cuccurullo, 2017). Although no universally accepted threshold exists for document age, values below approximately 3-5 years generally indicate that a research field is characterised by recent and actively growing literature. Together, these indicators suggest that farmers' climate resilience and agricultural extension constitute a relatively young and rapidly expanding research area. A total of 1,636 authors contributed to the dataset, with only 19 publishing as sole authors and 20 documents being single-authored; the mean of 5.07 co-authors per document and an international co-authorship rate of 43.91 per cent point to a field that is collaborative and globally networked at the level of individual papers.

Trends in annual scientific production

The annual distribution of publications (Figure 2) shows a marked increase in research output across the study period. During the initial years of the analysed timeframe (2015-2017), publication volumes remained relatively low, with two, two, and four documents, respectively. This pattern reflects the limited number of publications captured within the selected observation period rather than the origin of the broader climate resilience research field. Publication output increased gradually between 2018 and 2020 (12, 11, and 14 documents), suggesting growing scholarly attention to the intersection of farmers' resilience and agricultural extension. From 2021 onward the field entered a phase of sustained, accelerating output to 29 documents in 2021, a modest dip to 26 in 2022, 29 in 2023 and 39 in 2024, before output more than doubled to 100 documents in 2025.

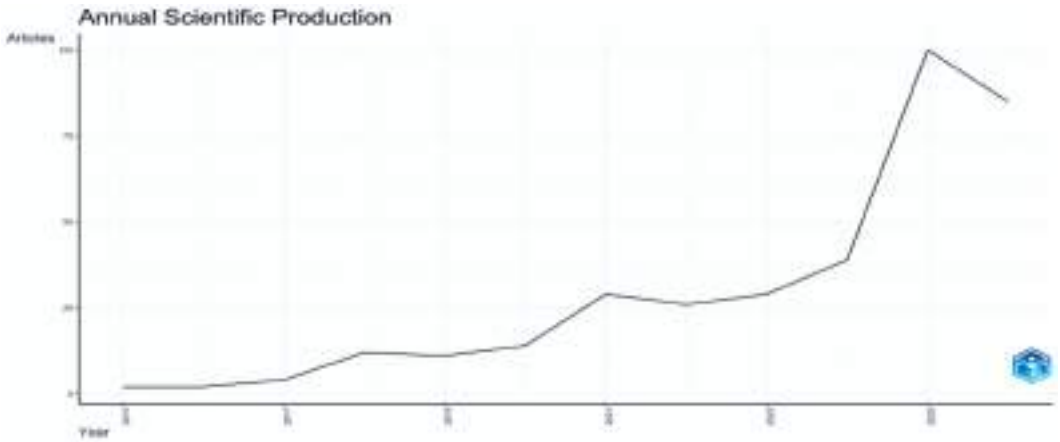


Figure 2. Annual scientific production on farmers' resilience to climate change and agricultural extension (2015-2026).

Field maturity: a growth-curve projection

To situate the observed growth within the broader life cycle of a research field, a non-linear diffusion model was fitted to the annual publication series (Figure 3), achieving a strong fit (R^2 = 0.885) and projecting an inflection point the year of peak annual output, around 2028-2029. The corresponding cumulative growth curve (Figure 4) indicates that the literature has, as of 2026, covered only a modest share of its projected eventual volume, well short of the 50 per cent mark, let alone the 90 or 99 per cent saturation thresholds typically associated with a mature field. Read together with the keyword and collaboration patterns discussed below, this places the resilience-extension literature firmly in an emergent-to-growth stage rather than a mature one: the underlying knowledge base is still being assembled, theoretical consolidation is incomplete, and a substantial share of the eventual literature has yet to be written. This projection should be interpreted with caution, as it extrapolates from a comparatively short time series and assumes a continuation of current policy and funding conditions; abrupt shifts in global climate governance or research funding could shift the timing of the projected peak in either direction.

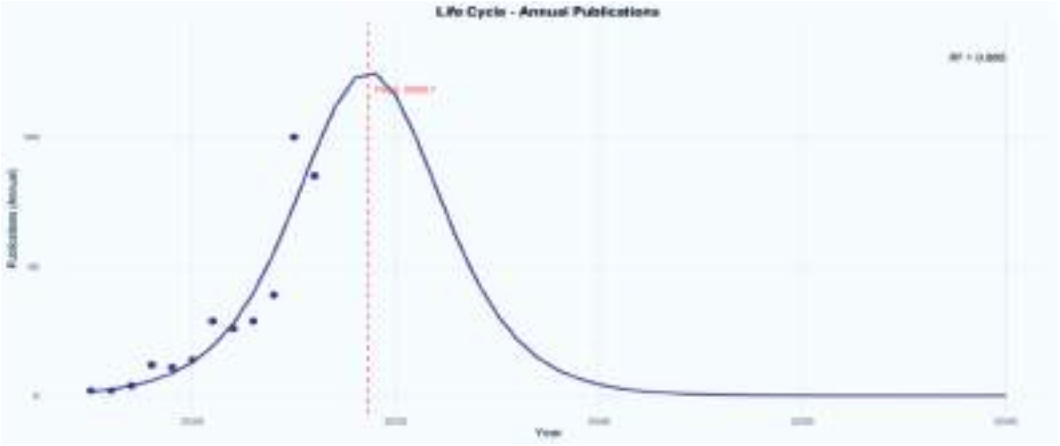


Figure 3. Fitted diffusion (life-cycle) curve of annual publication counts, with a projected peak near 2028-2029.

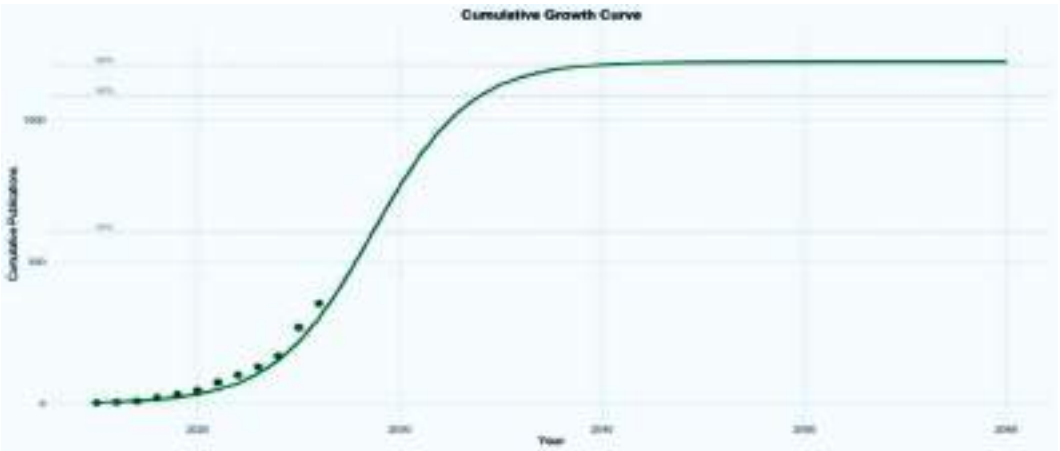


Figure 4. Cumulative growth curve of the literature, indicating the field has not yet approached saturation.

Citation impact and the most globally cited documents

Citation analysis (Figure 5, Table 2) shows that the most influential document in the dataset is Makate et al. (2016), which examined crop diversification and adaptive management among smallholder farmers in Zimbabwe and has accumulated 308 citations. It is followed by Schmidt et al. (2018) on long-term cover-cropping and soil microbial resilience (221 citations) and Heeb et al. (2019) on climate-smart pest management (204 citations). Notably, several of the most-cited documents address the determinants of climate-smart agricultural practice adoption are; Abegunde et al. (2020) in South Africa (198 citations), Zakaria et al. (2020) in Ghana (149 citations) and Bedeke et al. (2019) in Ethiopia (126 citations). In each case extension or training access emerges as a significant explanatory variable rather than the principal object of study. Zakaria et al. (2020), for instance, demonstrates that farmer participation in extension training programmes is a strong predictor of climate-smart agriculture adoption in Ghana, illustrating how extension surfaces as an enabling mechanism even within a citation landscape dominated by agronomic and adoption-economics framing. With an average document age of only 2.41 years against an average of 17.86 citations per document, the field's citation profile is still maturing; the apparent prominence of pre-2021 documents in the top-cited list partly reflects citation lag, and the influence of the much larger 2023-2026 publication cohort is likely to become more visible as those documents continue to accrue citations.

Leading source journals

The 353 documents were distributed across 198 journals, although a relatively small group of multidisciplinary sustainability and food-system journals accounted for a substantial share of the output (Table 3). Sustainability (Switzerland) was the leading source with 20 documents, followed by Frontiers in Sustainable Food Systems (13), Discover Sustainability and Environment, Development and Sustainability (nine each), Climate Services and Cogent Food and Agriculture (eight each), and Climate (seven). In

Table 2. Top ten most globally cited documents on farmers' resilience to climate change and agricultural extension

Authors	Year	Title	Source	Citations
Makate, C. et al.	2016	Crop diversification and livelihoods of smallholder farmers in Zimbabwe: Adaptive management for environmental change	SpringerPlus	308
Schmidt, R. et al.	2018	Long-term use of cover crops and no-till shift soil microbial community life strategies in agricultural soil	PLoS ONE	221
Heeb, L. et al.	2019	Climate-smart pest management: building resilience of farms and landscapes to changing pest threats	Journal of Pest Science	204
Abegunde, V.O. et al.	2020	Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in South Africa	Sustainability (Switzerland)	198
Zakaria, A. et al.	2020	Adoption of climate-smart agricultural practices among farm households in Ghana: the role of farmer participation in training programmes	Technology in Society	149
Bedeke, S.B.	2023	Climate change vulnerability and adaptation of crop producers in sub-Saharan Africa: a review on concepts, approaches and methods	Environment, Development and Sustainability	144
Bedeke, S. et al.	2019	Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia	NJAS -Wageningen Journal of Life Sciences	126
Ahmed, Z. et al.	2021	Climate change risk perceptions and agricultural adaptation strategies in vulnerable riverine char islands of Bangladesh	Land Use Policy	125
Nkiaka, E. et al.	2019	Identifying user needs for weather and climate services to enhance resilience to climate shocks in sub-Saharan Africa	Environmental Research Letters	122
Ma, W. & Rahut, D.B.	2024	Climate-smart agriculture: adoption, impacts, and implications for sustainable development	Mitigation and Adaptation Strategies for Global Change	121

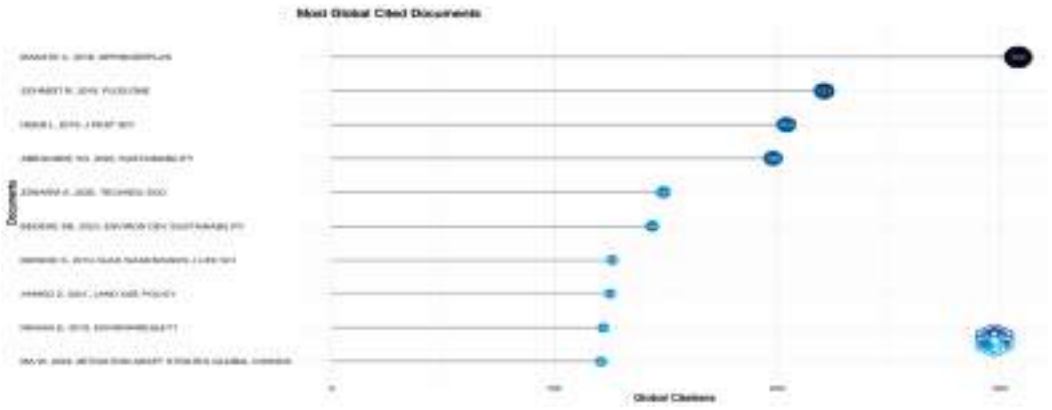


Figure 5. Most globally cited documents in the dataset.

contrast, specialised agricultural extension journals, including the South African Journal of Agricultural Extension and the Journal of Agricultural Education and Extension, contributed only a small proportion of publications.

The prominence of Sustainability reflects the increasingly interdisciplinary nature of climate resilience research. Farmers' resilience is no longer examined solely from the perspective of agricultural production or extension education but is increasingly framed within broader sustainability challenges, including climate adaptation, food security, sustainable livelihoods, environmental governance, and the Sustainable Development Goals. Consequently, multidisciplinary sustainability journals provide a broader platform for integrating environmental, social, economic, and institutional dimensions of resilience than discipline-specific agricultural journals.

This publication pattern also has important implications for agricultural extension research. Rather than emerging as an independent field, agricultural extension is predominantly treated as an enabling mechanism that supports climate adaptation, technology adoption, knowledge exchange, and resilience building within wider sustainability research. The limited representation of extension journals therefore suggests that extension research remains embedded within interdisciplinary climate and sustainability studies instead of developing as a distinct conceptual domain. This finding is consistent with the keyword co-occurrence and thematic analyses, which show that agricultural extension is closely linked to adaptation and resilience themes but does not form an independent thematic cluster.

Bradford's Law further (Figure 6) confirms the concentration of publications within a limited group of core journals. Sustainability (Switzerland) occupies the leading position, followed by Frontiers in Sustainable Food Systems, Discover Sustainability, Environment, Development and Sustainability, and several climate, and food-system-oriented outlets. The composition of the core zone indicates that research on farmers' climate resilience is primarily disseminated through multidisciplinary sustainability and climate journals rather than specialised agricultural extension outlets. This pattern reinforces the finding that agricultural extension remains embedded within broader adaptation and resilience scholarship.

Table 3. Leading source journals publishing on farmers' resilience to climate change and agricultural extension

Source	Articles
Sustainability (Switzerland)	20
Frontiers in Sustainable Food Systems	13
Discover Sustainability	9
Environment, Development and Sustainability	9
Climate Services	8
Cogent Food and Agriculture	8
Climate	7
Mitigation and Adaptation Strategies for Global Change	5
Agricultural Systems	5
Frontiers in Climate	5
International Journal of Climate Change Strategies and Management	5

Geographic distribution of research

Analysis of author affiliations (Table 4) indicates that Ethiopia (50 affiliation records), India (43), China (40), the United States (37), Ghana (32), the United Kingdom (32), South Africa (29), Australia (27), Nigeria (25), and Kenya (18) are the countries with the highest numbers of author affiliations in the dataset. This distribution mirrors findings reported by Anuranj and Vishnu (2026), where African and South Asian case studies are often conducted through collaborations with European, North American, and Australian partners. While such partnerships facilitate

Table 4. Leading countries by author-affiliation frequency

Country	Affiliation mentions
Ethiopia	50
India	43
China	40
United States	37
Ghana	32
United Kingdom	32
South Africa	29
Australia	27
Nigeria	25
Kenya	18

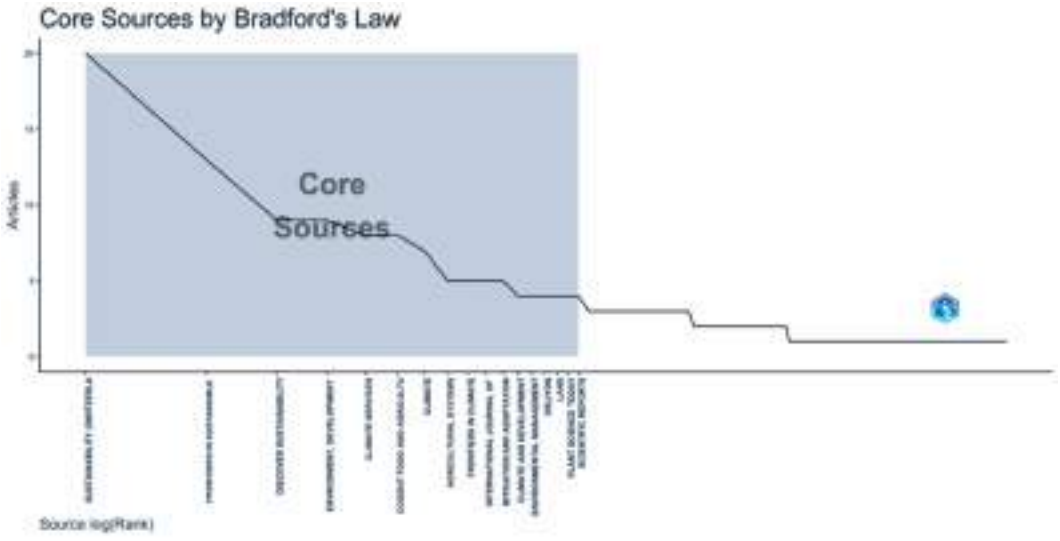


Figure 6. Bradford's Law

knowledge exchange and methodological development, they also raise questions about the extent to which Southern institutions lead the formulation of research agendas concerning their own farmers and extension systems. Latin America and Southeast Asia remain visibly under-represented relative to their own climate-vulnerability profiles, indicating a geographic imbalance that mirrors findings reported elsewhere in the climate-adaptation bibliometrics literature.

Institutional-level data (Table 5) further highlight Ethiopia's prominent contribution to the analysed literature. Bahir Dar University emerged as the most productive institution with 23 publications, followed by Tamil Nadu Agricultural University (19) and Kwame Nkrumah University of Science and Technology (16). Five Ethiopian universities: Bahir Dar, Addis Ababa, Haramaya, Hawassa, and Mekelle, collectively contributed 62 publications, indicating that research output was distributed across several national institutions rather than concentrated in a single university. Outside Ethiopia, Tamil Nadu Agricultural University was the leading institutional contributor from India, while Kwame Nkrumah University of Science and Technology and Universiti Putra Malaysia (11) represented important research centres in West Africa and Southeast Asia, respectively. The University of California (12) and the University of Florida (8) were the only institutions from outside the Global South among the ten most productive affiliations.

Table 5. Most relevant affiliations (institutions) in the dataset

Affiliation	Articles
Bahir Dar University	23
Tamil Nadu Agricultural University	19
Kwame Nkrumah University of Science and Technology	16
Addis Ababa University	13
University of California	12
Universiti Putra Malaysia	11
Haramaya University	10
Hawassa University	8
Mekelle University	8
University of Florida	8

Author productivity and collaboration network

Table 6 identifies the most prolific authors in the dataset. Philip Antwi-Agyei and Andrew J. Dougill each contributed five publications, followed by Belay Simane and Frank Baffour-Ata with four publications. Several other authors, including Assefa A. Berhanu, Zewdu B. Ayele, Dessalegn C. Dagnew, Melusi Sibanda, P.P. Murugan, T.S. Amjath-Babu, Timothy J. Krupnik, Muhammad Ali Imran, Asghar Ali, and Azhar Abbas, each published three documents.

Table 6. Most productive authors in the dataset

Author	Documents
Antwi-Agyei, Philip	5
Dougill, Andrew J.	5
Simane, Belay	4
Baffour-Ata, Frank	4
Berhanu, Assefa A.	3
Ayele, Zewdu B.	3
Dagnew, Dessalegn C.	3
Sibanda, Melusi	3
Murugan, P.P.	3
Amjath-Babu, T.S.	3
Krupnik, Timothy J.	3
Imran, Muhammad Ali	3
Ali, Asghar	3
Abbas, Azhar	3

Temporal analysis of author productivity indicates that most leading contributors became active after 2020, coinciding with the rapid expansion of the literature. Andrew J. Dougill and Philip Antwi-Agyei exhibited the longest and most consistent publication trajectories, maintaining research output from 2019 to 2024. In contrast, Belay Simane, Frank Baffour-Ata, and Zewdu B. Ayele demonstrated more recent but intensive publication activity concentrated between 2021 and 2025. These patterns suggest that the recent growth of the field has been driven by both sustained contributions from established researchers and the emergence of new author groups.

The co-authorship network (Figure 7) reveals several well-defined regional collaboration clusters rather than a single integrated research community. The largest and most densely connected cluster is centred on Dougill, Antwi-Agyei, and Baffour-Ata, reflecting sustained collaboration on climate-smart agriculture, resilience, and

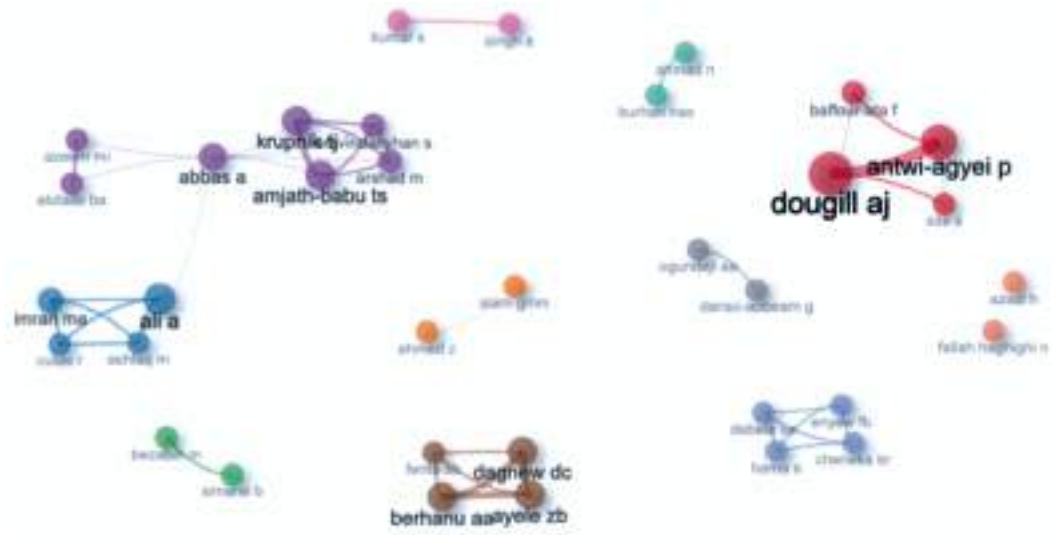


Figure 7. Co-authorship (collaboration) network among researchers publishing on farmers' resilience and agricultural extension

farmers' adaptive capacity in African farming systems (Dougill et al., 2021; Gyimah et al., 2024).

A second major cluster links Krupnik, Amjath-Babu, Abbas, and Arshad, whose collaborative research focuses on climate variability and yield risk in South Asia's rice-wheat systems (Arshad et al., 2017, 2018). A related but separate cluster involving Imran, Ali, Ashfaq, and Culas examines the livelihood implications of climate-smart cotton production in Punjab (Imran et al., 2018). Another cluster, comprising Dagnew, Berhanu, Ayele, and Fenta, focuses primarily on smallholder coping strategies and the hydrological dimensions of climate resilience in Ethiopia (Berhanu et al., 2024). Smaller collaboration pairs, including Bezabih-Simane and Ahmed-Alam, remain relatively isolated with limited connections to other research groups, reflecting work on livelihood vulnerability in Ethiopia and climate-risk perception in Bangladesh, respectively (Ahmed et al., 2021).

Despite a relatively high mean of 5.07 co-authors per document and an international co-authorship rate of 43.91% (Table 1), the collaboration network remains fragmented. Most collaborations occur within regional or institutional groups, whereas cross-cluster collaboration remains relatively limited.

Author productivity broadly follows Lotka's Law (Figure 8), with the overwhelming majority of researchers contributing only one documents and progressively fewer authors producing two or more documents. The observed proportion of single documents authors is higher than the theoretical distribution, while the proportion of authors with multiple papers declines more sharply than expected. This pattern indicates a dispersed and still-emerging research community in which sustained authorship is concentrated among a small group of scholars.

Keyword co-occurrence and thematic structure

Author keyword co-occurrence analysis identified "climate change" as the most frequently occurring keyword, appearing 219 times, more than three times the frequency of "food security" (64 occurrences), the second most common term. Other prominent author keywords included "agriculture" (61), "smallholder" (52), "adaptation" (47), "climate-smart agriculture" and "resilience" (42 each), "adaptive management" (37), and both "livelihood" and "smallholder farmers" (34 each) (Table 7; Figure 13). Notably, neither "climate resilience" nor "farmers' resilience" appeared among the most frequently used author keywords. Instead, researchers predominantly adopted broader concepts related to climate adaptation, agricultural sustainability, and resilience, suggesting that climate resilience remains conceptually embedded within these wider research themes rather than functioning as a distinct keyword domain. The author keyword co-occurrence network organised these terms into two major clusters linked through the central "climate change" node. The larger cluster comprised keywords related to food security, resilience, adaptation, climate-smart agriculture, agricultural extension, adaptive capacity, farming systems, and sustainable development, together with geographically focused terms such as Ethiopia, Ghana, Pakistan, and Sub-Saharan Africa. This cluster represents the policy and adaptation-oriented core of the literature, where resilience and extension-related themes are most closely interconnected. The second cluster included agriculture, productivity, adoption, drought, crop production, agroforestry, and demographic descriptors (e.g., female, male, and human), reflecting the predominance of empirical, survey-based studies in the field.

Within the first, substantive cluster, "agricultural extension" sits close to "agricultural management" and "adaptation strategies" rather than forming an independent sub-cluster of its own. This pattern suggests that agricultural extension is largely embedded within broader adaptive-management discussions rather than conceptualized as a distinct resilience-building mechanism. This finding aligns with recent calls to redefine extension beyond information delivery toward facilitation, coordination, and co-learning roles (Knook et al., 2020; Mburu et al., 2024; Maka, 2025). The relative absence of a dedicated extension sub-cluster, despite extension's frequent appearance as an explanatory variable in the most-cited documents, is one of the clearest knowledge gaps this bibliometric mapping identifies.

The strategic thematic map (Figure 9) provides a complementary view of the conceptual structure by positioning keyword clusters according to two dimensions: centrality, which reflects a theme's importance and connectivity within the overall research field, and density, which indicates its level of internal development and conceptual maturity. Based on these dimensions, themes are classified into four quadrants: Motor Themes (high

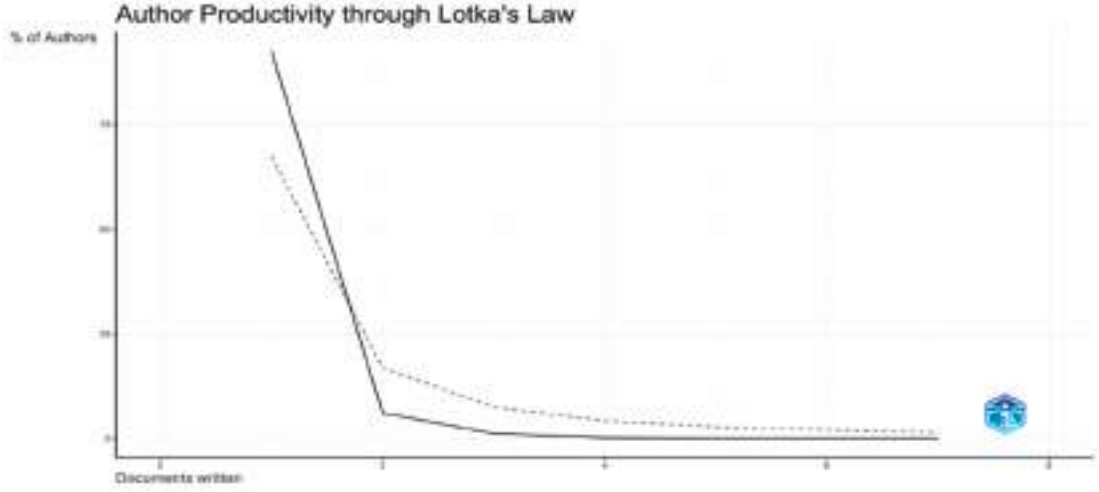


Figure 8. Lotka's Law

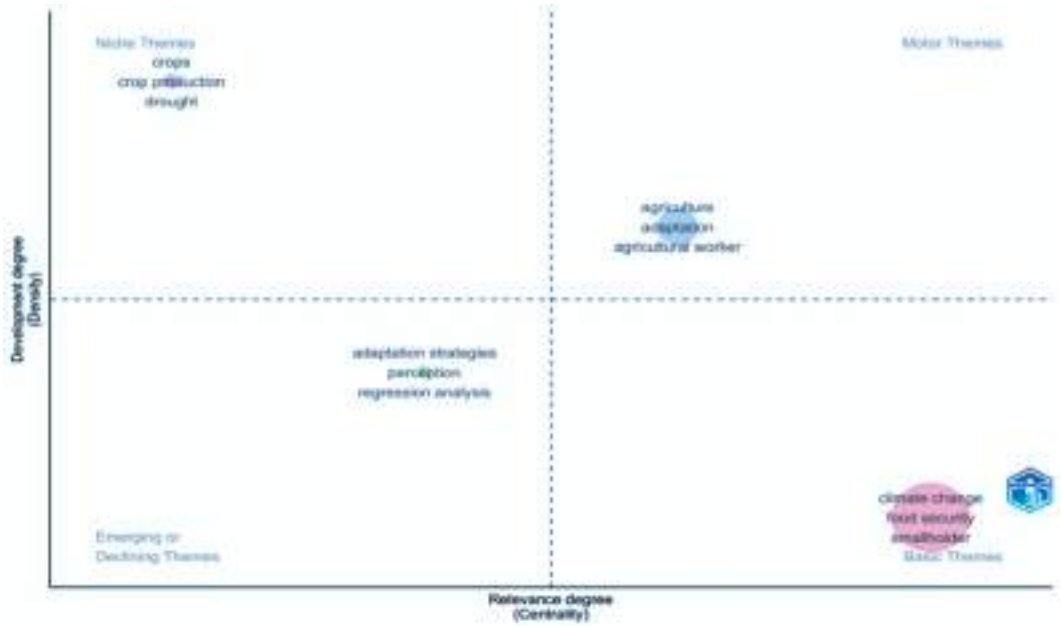


Figure 9. Thematic strategic diagram

centrality and high density), representing well-developed themes that drive the field; Basic Themes (high centrality but low density), representing fundamental topics that underpin the literature but remain comparatively less developed; Niche Themes (low centrality but high density), representing specialised and internally mature topics with limited influence on the broader field; and Emerging or Declining Themes (low centrality and low density), representing either newly developing topics or areas experiencing declining scholarly attention.

Three keyword clusters: climate change, food security, and smallholder are located in the Basic Themes quadrant, indicating that they constitute the conceptual foundation of the literature despite remaining less internally developed. A second cluster comprising agriculture, adaptation, and agricultural worker appears in the Motor Themes quadrant, suggesting that these topics are both well developed and central to current research. In contrast, crops, crop production, and drought occupy the Niche Themes quadrant, indicating specialised research areas with strong internal development but relatively limited influence on the wider resilience literature. Another cluster consisting of adaptation strategies, perception, and regression analysis falls within the Emerging or Declining Themes quadrant, suggesting either newly developing research directions or topics receiving diminishing scholarly attention. Notably, agricultural extension does not emerge as a distinct thematic cluster in any quadrant.

The three-field plot (Figure 10) connects the principal research topics, leading authors, and their countries of affiliation. Climate change forms the dominant thematic stream and is linked to most of the leading authors and national research communities. Agricultural extension appears as a smaller thematic flow, connecting selected authors and countries rather than forming a broadly distributed research stream. Ethiopia, India, Pakistan, the United Kingdom, and Ghana account for the strongest author-country linkages, confirming the geographical concentration identified in the country and institutional analyses. Overall, the plot demonstrates that the field's leading authors are primarily associated with climate adaptation, livelihoods, smallholder farming, and vulnerability, whereas extension-specific scholarship remains comparatively limited.

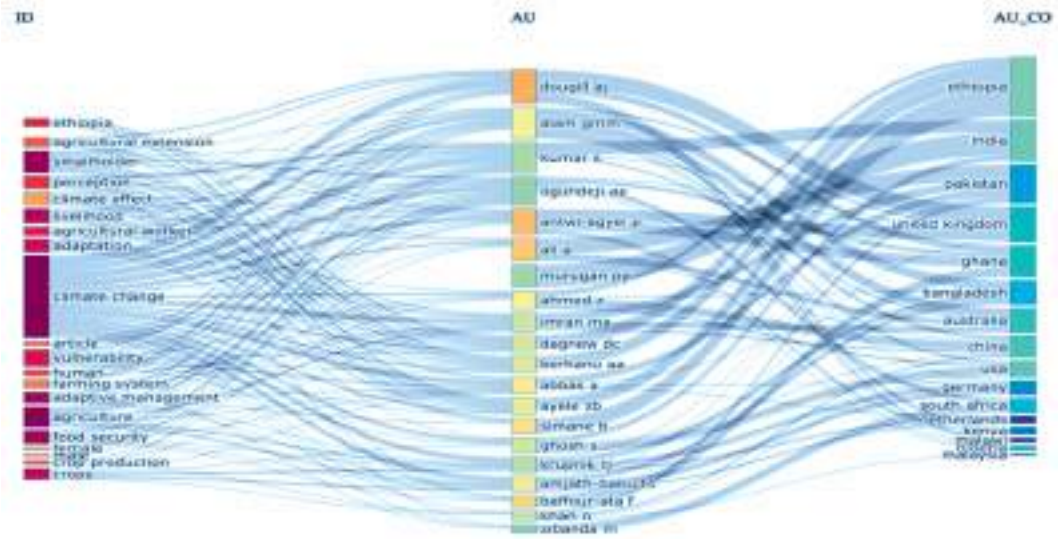


Figure 10. The three-field plot

The trend topics analysis (Figure 11) adds a temporal perspective to the thematic structure of the literature. Early keywords such as zea mays, Malawi, and agricultural land peaked between 2018 and 2020, reflecting the prominence of location- and commodity-specific case studies during the initial stage of research development. Between 2021 and 2023, attention shifted toward methodological and analytical themes, including farming system, decision making, regression analysis, adaptive management, mitigation, and crop production. This period broadly corresponds to the adoption-determinants phase identified in Table 8.

More recently, climate change, agriculture, and adaptation reached their highest frequencies around 2024 and remain the dominant themes in the field. The newest keywords to emerge are smallholder, smallholder farmers, food security, household, household survey, and climate, all peaking during 2025-2026. This pattern suggests a growing emphasis on household-level empirical research and survey-based analysis. Notably, extension-related terms do not appear among the emerging frontier topics. This finding is consistent with the co-occurrence and thematic-map analyses, indicating that agricultural extension is primarily examined within broader adaptation and resilience studies rather than as a distinct conceptual research domain.

A word cloud based on Author Keywords (DE) was generated to visualise the relative frequency of keywords in the dataset, with larger words indicating higher occurrence frequencies (Figure 12). Although this study focuses on farmers' climate resilience, the author keyword analysis reveals that the literature is predominantly organised around broader concepts such as "climate change", "adaptation", and "resilience", rather than the explicit term "climate resilience" (Table 7). This finding suggests that climate resilience remains a conceptually fragmented construct that is operationalised through multiple related themes rather than consistently represented by a single keyword.

Local impact analysis complements the productivity ranking by showing that documents output does not always correspond

Table 7. Most frequent author keywords in the dataset

Term	Frequency
climate change	219
food security	64
agriculture	61
smallholder	52
adaptation	47
climate-smart agriculture	42
resilience	42
adaptive management	37
livelihood	34
smallholder farmers	34

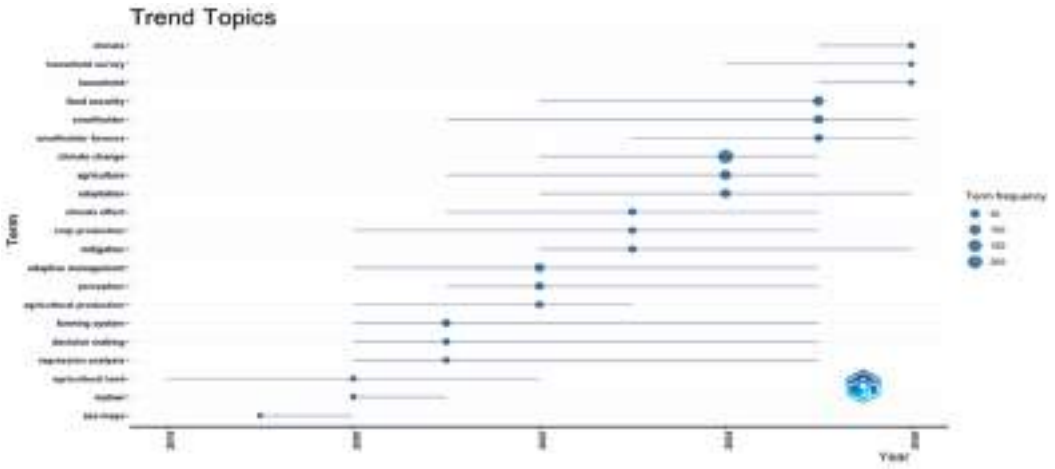


Figure 11. Trend topics showing the period of peak usage and relative frequency of leading author keywords, 2015-2026.



Figure 12. Word cloud of the most frequent author keywords in the dataset.

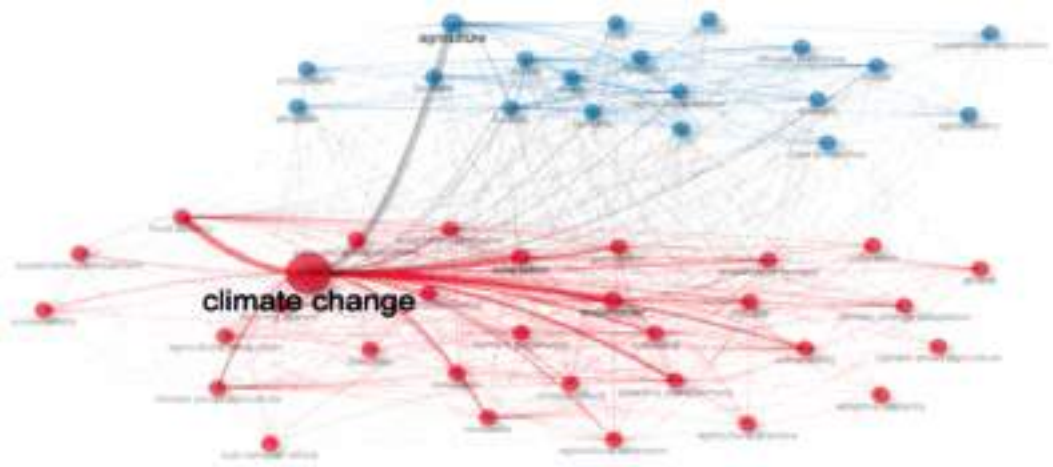


Figure 13. Keyword co-occurrence network showing the substantive (red) and methodological/demographic (blue) thematic clusters.

directly to citation influence within the dataset. Andrew J. Dougill recorded the highest local H-index (h = 7), followed by Philip Antwi-Agyei (h = 5) and Asghar Ali (h = 4). Azhar Abbas, Frank Baffour-Ata, S. Ghosh, Muhammad Ali Imran, A.A. Ogundeji, and Belay Simane each recorded a local H-index of three. These results identify Dougill and Antwi-Agyei as both productive and consistently influential contributors to the field.

Thematic evolution and synthesis of the resilience-extension research focus

The thematic evolution analysis (Figure 14) confirms the developmental trajectory of the field across four periods (2015-2016, 2017-2019, 2020-2022, and 2023-2026). The earliest period was dominated by only two keywords, farmers and adaptive, reflecting the limited number of documents during these years. These themes evolved into a broader vocabulary during 2017-2019, including climate, livelihood, resilience, adoption, farming, and variability. This pattern aligns with the early focus on livelihood vulnerability and adaptation determinants.

During 2020-2022, the thematic structure became more diverse. New keywords such as coastal, south, rice, and adaptations emerged alongside established themes including resilience, climate, agriculture, and awareness. This shift reflects the expansion of research into new geographic contexts and empirical applications, while maintaining a strong emphasis on climate adaptation and farmer resilience.

During 2023-2026, the thematic structure became more consolidated around four dominant themes: climate, agriculture, resilience, and adoption. Notably, Ethiopia emerged as a distinct thematic node rather than merely a geographic reference. This finding complements the country- and institution-level analyses (Tables 4 and 5), indicating that Ethiopia has become both a major contributor to and a substantive focus of the literature.

Taken together, the thematic evolution map, strategic diagram (Figure 9), and trend-topics analysis (Figure 11) reveal a clear

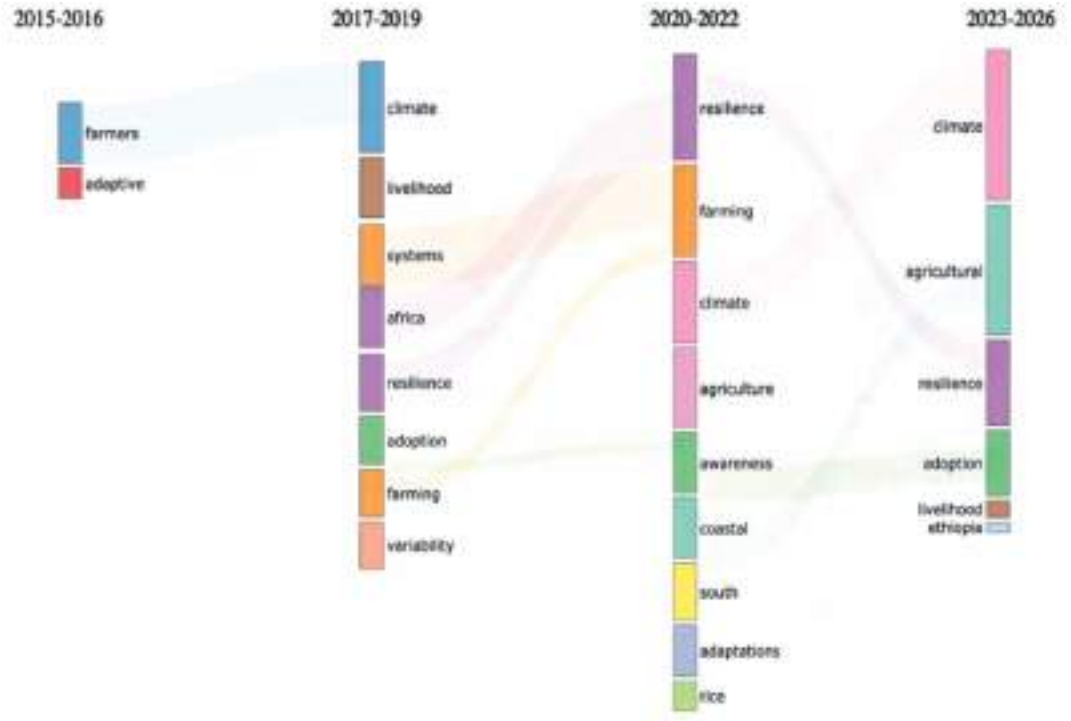


Figure 14. Thematic evolution of author-keyword vocabulary across four periods, 2015–2026.

Table 8. Evolution of the farmers' resilience–agricultural extension research focus

Period	Dominant focus	Representative evidence
2015-2016	Initial, narrowly empirical framing of farmers' adaptive behaviour	Makate et al. (2016)
2017-2019	Conceptual framing of livelihood vulnerability and early climate-smart agriculture operationalisation	Akrofi-Atitianti et al. (2018); Bedeke et al. (2019); Heeb et al. (2019)
2020-2022	Geographic and methodological diversification; quantifying determinants of climate-smart practice adoption, with extension/training access as a recurrent factor	Abegunde et al. (2020); Zakaria et al. (2020); Ahmed et al. (2021); Setsoafia et al. (2022)
2023-2026	Thematic consolidation around climate, agriculture, resilience and adoption, anchored in Ethiopian evidence; extension–resilience synergy and digital/AI-enabled advisory services	Bedeke (2023); Thottadi & Singh (2024); Berhanu et al. (2024); Billah et al. (2025); Singh et al. (2025); Mkuna (2026)

developmental trajectory. The field evolved from broad livelihood-oriented studies (2015-2019) to a period of geographic and methodological diversification (2020-2022), before converging on climate adaptation, resilience, and adoption research in recent years (2023-2026). Despite this evolution, agricultural extension never emerged as a distinct thematic cluster. Instead, it remained embedded within broader adaptation and resilience research, highlighting a persistent knowledge gap in the literature.

DISCUSSION

This bibliometric mapping confirms the rapid growth of research on farmers' resilience to climate change since 2015. The annual growth rate of 40.62%, the young average document age of 2.41 years, and the diffusion-curve projection indicating a documents peak around 2028-2029 suggest that the field remains in an active stage of development. The marked acceleration in publication output after 2021 likely reflects broader scientific and policy developments rather than a continuation of historical publication trends. Growing international attention to climate adaptation following the implementation of the Paris Agreement, together with heightened concerns over food-system resilience during and after the COVID-19 pandemic, has stimulated research on farmers' resilience. At the same time, increasing investments by governments and international development agencies in climate adaptation, climate-smart agriculture, and agricultural extension programmes have expanded research opportunities and strengthened scholarly interest in institutional mechanisms that support farmers' adaptive capacity. Although the bibliometric data do not establish causal relationships, these developments are consistent with the sustained publication growth observed in this study. Despite this youth, the average document has already accumulated 17.86 citations, suggesting strong and immediate uptake of the literature by the wider research community. Consequently, this review captures a literature whose intellectual structure is still evolving, and future bibliometric analyses may reveal a more consolidated and theoretically integrated research landscape.

The geographic and collaboration patterns identified in this study are consistent with findings from the extension-climate-smart agriculture literature (Anuranj & Vishnu, 2026). Research activity is concentrated in climate-vulnerable regions, particularly Ethiopia, Ghana, Nigeria, South Africa, and South Asia. However, a substantial share of co-authored documents involves institutions from the United States, the United Kingdom, Australia, and continental Europe, indicating their continued influence on the field's analytical framing. Such partnerships have unquestionably supported methodological capacity-building and resource mobilisation (Cobon et al., 2021; Nkiaka et al., 2019), but the fragmented, regionally siloed structure of the collaboration network (Figure 7) suggests that this support has not yet translated into a single, integrated global research community; rather, several parallel bilateral or small-group partnerships coexist with comparatively little cross-fertilisation. Strengthening South-South collaboration and ensuring that Southern institutions lead, rather than merely host, the framing of research questions would help convert the field's rapid growth into more cumulative and contextually grounded knowledge.

The thematic analysis carries a more specific implication for agricultural extension scholarship. Although extension-related variables, training participation, advisory access, and extension contact frequency recur as significant predictors across many empirical studies (Zakaria et al., 2020; Bedeke et al., 2019), agricultural extension does not constitute an independent thematic cluster within the keyword network; instead, it is embedded within a broader adaptive-management discourse. This finding suggests that extension continues to be treated primarily as an explanatory factor supporting adaptation outcomes rather than as a distinct field of theoretical inquiry. This interpretation is consistent with longstanding critiques that extension research is often positioned within adoption and adaptation studies instead of being conceptualised as an independent resilience-building discipline (Knook et al., 2020; Witinok-Huber et al., 2021). Recent empirical evidence from Indonesia nevertheless demonstrates that agricultural extension significantly strengthens farmers' climate resilience, both directly and indirectly, by improving livelihood capitals, adaptive capacity, and farming sustainability (Azhari et al., 2025a). These findings therefore reinforce the argument that, despite its peripheral intellectual position in the bibliometric structure, agricultural extension plays a fundamental role in strengthening farmers' resilience to climate change. Recent systematic reviews focused specifically on extension's role in climate-smart agriculture (Billah et al., 2025; Thottadi & Singh, 2024) and emerging work on the usability of climate information for extension officers themselves (Wiréhn, 2024) suggest the beginnings of a more dedicated research front, but this study's network evidence indicates that such work remains a secondary current within the wider resilience literature rather than its mainstream.

The bibliometric patterns identified in this study are broadly consistent with previous science-mapping studies on climate

adaptation and agricultural sustainability, while also revealing several distinctive characteristics of the resilience-extension literature. Similar to the bibliometric review of climate adaptation research in agricultural systems by Jiang et al. (2023), this study confirms that documents output has accelerated markedly since the mid-2010s, reflecting growing scientific and policy attention following the Paris Agreement and the expansion of climate adaptation initiatives. Likewise, Baraj et al. (2024) found that climate change, adaptation, sustainable agriculture, and resilience constitute the dominant conceptual pillars of agricultural climate research, a pattern also observed in the present keyword co-occurrence network. However, unlike these earlier bibliometric studies, our analysis explicitly demonstrates that agricultural extension remains embedded within broader adaptation and resilience themes rather than emerging as an independent research domain. This finding extends previous bibliometric evidence by identifying the relatively peripheral intellectual position of extension despite its acknowledged practical importance for strengthening farmers' adaptive capacity.

The observed thematic structure reflects the ongoing evolution of agricultural extension from the traditional technology-transfer paradigm toward facilitation-oriented and agricultural innovation system (AIS) approaches. Contemporary extension theory no longer conceptualizes extension professionals solely as disseminators of agricultural technologies but increasingly recognizes them as facilitators of collective learning, innovation brokers, and coordinators of adaptive decision-making under conditions of climatic uncertainty. Accordingly, the absence of agricultural extension as a distinct thematic cluster should not be interpreted as evidence of diminishing relevance. Instead, it indicates that extension has become embedded within broader resilience-building processes encompassing climate information services, social learning, institutional coordination, and innovation support. This interpretation is consistent with recent studies suggesting that modern extension systems strengthen farmers' climate resilience primarily by enhancing adaptive capacity, facilitating knowledge exchange, fostering collaborative learning, and supporting innovation, rather than merely promoting technology adoption (Knook et al., 2020; Mukherjee et al., 2025). Empirical evidence from Indonesia further shows that resilience-oriented extension becomes substantially more effective when integrated with livelihood capitals and pluralistic advisory approaches, enabling improvements in farmers' resilience capacity and long-term farming sustainability (Azhari et al., 2025b).

The findings also align closely with the broader climate adaptation literature, which increasingly recognises resilience as a multidimensional process shaped by interactions among institutional support, livelihoods, social learning, and governance rather than by technological interventions alone. Recent climate adaptation studies have consistently shown that adaptive capacity depends not only on farmers' access to technologies but also on extension services, climate information, financial resources, and institutional arrangements. The predominance of keywords related to food security, adaptive management, livelihoods, and smallholder farming observed in this study therefore reflects the evolution of resilience research from hazard-centred analyses toward integrated socio-ecological adaptation frameworks. At the same time, the limited visibility of extension-specific concepts suggests that future research should more explicitly examine how extension contributes to resilience through advisory systems, participatory learning, digital services, and innovation platforms. Such a shift would strengthen the theoretical integration between agricultural extension and climate adaptation research.

These findings have important practical implications for agricultural extension systems. Rather than focusing primarily on technology dissemination, extension organisations should adopt facilitation-oriented advisory approaches that promote collective learning, climate-informed decision-making, innovation co-creation, and stronger multi-stakeholder collaboration. Recent evidence further indicates that strengthening extensionists' participatory, pluralistic, entrepreneurial, and gender-sensitive facilitation capacities substantially improves the effectiveness of extension programmes and enhances the ability of farmer groups to respond to increasingly complex climate and livelihood challenges (Amanah et al., 2026).

The observed geographical concentration of documents in Ethiopia, India, and China reveals persistent regional disparities in scientific knowledge production, despite the widespread exposure of many developing regions to climate-related risks. This finding suggests the need for policy interventions that strengthen agricultural extension research and climate adaptation capacity in underrepresented regions, particularly Southeast Asia and Latin America. Governments, funding agencies, and international development organisations should prioritise investments that support cross-regional research collaboration, institutional capacity building, and knowledge-sharing networks. Such policies would contribute to a more geographically balanced evidence base while enabling the development of locally relevant extension systems and resilience strategies tailored to diverse agroecological and socio-economic contexts.

Future bibliometric studies could broaden database coverage by integrating multiple indexing sources, such as Web of Science and Dimensions, thereby improving the comprehensiveness and robustness of scientific mapping. Furthermore, longitudinal analyses incorporating co-citation, bibliographic coupling, and thematic evolution techniques would provide deeper insights into the intellectual development and theoretical maturation of agricultural extension within climate resilience research. Beyond bibliometric investigations, future empirical studies should examine the mechanisms through which agricultural extension strengthens farmers' adaptive capacity, with particular attention to digital extension, climate advisory services, innovation platforms, and social learning processes across diverse agroecological and socio-economic contexts. Such research would contribute to a more nuanced understanding of how extension systems facilitate long-term climate resilience among farming communities.

CONCLUSION

Research on farmers' resilience to climate change has expanded rapidly since 2015 and remains in a growth phase. The literature is largely concentrated in climate-vulnerable regions of Sub-Saharan Africa and South Asia, although collaboration networks remain fragmented across regions. Agricultural extension is consistently

identified as an important factor supporting resilience and adaptation, yet it has not developed into a distinct research theme and is still embedded within broader adaptation and livelihood studies. Future research should strengthen cross-regional collaboration, develop stronger theoretical and empirical frameworks explaining how extension enhances resilience through facilitation, co-learning, and digital advisory services, and expand empirical evidence from underrepresented regions such as Latin America and Southeast Asia. Addressing these priorities will help align resilience research more closely with the evolving role of agricultural extension in climate adaptation.

DECLARATIONS

Ethics approval and informed consent: Not applicable. This study is based exclusively on secondary bibliometric metadata retrieved from the Scopus database and does not involve human or animal subjects.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The authors declare that during the preparation of this work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

Data availability: The Scopus BibTeX export and the Biblioshiny-generated outputs (descriptive tables, annual production, keyword and collaboration network visualisations) analysed in this study are available from the corresponding author on reasonable request.

Declaration of generative AI and AI-assisted technologies in the writing process: During the preparation of this work, the authors used AI to improve the readability and language of the manuscript. After using this tool, the authors carefully reviewed and edited the manuscript and take full responsibility for its content.

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Comparative Nutritional Security of Tribal Farm Women in Andhra Pradesh Using Canonical Correlation Analysis

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HIGHLIGHTS

- The study highlighted a significant multivariate relationship between socioeconomic, livelihood variables and nutritional security among Chenchu and Lambada tribal women in South Coastal Andhra Pradesh
- Annual income, economic motivation, education and the impact of major government food and nutritional security schemes were important for the first canonical function, while age and BMI were most influential for the second canonical function.
- The first two canonical functions were significant in both groups, whereas the third function was non-significant.
- There was a distinct difference in the strength of association between the two tribes, with Lambada women showing relatively stronger multivariate relationships than Chenchu women.

ARTICLE INFO

Keywords: BMI, Tribal women, Canonical correlation analysis, Food security, Nutritional security.

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ABSTRACT

The study was conducted during 2025-2026 in the Palnadu and Prakasam districts of Andhra Pradesh and examined the significant relationship between a selected set of socioeconomic, livelihood and nutritional security indicators among Chenchu and Lambada tribal women. Canonical Correlation Analysis was used to assess the connection between a set of 14 independent and 3 dependent variables, namely Body Mass Index (BMI), Food security and Nutritional security for both tribes separately. For Chenchu, the first and second canonical functions were significant at a level of 0.01 with canonical correlations of 0.775 and 0.728 respectively and were supported by eigenvalues of 2.419 and 1.128 and low Wilks'lambda values of 0.165 and 0.412 whereas the third function with a correlation of 0.351, was non-significant. The significance of the first two canonical functions of Lambada's was found to be 0.01 with canonical correlations of 0.841 and 0.810, respectively, with eigenvalues of 2.419 and 1.907, respectively and with Wilks' lambda of 0.085 and 0.292, respectively. However, the third function was insignificant with a canonical correlation of 0.389. Thus, there was a multivariate relationship between BMI, food security and nutritional security with socioeconomic and livelihood variables in both samples.

INTRODUCTION

Tribes are indigenous groups officially classified as scheduled tribes and constitute a significant part of India's population (Xaxa, 1999). They are spread across several districts of Andhra Pradesh such as Srikakulam, Vizianagaram, Visakhapatnam, East and West Godavari, Guntur, Prakasam, and Kurnool, exhibiting considerable diversity in ecological and economic settings (Subramanyam & Narayana Rao, 2023). Their livelihood security is shaped by complex socio-economic and behavioural factors (Ghosh et al., 2025)

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The major sources of food and income for such communities include forest products, small-scale farming, and subsistence agriculture (Ghosh-Jerath et al., 2025). While the consumption of these traditional foods is often kept moderate because of several socio-economic and environmental factors, the food and agricultural system plays an essential role in affecting the nutrition status of tribal communities depending on wild vegetables, root vegetables, and traditional crops (Ghosh-Jerath et al., 2016). Nevertheless, food and nutrition insecurity remain prevalent amongst tribal women since their intake of foods rich in micronutrients remains lower than dietary recommendations (Kapoor et al., 2022). Compared to the non-tribal population, the tribes show more malnutrition and mineral deficiency cases, where many women have chronic energy shortage (Kshatriya et al., 2016). Socioeconomic determinants such as wealth, education, and resources play a key role in the BMI of scheduled tribes and their nutritional security (Biswas et al., 2022). Food and nutritional security are negatively impacted by poor availability of agricultural and nutrition-related knowledge due to a lack of proper education, extension services, and limited information access (Bahubalendra et al., 2025). The use of nutrition-focused agricultural practices among farmers is significantly shaped by socioeconomic and attitudinal considerations (Mishra et al., 2025).

The forest-dependent hill tribe Chenchu and the tanda-settled plain tribe Lambada were selected for this study due to their distinct ecology and settlement patterns that influence their availability of food, dietary diversity, and health status (Jinka Ramamurthy & Hoffman, 2023; Kishore, 2016). Studies indicated that these communities often face disproportionate food and nutritional insecurity (Webb et al., 2016). The occurrence of deficiencies of micronutrients and undernutrition is more common among Chenchu women (Rao et al., 2015; Garg et al., 2023). Similarly, in the case of Lambada women, malnutrition, anaemia, and chronic disease incidence have been linked to poverty, lack of healthcare access, and poor educational levels (Anil, 2024). Poor dietary diversity and inadequate food intake adversely affected nutritional security among tribal women (Kujur et al., 2026).

Food security and nutritional security are multidimensional and dynamic constructs encompassing food availability, access, utilization, dietary quality, health status and stability over time (Sharma, 2019). In the present study, these concepts were operationalized through validated composite indicators integrating dietary diversity, nutrient adequacy, food access and anthropometric measures. Nutritional security goes beyond food security by including food quality, utilisation, and health outcomes and is especially important for tribal and rural communities with staple based, low diversity diets (Nandi, 1999). It is hypothesised that socio-economic and agricultural variables significantly influence nutritional security among tribal women. The study applies canonical correlation analysis to examine these multivariate relationships among Chenchu and Lambada tribal farm women in South Coastal Andhra Pradesh.

METHODOLOGY

The study was conducted in Palnadu and Prakasam districts of Andhra Pradesh using an ex-post facto design. A total of 192 respondents were selected through random sampling: 96 Chenchu and 96 Lambada tribal farm women. A pre-tested interview schedule was used for data collection. Data were analysed using Canonical Correlation Analysis (CCA) in SPSS, which identified relationships between two sets of variables by maximising inter-set correlations (Keskin & Yasar, 2007; Pujitha et al., 2024). The analysis identified key variables influencing the dependent variable. Two sets of variables were considered: 14 independent variables (C) and 3 dependent Variables (D) for both tribes.

$C = c_1, c_2, \ldots\ldots c_{14}$; $D = d_1, d_2, d_3$

c_1 = Age, c_2 = Education, c_3 = Family type, c_4 = Farming experience, c_5 = Landholding, c_6 = Occupation, c_7 = Number of crops grown, c_8 = Annual income, c_9 = Livestock ownership, c_{10} = Natural capital, c_{11} = Access to basic services, c_{12} = Agricultural mass media contact, c_{13} = Economic motivation, c_{14} = Impact of major government food and nutritional security schemes and d_1 = Body Mass Index (BMI), d_2 = Food security, d_3 = Nutritional security.

Body Mass Index (BMI) was calculated as weight (kg)/height² (m²) and classified according to the WHO Expert Consultation for Asian populations: <18.5 kg/m² (underweight), 18.5–22.9 kg/m² (normal), 23.0–24.9 kg/m² (overweight at risk) and e"25.0 kg/m² (obese). This classification is considered more appropriate for Asian populations due to their increased metabolic risk at lower BMI levels (Kshatriya et al., 2016). Food security was measured using a modified 35-point composite index developed from Riley et al. (1999). The index comprised seven dimensions: household food availability, food accessibility, affordability, food utilization, food stability, dietary sufficiency, and coping strategies. Each component was assessed through multiple statements using a five-point Likert scale, where higher scores indicated better food security. The cumulative score ranged from 0-35, with higher values representing higher household food security. Nutritional security was assessed using diet diversity score, 24-hour dietary recall and Mean Adequacy Ratio from 7-day nutrient intake (MAR) (FAO, 2018; FAO & FHI 360, 2016; Gibson, 2005).

The number of canonical correlation pairs equals the number of variables in the smaller set. In the study, 3 canonical correlation pairs are estimated: (O_1, P_1); (O_2, P_2); (O_3, P_3) and (Q_1, R_1); (Q_2, R_2) and (Q_3, R_3). Linear combinations of independent and dependent variables for Chenchu and Lambada are O1 and P1; Q1 and R1, respectively, called as Canonical variates (Sahoo et al., 2024).

$O_1 = o_{11} .c_1 + \ldots\ldots\ldots + o_{1i} .c_{1i}$,

$O_2 = o_{21} .c_1 + \ldots\ldots\ldots + o_{2i} .c_{2i}$.

$O_x = o_{i1} .c_1 + \ldots\ldots\ldots + o_{ii} .c_i$

$P_1 = p_{11}. d_1 + p_{12}. d_2 + p_{13}. d_3$

$P_2 = p_{21}. d_1 + p_{22}. d_2 + p_{23}. d_3$

$P_3 = p_{31}. d_1 + p_{32}. d_2 + p_{33}. d_3$

$Q_1 = q_{11} .c_1 + \ldots\ldots\ldots\ldots + q_{1i} .c_{1i}$

$Q_2 = q_{21} .c_1 + \ldots\ldots\ldots\ldots + q_{2i} .c_{2i}$.

$Q_x = q_{i1} .c_1 + \ldots\ldots\ldots + q_{ii} .c_i$

$R_1 = r_{11}. d_1 + r_{12}. d_2 + r_{13}. d_3$

$R_2 = r_{21}. d_1 + r_{22}. d_2 + r_{23}. d_3$

$R_3 = r_{31}. d_1 + r_{32}. d_2 + r_{33}. d_3$

Table 1. Descriptive Nutritional Indicators of Chenchu and Lambada Tribal Farm Women

Indicator	Chenchu (Mean ± SD / %)	Lambada (Mean ± SD / %)
Body Mass Index (kg/m²)	23.35 ± 4.54	23.87 ± 3.66
Underweight (%)	20.84	5.20
Normal BMI (%)	52.08	44.79
Overweight (%)	14.58	17.72
Obese (%)	12.50	32.29
Food Security Score (0-35)	23.68 ± 1.80	24.46 ± 1.92
Dietary Diversity Score (DDS)	12.09 ± 0.99	12.26 ± 1.01
Mean Adequacy Ratio (MAR)	0.79 ± 0.05	0.81 ± 0.05
Daily Energy Intake (kcal/day)	1782.2 ± 217.41	1779.12± 172.13
Protein Intake (g/day)	47.46± 4.53	48.44 ± 4.33
Fat Intake (g/day)	20.32 ±3.00	20.75 ± 3.10
Calcium Intake (mg/day)	350.33 ± 47.73	370.60 ± 69.55
Iron Intake (mg/day)	10.45± 1.81	11.95± 2.31
Thiamine (mg/day)	1.09 ± 0.17	1.20 ± 0.24
Riboflavin (mg/day)	0.74 ± 0.10	0.80 ± 0.12
Ascorbic Acid (mg/day)	113.41 ± 20.73	118.1 ± 22.95

where i = 14 independent variables, standardised correlation coefficients for C and D are denoted as o_{11} ,....o_{1i}; p_{11}, p_{12}, p_{13}; q_{11}, ...q_{1i} and r_{11}, r_{12}, r_{13}, Canonical correlation between (O_i, P_i); (Q_i, R_i) = $\frac{cov(OiPi)}{\sqrt{var(Oi)var(Pi)}}$; $\frac{cov(QiRi)}{\sqrt{var(Qi)var(Ri)}}$

RESULTS

The canonical correlation analysis was performed using SPSS between socioeconomic and livelihood variables with BMI, food security and nutritional security among Chenchu and Lambada tribal farm women is presented in Table 2. In both groups, the first and second canonical functions were significant ($p<0.01$), whereas the third canonical function was non-significant. Among the Chenchu women, the first canonical function recorded a canonical correlation of 0.775 and the second function recorded 0.728. In the Lambada group, comparatively higher canonical correlations of 0.841 and 0.810 were observed for the first and second canonical functions, respectively. Lower Wilks' lambda values in the first two functions indicated stronger multivariate relationships between the two sets of variables in both groups.

The standardised and unstandardised canonical correlation coefficients of independent and dependent variables are presented in Table 3. In the Chenchu group, the first canonical function showed relatively higher coefficients for economic motivation, annual income, education and the impact of major government food and nutritional security schemes. Among the dependent variables, BMI, food security and nutritional security recorded comparatively higher coefficients. In the second canonical function, age showed the highest coefficient among the independent variables, whereas BMI recorded the highest coefficient among the dependent variables. In

Table 2. Canonical correlation analysis of Chenchu and Lambada tribal farm women with nutritional security variables

Pair of canonical variates		Canonical correlation		Square of correlation		Eigenvalue		Wilks statistic		Significance	
Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada
O_1, P_1	Q_1,R_1	0.775	0.841	0.601	0.707	2.419	2.419	0.165	0.085	0.000	0.000
O_2, P_2	Q_2, R_2	0.728	0.810	0.530	0.656	1.128	1.907	0.412	0.292	0.000	0.000
O_3, P_3	Q_3, R_3	0.351	0.389	0.123	0.151	0.140	0.178	0.877	0.849	0.505	0.296

Table 3. Standardised and unstandardised canonical correlation coefficients analysis, Chenchu and Lambada tribal farm women

IndependentVariables	Standardised Canonical Correlation Coefficient				Unstandardized Canonical Correlation Coefficient			
	Chenchu		Lambada		Chenchu		Lambada	
	O1	O2	Q1	Q2	P1	P2	R1	R2
Age	-.374	.963	.227	-.781	-.025	.065	.018	-.063
Education	-.331	-.131	-.025	-.083	-.332	-.132	-.020	-.068
Family Type	-.047	-.209	-.043	.167	-.093	-.416	-.090	.353
Farming Experience	-.001	-.170	.005	-.227	.000	-.017	.001	-.028
Land Holding	.063	-.195	.074	.198	.085	-.264	.095	.255
Occupation	-.058	-.097	-.006	-.128	-.056	-.093	-.005	-.105
Crops Grown	.067	-.161	-.018	-.044	.055	-.133	-.014	-.033
Annual Income	-.331	-.235	-.426	-.105	.000	.000	.000	.000
Livestock Ownership	-.206	-.167	-.103	-.162	-.468	-.379	-.243	-.383
Natural Capital	.039	-.211	-.069	.091	.089	-.484	-.089	.117
Access to Basic Services	.028	.106	-.132	-.125	.271	1.043	-1.289	-1.222
Agricultural Mass Media Contact	.054	-.168	-.117	.060	.055	-.170	-.088	.045
Economic Motivation	-.424	.103	-.327	.079	-.209	.051	-.090	.022
Impact of Major Government Food and Nutritional Security Schemes	-.324	-.056	-.427	.061	-.760	-.130	-1.113	.159
Body Mass Index (BMI)	-.405	1.100	.020	-1.030	-.089	.242	.006	-.281
Food Security	-.378	-.225	-.295	.108	-.210	-.125	-.153	.056
Nutritional Security	-.392	-.786	-.759	.122	-6.885	-13.790	-12.980	2.082

Table 4. Sample correlation between the original variable and the canonical variables

Independent Variables	Loadings				Cross loading			
	Chenchu		Lambada		Chenchu		Lambada	
	O1	O2	Q1	Q2	P1	P2	R1	R2
Age	-.363	.867	.145	-.922	-.281	.632	.122	-.747
Education	-.329	-.503	-.432	.151	-.255	-.366	-.363	.122
Family Type	.019	-.183	-.319	.124	.015	-.133	-.268	.100
Farming Experience	-.460	.685	-.236	-.681	-.356	.499	-.198	-.552
Land Holding	-.048	-.318	-.172	.167	-.037	-.232	-.145	.135
Occupation	-.096	.040	-.361	-.026	-.074	.029	-.304	-.021
Crops Grown	-.280	-.062	-.283	.159	-.217	-.045	-.238	.129
Annual Income	-.617	-.103	-.690	-.322	-.478	-.075	-.581	-.261
Livestock Ownership	-.467	-.269	-.410	-.145	-.362	-.196	-.345	-.118
Natural Capital	-.056	-.088	-.082	.058	-.043	-.064	-.069	.047
Access to Basic Services	-.188	-.094	-.305	-.128	-.146	-.069	-.257	-.104
Agricultural Mass Media Contact	.045	-.209	-.336	.322	.035	-.152	-.283	.260
Economic Motivation	-.684	-.128	-.653	.073	-.530	-.094	-.549	.059
Impact of Major Government Food and Nutritional Security Schemes	-.577	-.154	-.738	-.255	-.447	-.112	-.621	-.207
Body Mass Index (BMI)	-.803	.583	-.208	-.978	-.623	.425	-.175	-.792
Food Security	-.879	-.216	-.874	-.067	-.681	-.157	-.736	-.054
Nutritional Security	-.873	-.394	-.983	.000	-.677	-.287	-.827	.000

the Lambada group, the first canonical function recorded relatively higher coefficients for annual income, the impact of major government food and nutritional security schemes and economic motivation. Among the dependent variables, nutritional security and food security showed comparatively higher coefficients. In the second canonical function, age, landholding and family type recorded relatively higher coefficients among the independent variables, whereas BMI recorded the highest coefficient among the dependent variables. The third canonical function was non-significant in both groups and therefore was not interpreted further.

The sample correlations between the original variables and canonical variables are presented in Table 4. In the Chenchu group, the first canonical function showed relatively higher loadings for economic motivation, annual income, impact of major government food and nutritional security schemes, livestock ownership and farming experience. Among the dependent variables, food security, nutritional security and BMI recorded comparatively higher loadings. In the second canonical function, age and farming experience showed relatively higher loadings among the independent variables, whereas BMI recorded the highest loading among the dependent variables.

In the Lambada group, the first canonical function recorded relatively higher loadings for the impact of major government food and nutritional security schemes, annual income, economic motivation, education and livestock ownership. Among the dependent variables, nutritional security and food security showed comparatively higher loadings. In the second canonical function, age and farming experience showed relatively higher loadings among the independent variables, whereas BMI recorded the highest loading among the dependent variables. The third canonical function was non-significant in both groups and therefore was not interpreted further.

The proportion of variance explained by the canonical variables is presented in Table 5. In both groups, the first canonical function accounted for the highest proportion of explained variance compared with the second and third canonical functions. Among the Chenchu farm women, the first canonical function explained higher variance in Set 2 by self (0.727) compared with Set 1 by self (0.141). Similarly, in the Lambada farm women, the first canonical function explained higher variance in Set 2 by self (0.591) than in Set 1 by self (0.174). The second canonical function explained comparatively lower variance, whereas the third canonical function contributed minimal variance in both groups.

The socioeconomic and livelihood variables were significantly associated with the BMI of the Chenchu and Lambada tribal farm women in multivariate relationship and food security and nutritional security with both the tribal farm women groups. Some variables such as annual income, economic motivation, livestock ownership and the impact of significant government food and nutrition security programs had higher values of the loading and coefficient for the first canonical function. The results are consistent with previous

Table 5. Proportion of Variance for both Chenchu and Lambada farm women

Proportion of Variance Explained								
Canonical	Chenchu				Lambada			
Variable	Set 1 by Self	Set 1 by Set 2	Set 2 by Self	Set 2 by Set 1	Set 1 by Self	Set 1 by Set 2	Set 2 by Self	Set 2 by Set 1
1	.141	.085	.727	.437	.174	.123	.591	.418
2	.129	.068	.181	.096	.123	.081	.320	.210
3	.037	.004	.092	.011	.078	.012	.089	.013

research which found that livelihood resources, household income and institutional support have a significant impact on food and nutritional security of rural households (Jairu et al., 2023). The present study also confirmed the significant association that were found between BMI, food security and nutrition security, which is consistent with previous studies that suggests the socioeconomic factors and food access plays a significant role in nutrition status and food consumption among rural women (Kumbhare et al., 2023).

DISCUSSION

The findings indicate significant multivariate relationships between socioeconomic and livelihood variables with BMI, food security and nutritional security among both Chenchu and Lambada farm women. The significance of the first and second canonical functions in both groups indicates that the selected independent variables collectively contribute to variations in nutritional outcomes. Comparatively higher canonical correlations among the Lambada farm women indicate relatively stronger multivariate relationships between socioeconomic and livelihood characteristics with nutritional security variables than among the Chenchu farm women. The lower Wilks' lambda values observed in the first two functions further indicate the existence of stronger associations between the two variable sets.

The higher coefficients and loadings observed for annual income, education, economic motivation, livestock ownership, farming experience and the impact of major government food and nutritional security schemes indicate the importance of socioeconomic and livelihood conditions in relation to BMI, food security and nutritional security among tribal farm women. The stronger contribution of annual income and livestock ownership suggests the importance of livelihood resources in improving food access and nutritional outcomes. Similarly, education and economic motivation appear to influence awareness, decision-making ability and utilisation of nutrition-related resources. The higher loadings of food security and nutritional security in the first canonical function in both groups further indicate that nutritional outcomes among tribal women are multidimensional and influenced by several interrelated socioeconomic and agricultural factors. The stronger association of government food and nutritional security schemes with the canonical functions in both tribal groups indicates the importance of public welfare interventions in improving food and nutritional conditions among vulnerable populations. Access to basic services and agricultural mass media contact also contributed to the canonical relationships, indicating the role of information access and institutional support in nutritional improvement. The contribution of farming experience and number of crops grown further suggests the importance of agricultural livelihood diversification in maintaining food availability and dietary adequacy among tribal households.

The findings are in conformity with earlier studies reporting that socioeconomic resources, livelihood conditions and access to services significantly influence food and nutritional security among tribal communities (Biswas et al., 2022) and the need for integrated policies addressing economic participation, education access, and community engagement to dismantle systemic barriers (Kujur et al., 2026). The observed relationships also support earlier findings that nutrition-sensitive agricultural practices and livelihood-related factors contribute to nutritional security among rural and tribal populations (Mishra et al., 2025). Earlier studies also reported that poor education, limited information access and inadequate livelihood opportunities adversely affect food and nutritional security among tribal households (Bahubalendra et al., 2025). The present findings further support earlier observations that tribal women often experience nutritional vulnerability because of interconnected socioeconomic and livelihood constraints (Kapoor et al., 2022; Kshatriya et al., 2016).

CONCLUSION

The current study shows that a complex interaction of socioeconomic, livelihood, and institutional factors, rather than a single driver, affects nutritional security among tribal farm women. The Chenchu and Lambada populations' nutritional outcomes were found to be significantly influenced by household income, education, livelihood assets, economic incentive, and access to government food and nutrition security programs. Food availability, accessibility, consumption, dietary quality, nutrient adequacy, and health status are all included in the dynamic and multifaceted concepts of food security and nutritional security. Canonical Correlation Analysis was used in this work to analyze these constructs after they were operationalized using approved composite indicators. Consequently, rather than being direct indicators of food or nutritional security, the canonical coefficients should be seen as markers of multivariate correlations. The results emphasize the necessity of comprehensive interventions that combine livelihood improvement, nutrition education, nutrition-sensitive agriculture, and efficient public welfare program execution. To provide a more thorough picture of nutritional security among indigenous populations, future research should include biochemical indicators and longitudinal approaches.

DECLARATIONS

Ethics approval and informed consent: The study was conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethical approval was waived by the Divisional Ethics Committee, Extension Division of Centurion University of Technology and Management, Paralakhemundi, Odisha, India. Throughout the study, the respondents were asked for their informed consent.

Conflict of interest: The research was carried out without any financial or commercial ties that might be seen as a potential conflict of interest, according to the authors. The authors affirm that they carefully examined, amended and edited the content as necessary when preparing this work. The final content of this publication is entirely the authors' responsibility.

Data availability Statement: Data is available upon reasonable request from the first author as well as corresponding author.

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Research Article

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Strengthening Agricultural Household Livelihoods through Guaranteed Employment: Differential Welfare Effects of MGNREGA in India

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HIGHLIGHTS

- MGNREGA participation improves agricultural household income and consumption while generating varied financial outcomes.
- Programme impacts differ significantly across social groups, education levels, gender, and farm-size categories.
- ST households, female-headed households, and small farmers derive relatively greater livelihood benefits.

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Keywords: Employment guarantee, MGNREGA, Agricultural households, Sustainable rural development, Livelihood security, Indebtedness.

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ABSTRACT

Enhancing the livelihood security of agricultural households remains a central challenge for rural development policy in India. As India's largest welfare programme, MGNREGA, which is presently renamed as Viksit Bharat–Guarantee for Rozgar and Ajeevika Mission (Gramin) (VB-G RAM G), seeks to address this challenge by providing supplementary wage employment and strengthening rural economic security. This study examined MGNREGA's impact (presently, VB-G RAM G) on the socio-economic well-being of agricultural households, with emphasis on income, consumption expenditure, and indebtedness, using unit-level data from NSSO Situation Assessment Survey covering 42,819 households. Propensity Score Matching (PSM) was employed to estimate the average treatment effect while addressing selection bias, and propensity score-weighted regression was used to assess robustness. The findings indicated that programme participation improved income and consumption outcomes, although its effects on indebtedness varied across beneficiary groups. The disaggregated analysis revealed substantial heterogeneity in programme impacts across social categories, gender, educational and farmer groups. Household income increased by up to 20.2% among beneficiary groups, with comparatively larger gains observed for graduate households (19.5%) and small farmers (20.1%). The findings reaffirm importance of employment guarantees in strengthening agricultural livelihoods and promoting inclusive rural development while highlighting need for targeted extension and livelihood interventions.

INTRODUCTION

Rural livelihoods in India are characterised by persistent challenges of seasonal unemployment, income instability, underemployment, and indebtedness, particularly among small and marginal farming households. The dependence of agricultural households on uncertain farm incomes, combined with limited access to productive assets and non farm employment opportunities, exacerbates economic vulnerability and constrains rural development (Lahiri et al., 2024; (Bharne et al., 2025). In this context, Employment Guarantee Schemes (EGS) have emerged as important policy instruments for enhancing livelihood security and stabilising household incomes during periods of agrarian distress (Kumar & Maya, 2023; Pavana Kumar et al., 2024; Chandegara et al., 2024). MGNREGA, which is presently renamed as VB-G RAM G (Viksit Bharat – Guarantee for Rozgar and Ajeevika Mission (Gramin), is

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one of the most significant rural livelihood interventions in India. By guaranteeing up to 100 days of wage employment to rural households, the programme seeks to supplement farm income, reduce livelihood insecurity, and create productive rural assets (Arun et al., 2011). Beyond its employment generation, MGNREGA is expected to influence broader household welfare outcomes through more stable incomes, improved consumption capacity, and reduced financial vulnerability (Mohapatra & Abi, 2022).

A substantial body of literature highlights MGNREGA's contribution to rural welfare and reports positive effects on wage growth, poverty reduction, consumption smoothing, and rural asset creation (Imbert & Papp, 2015; Deininger & Liu, 2019). Research also suggests that the programme improves bargaining power in rural labour markets and promotes greater participation of socially disadvantaged groups (Chopra, 2014; Narayanan et al., 2019; Pavana Kumar & Lahiri, 2023). Nevertheless, evidence regarding its impact on agricultural households remains inconclusive. While several studies document improvements in income and consumption expenditure (Narayanan et al., 2017; Bose, 2017), others indicate substantial variations in programme outcomes across social groups, educational categories, and farm-size classes (Klonner & Oldiges, 2013; Joshi et al., 2017). Consequently, the benefits derived from EGS may not be distributed uniformly across beneficiary groups (Shaba & Alam, 2024). Understanding such differential effects is essential for evaluating the inclusiveness and effectiveness of MGNREGA as a rural development intervention. However, existing empirical evidence on the heterogeneous impacts of MGNREGA on agricultural households remains fragmented and insufficiently developed, particularly with respect to differences across social groups, educational levels, and farm-size classes (Reddy & Babu, 2018).

The policy relevance of this issue has become even more pronounced following the enactment of the VB G RAM G, which replaced MGNREGA and expanded the EGS framework for rural households (VB G RAM G ACT, 2025). In this context, an assessment of MGNREGA's distributional effects provides valuable insights for future employment and livelihood policies. Using unit-level data from the NSSO, the study employs Propensity Score Matching (PSM) to estimate programme impacts while accounting for selection bias. By estimating both overall and subgroup-specific effects using nationally representative data, the study extends previous PSM studies on MGNREGA by focusing on a more specific beneficiary group and by examining how programme gains vary across the levels of society.

METHODOLOGY

The study used unit-level data from the latest available 'Situation Assessment of Agricultural Households and Land and Livestock Holdings of Households in Rural India' (NSSO, 2022), which adopts a multistage stratified sampling design with survey weights to ensure national representativeness. The survey provides nationally representative information on agricultural households, including demographic characteristics, income sources, consumption expenditure, indebtedness, landholding, and participation in the MGNREGA. After excluding observations with incomplete information and outliers, a final sample of 42,819 agricultural households was retained for analysis.

MGNREGA participation was treated as a binary treatment variable and coded as 1 if any household member had worked under the programme during the previous 365 days and 0 otherwise. The main outcome variables were monthly household income, monthly household consumption expenditure, and total outstanding loan amount. Because these variables exhibited positively skewed distributions, their natural logarithms were used in the empirical analysis. Household size, age, and gender of the household head, social category, educational attainment, farmer category, access to irrigated land, expenditure on fertilisers, non farm income and possession of a Kisan Credit Card (KCC) were included as covariates to capture relevant socio economic and production characteristics.

To estimate the impact of programme participation, PSM was employed following Rosenbaum and Rubin (1983). Propensity scores were estimated using a binary logistic regression model, where the probability of MGNREGA participation was expressed as:

$$P(X_i) = Pr(D_i = 1 \mid X_i)$$

where (D_i) denotes participation status and (X_i) represents the vector of observed household characteristics. Based on the estimated propensity scores, beneficiary households were matched with comparable non-beneficiary households to estimate the Average Treatment Effect on the Treated (ATT):

$$ATT = \mathbb{E}[Y_i(1) - Y_i(0) \mid D_i = 1]$$

where (Y_i (1)) and (Y_i (0)) represent the potential outcomes with and without programme participation, respectively. Covariate balance between matched treatment and control groups was assessed using Standardised Mean Difference (SMD) and summary statistics for the propensity score distributions, with all post matching standardised mean differences falling below the 0.1 threshold after Nearest Neighbour Matching (NNM) (Thoemmes & Kim, 2011). ATT values were computed for different social categories, education levels, gender of household head, and farmer categories to assess the distribution of programme benefits across agricultural households. Using RStudio, model fit was evaluated using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) to confirm logit specification adequacy. Sensitivity analysis based on Rosenbaum bounds was used to examine the robustness of the estimated effects to potential unobserved bias. Taken together, these procedures provide a credible basis for estimating both overall and subgroup specific programme impacts for agricultural households.

RESULTS

Descriptive statistics and covariate imbalance

Descriptive statistics in Table 1 revealed significant differences between MGNREGA participants (n = 10,481) and non-participants (n = 30,392) across socio-economic and agricultural variables before matching. Participants were disproportionately from ST (35.7% vs 14.4%; SMD = 0.581) and had lower educational attainment (HHEdu_Cat), with 36.3% illiterate compared to 32.0% among non-participants (SMD = 0.272). Participants showed higher marginal farmer representation (66.1% vs 60.7%; SMD = 0.147)

Table 1. Standardised Mean Differences Before and After Logit Matching (N= 42,819)

S. No.	Variable	Type	Non-participants	Mean	SD	Participants	Mean	SD	SMD	logit SMD
1	HH Size	Continuous	31991	5.06	2.46	10828	4.85	2.1	0.091	
2	Soc Ctgry (%)	Categorical							0.581	0.0091
	Others		9339 (29.2)			1492 (13.8)		-0.1541	0.0127	
	ST		4608 (14.4)			3865 (35.7)		0.2129	0.0187	
	SC		4310 (13.5)			1693 (15.6)		0.0216	-0.0099	
	OBC		13734 (42.9)			3778 (34.9)		-0.0804	-0.0214	
3	Gender (%)	Categorical (Female = 0, Male =1)	29256 (91.5% Male)			9912 (91.5% Male)	0.003	-0.0057		
4	Age	Continuous	31991	51.37	13.61		49.99	12.68	0.105	0.0078
5	HH Edu Cat (%)	Categorical							0.272	
	Illiterate		10233 (32)			3931 (36.3)		0.0432	-0.0132	
	Primary		12616(39.4)			4953 (45.7)		0.0631	0.002	
	Secondary		6848 (21.4)			1626 (15)		-0.0639	0.0076	
	Graduate		2294 (7.2)			318 (2.9)		-0.0423	0.0036	
6	Farmer Cat (%)	Categorical							0.147	
	Others		4181 (13.1)			957 (8.8)			-0.0423	0.0008
	Marginal		19417 (60.7)			7160 (66.1)			0.0543	-0.0092
	Small		8393 (26.2)			2711 (25)			-0.012	0.0084
7	LNHH Income	Continuous	31991	8.97	1.05	10828	8.91	0.93	0.059	0.032
8	LN Inc Non CP	Continuous	31991	7.34	3.1	10828	7.92	2.13	0.219	-0.0099
9	LN Ferti	Continuous	31991	5.58	2.25	10828	4.68	2.7	0.362	-0.0277
10	LN Con Exp M	Continuous	31991	9.04	0.54	10828	9.01	0.49	0.045	0.0005
12	KCC (%)	Binary (No = 0, Yes = 1)	6356 (19.9% Yes)			1466 (13.5% Yes)	0.17	0.0045		
13	If Any Irrigted (%)	Binary (No = 0, Yes = 1)	22024 (68.8% Yes)			5478 (50.6% Yes)	0.379	-0.009		
14	LN Loan	Continuous	31991	5.6	5.68	10828	5.46	5.54	0.026	0.032

Note: All SMDs after matching fall below the 0.1 threshold, indicating successful covariate balance.

and lower access to irrigated land (50.6% vs 68.8%; SMD = 0.379). Non-participants invested more in agricultural inputs, spending significantly more on fertilisers, manure and pesticides (SMD = 0.362) and holding more KCC (19.9% vs 13.5%; SMD = 0.170). Household income (LNHH_Income) was slightly higher among non-participants (mean LNHH income = 8.97 vs 8.91; SMD = 0.059), while participants reported higher non-crop income (mean = 7.92 vs 7.34; SMD = 0.219). These pre existing imbalances across key covariates justified the use of PSM to reduce selection bias before estimating programme effects.

Propensity score estimation and balance diagnostics

Propensity scores were estimated using a logistic regression model that related MGNREGA participation to the observed household characteristics specified in the methodology. After Nearest Neighbour Matching (NNM), covariate balance improved substantially across all variables. The logit model reduced SMDs (logitSMD) to acceptable levels (<0.1) for all covariates, demonstrating effective balancing of treatment and control groups in Table 1. Household size (HHSize) balanced to SMD = 0.0091, SC status to SMD = -0.0099, and ST status to SMD = 0.0187. Non-crop income (LNIncNonCP), which showed a substantial pre-matching imbalance (SMD = 0.2738), balanced to SMD = -0.0099. Fertiliser expenditure (LNFerti) improved from SMD = -0.3339 to SMD = -0.0277. Irrigated land access (IfAnyIrrigted) balanced from SMD = -0.1825 to SMD = -0.0090. Household income (LNHHIncome) was balanced to SMD = 0.0320, and KCC access was balanced to SMD = 0.0045. All post-matching SMDs fell below the 0.1 threshold, indicating successful covariate balancing. Propensity score distributions converged after matching, with treated and control groups showing similar score distributions compared to substantial pre-matching differences (Thoemmes & Kim, 2011). The logit model achieved adequate balance across all covariates, validating the non-confoundedness assumption required for causal inference.

Average treatment effect on the treated (ATT)

The PSM estimates indicated that participation in MGNREGA was associated with higher household income and consumption expenditure among agricultural households, together with modest reductions in outstanding loans on average. In Table 2, the ATT suggested that beneficiary households experienced statistically significant improvements in livelihood indicators relative to comparable non beneficiary households. However, the size and direction of these effects varied across social categories, gender, education levels, and farmer categories, indicating substantial

Table 2. ATT by Subgroup (N= 42,819)

Subgroup	Category	ATT (Expenditure)	Expenditure ATT (%)	ATT (Income)	Income ATT (%)	ATT (Loan)	Loan ATT (%)
Social category	Others	0.0695	7.2	0.1836	20.15	–0.1057	–10.03
	ST	0.0518	5.32	0.1074	11.34	–0.0846	–8.11
	SC	0.0331	3.37	0.0661	6.83	0.0381	3.88
	OBC	0.0336	3.42	0.0653	6.75	0.1013	10.66
Gender	Female	0.0597	6.15	0.1021	10.75	–0.0602	–5.84
	Male	0.0343	3.49	0.0747	7.76	+0.0311	+3.06
Education	Illiterate	0.0033	0.33	0.0553	5.69	–0.0026	–0.26
	Primary	0.0204	2.06	0.0746	7.75	–0.0083	–0.83
	Secondary	0.0764	7.94	0.1633	17.74	–0.0062	–0.62
	Graduate	0.0949	9.95	0.1781	19.49	–0.0798	–7.67
Farmer category	Others	0.0042	“0.42	0.0125	1.26	–0.0477	–4.66
	Marginal	0.0979	10.29	0.1491	16.08	0.0303	3.08
	Small	0.0887	9.28	0.1827	20.05	+0.0263	+2.60

Note: ATT is calculated as $(e^{\beta} - 1) \times 100$ where β = log coefficient.

heterogeneity in programme impacts. With respect to social categories, ST households saw expenditure gains of about 5.3%, income increases of around 11.3%, and reduction in outstanding loans of 8.1%. SC households recorded expenditure gains of about 3.4% and income growth of 6.8%, with a small increase in debt of around 3.9%. OBC households also showed expenditure and income gains of around 3.4% and 6.8%, but their loan burden rose by about 10.7%. Households in the “Others” category registered income and expenditure gains of about 20.2% and 7.2%, and a reduction in loans of around 10.0%.

Gender disaggregated estimates showed that female headed households experienced larger gains in income and consumption than male headed households, with consumption rising by about 6.2% and income by nearly 10.8%, compared with 3.5% and 7.8% for male-headed households. Outstanding loans also declined more for female-headed households, by around 5.8%, versus 3.1% for male-headed households, indicating relatively stronger debt relief for women. Education also shaped programme outcomes. Graduate households recorded the largest gains, with expenditure rising by about 10.0%, income by 19.5%, and loans falling by 7.7%. Secondary-educated households also did well, with income up by nearly 17.7% and expenditure by 7.9%. Illiterate and primary-educated households saw smaller gains, with income rising by 5.7% and 7.8% and expenditure by only 0.3% and 2.1%, respectively. These results suggest that better educated households were able to leverage MGNREGA participation more effectively, although less educated households also benefited in terms of income.

By farm size, marginal and small farmers both benefited from participation, but in different ways. Marginal farmers saw expenditure rise by about 10.3% and income by 16.1%, along with a modest 3.1% increase in loans. Small farmers recorded similar expenditure gains of 9.3% but stronger income growth of 20.1%, with a slight 2.6% fall in loans. The “Others” category showed almost no change in expenditure, a small income increase of 1.3%, and a 4.7% reduction in loans. This pattern indicates that small farmers were better able than marginal farmers to translate additional earnings into improved financial positions. Overall, the heterogeneous ATT estimates (Table 2) show that MGNREGA’s livelihood effects for agricultural households were not uniform. ST households, female headed households, better educated households and small farmers derived relatively larger gains from participation, while some other groups saw smaller improvements or higher loan burdens. These differences underline the importance of tailored implementation and extension support for different socio economic groups within the rural population.

Propensity score weighted regression results

To complement the matching estimates, PS–weighted regression models were estimated for household income, consumption expenditure and outstanding loans, using the same set of covariates as in the PS model in Table 3. These regressions adjusted for residual differences in observed characteristics between participants and non participants and provided an additional check on the direction and significance of programme effects. For household income, MGNREGA participation had a positive and statistically significant coefficient (0.322, $p < 0.01$), indicating higher income among participating households. Household size was negatively associated with income, suggesting lower income for larger families. Social category and other characteristics also influenced: ST households had lower income than the reference group, while OBC households had higher income. Male-headed households earned more than female-headed households, and households with a KCC recorded substantially higher income, highlighting the role of credit access.

For consumption expenditure, MGNREGA participation had a positive and significant effect (0.064, $p < 0.01$), suggesting that part of the additional income was used for higher household spending. Larger household size was linked to higher expenditure, reflecting greater needs. SC, ST, and OBC households spent less than the reference group, showing persistent consumption gaps. Higher education and access to irrigated land were positively associated with expenditure, while for outstanding loans, MGNREGA participation had a small but significant negative effect (–0.012, $p < 0.01$), indicating a modest debt reduction. ST households had higher debt than the reference group, and graduate

Table 3. PS-Weighted Regression Coefficients for Household Outcomes

Variable	Income Coefficient	Expenditure Coefficient	Loan Coefficient
MGNREGA Work	0.322***	0.064***	-0.012***
Household Size	-0.239**	0.122**	-0.010***
Scheduled Tribe	-1.913***	-0.157***	0.069***
Scheduled Caste	0.662**	-0.100**	-0.017
OBC	0.995***	-0.076**	0.003
Gender	0.614**	0.032*	-0.029*
Age	-0.016**	0.002***	0.005**
Primary Education	-0.504***	0.114**	0.103**
Secondary Education	-0.688***	0.174**	0.251**
Graduate Education	-0.740**	0.168**	0.380***
Marginal Farmer	-1.636***	-0.065**	-0.435***
Small Farmer	-0.929***	-0.026**	-0.191***
KCC	2.639**	-0.045*	-0.009**
Irrigated Land	0.267**	0.019***	0.069**

Note: *** p < 0.01, ** p < 0.05, * p < 0.10.

households also carried more loans, while fertiliser and pesticide spending and irrigation access were associated with higher borrowing.

Overall, the PS–weighted regression results were consistent with the matching estimates in indicating that MGNREGA participation was associated with higher income and consumption and a small reduction in outstanding loans, while confirming the importance of household size, social category, education, credit access and productive assets in shaping livelihood outcomes.

Model fit and sensitivity analysis

Model fit for the propensity score specification is assessed by comparing a baseline model (Mod0) with the covariate rich logit model using AIC, BIC and log likelihood values (Table 4). For all three outcome variables, the logit specification yields substantially lower AIC and BIC values and higher log likelihood than the corresponding Mod0 model, indicating markedly better fit. Household income improves from AIC 262210.3 and BIC 262392.2 in Mod0 to 131464.8 and 131632.5 in the logit model, with log-likelihood rising from -131084.1 to -65711.42. Similarly, consumer expenditure and outstanding loan also show the same pattern, confirming the superior fit of the logit specification. This confirms that the chosen set of covariates provides an adequate representation of the participation process and supports the use of the logit based propensity scores in the matching and weighting procedures.

To examine the robustness of the impact estimates to potential unobserved bias, a Rosenbaum sensitivity analysis is conducted for the Hodges–Lehmann point estimates (Table 5). For household income and consumption expenditure, the estimated effects remain positive, and their associated bounds stay away from zero even when the odds of programme participation are allowed to differ by up to fivefold between matched households (Γ = 5), suggesting that these results are robust to moderate levels of hidden bias. In contrast, the bounds for outstanding loans cross zero at lower values of Ã, indicating that the modest debt reducing effect is more sensitive to possible unobserved confounding. Together, these diagnostics strengthen confidence in the main findings on income and consumption while highlighting the need for a more guarded interpretation of the loan results.

DISCUSSION

The analysis shows that MGNREGA participation is associated with higher household income and consumption expenditure among agricultural households, together with modest reductions in outstanding loans on average. This pattern is consistent with earlier evidence that the programme raises rural wages, smooths consumption and reduces poverty (Deininger & Liu, 2019; Bose, 2017). At the same time, the present study confirms that these gains are not uniform: the magnitude and direction of effects vary systematically by social category, gender, education and farm size, in line with studies that document substantial heterogeneity in MGNREGA outcomes across regions and groups (Klonner & Oldiges, 2013).

Across social categories, the finding that ST households experience relatively high income and consumption gains, accompanied by a reduction in outstanding loans, supports Dreze's (2011) view of MGNREGA as particularly important for marginalised communities. However, the continued income disadvantage of ST households in the regression analysis and their higher overall debt levels are in line with Patwardhan and Tasciotti's (2023) evidence on persistent structural inequalities in tribal areas. For SC and OBC, the smaller expenditure and income gains and

Table 4. The goodness-of-fit analysis

	Household Income		Consumer Expenditure		Outstanding Loan	
	Mod0	Logit	Mod0	Logit	Mod0	Logit
AIC	262210.3	131464.8	39889.13	19415.83	93574.22	44755.8
BIC	262392.2	131632.5	40071.08	19583.46	93756.17	44923.43
logLik	-131084.1	-65711.42	-19923.57	-9686.91	-46766.11	-22356.9

Table 5. Rosenbaum Sensitivity Test for Hodges-Lehmann point estimates

Model	Unconfounded Estimate	Γ=1 Lower / Upper	Γ=2 Lower / Upper	Γ=3 Lower / Upper	Γ=4 Lower / Upper	Γ=5 Lower / Upper
Income	8.418	8.418/8.418	8.018/8.818	7.818/9.018	7.718/9.118	7.618/9.218
Consumer Expenditure	8.474	8.474/8.474	8.174/8.774	8.074/8.874	7.974/8.974	7.974/8.974
Outstanding Loan	5.472	5.472/5.472	3.972/5.672	-0.027/6.272	-0.527/9.072	-0.527/9.772

the rise in loans among OBC households resonate with Shankar and Gaiha's 2013 discussion of caste based income gaps, suggesting that MGNREGA mitigates but does not eliminate structural inequalities. In this sense, the programme functions as an important, but partial, instrument of redistribution for agricultural households.

Gender disaggregated results indicate that female headed agricultural households record larger percentage gains in income and consumption and stronger reductions in outstanding loans than male headed households. This aligns with Narayanan et al. (2017) and Chopra (2014), who show that MGNREGA expands women's participation in paid work and strengthens their bargaining position. At the same time, male headed households still enjoy higher absolute income, echoing Rodriguez's (2022) findings on persistent gender wage gaps. The evidence here suggests that MGNREGA narrows, but does not close, gender disparities in rural livelihoods and that complementary interventions are needed to sustain and deepen its benefits for women.

The education and farm-size patterns point to important interactions between public employment and household capabilities. The relatively larger income and expenditure gains for secondary and graduate educated households suggest that education improves households' ability to combine public employment with other livelihood activities and to allocate additional income effectively. This aligns with Deininger and Liu's (2019) argument that higher education enhances access to better opportunities and facilitates more informed financial decisions. At the same time, the positive income effects for illiterate and primary educated households indicate that MGNREGA remains accessible to less educated groups, though the smaller expenditure changes imply constraints in translating income gains into sustained improvements in living standards.

The results by farm size fit well with earlier findings that MGNREGA is particularly important for land poor households (Yadav & Ghosh, 2023). Marginal and small farmers both record notable improvements in income and consumption, but only small farmers reduce their outstanding loans. This divergence suggests that marginal farmers may still rely on borrowing to finance agricultural inputs and investments, even when MGNREGA strengthens their cash flow (Mohanakumar et al., 2018). The positive association between input expenditure, irrigation access and loan amounts is consistent with studies showing that productivity enhancing investments in agriculture often require credit (Patwardhan & Tasciotti, 2023; Jiragal et al., 2025).

Overall, the pattern of higher income and consumption and slightly lower debt among participants proves that MGNREGA acts as a partial buffer against distress borrowing, while the modest size of the loan effects underscores that the programme is not a substitute for targeted credit or debt relief policies. These findings provide nationally representative evidence on heterogeneous impacts specifically among agricultural households, a group that remains less explored in many earlier studies. Although the data precede the introduction of the VB-G RAM G, the distributional patterns documented here offer relevant lessons for that expanded employment guarantee framework. The evidence that ST households, female headed households and land poor farmers derive relatively larger gains suggests that any new scheme seeking to build on MGNREGA should explicitly preserve and strengthen its pro vulnerable features. Extension agencies and local institutions can use these findings to inform labour-budget planning, selection of works, and convergence with credit and input programmes under VB G RAM G so that the households that benefit most from employment guarantees continue to receive priority support.

CONCLUSION

The findings substantiate that participation in the MGNREGA contributes positively to the socio-economic development of agricultural households by enhancing household income and consumption while generating differential financial outcomes across beneficiary groups. The variation in programme effects across social categories, gender, educational attainment, and farm-size classes demonstrates that agricultural households are heterogeneous in their ability to derive livelihood benefits from participation. Hence, extension practitioners require evidence-based guidance for designing targeted interventions across vulnerable subgroups, with differentiated financial literacy programs needed for marginal farmers and simplified communication strategies essential for illiterate households. Such complementary interventions can help improve both the efficiency and equity of rural employment policy. Future research should look at long-term impacts, include broader contextual factors, and compare outcomes across regions. The study provides useful insights for the design and implementation of emerging rural livelihood policies, including the evolving employment guarantee framework under the VB-G RAM G Act.

DECLARATIONS

Ethics approval and informed consent: The study used NSSO data hence , Departmental Committee of Political Science Department, Institute for Excellence in Higher Education, Bhopal, 462026, M.P., India waived the ethical approval.

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Research Article

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Perception and Utilisation of *Rythu Seva Kendra* (RSK) Services among Tribal Farmers in North Coastal Andhra Pradesh

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HIGHLIGHTS

- Canonical correlation analysis revealed a strong association between tribal farmers' characteristics and RSK perception and utilisation behaviour.
- Education, innovative proneness and extension contact were the strongest determinants of RSK service utilisation.
- The first canonical function explained 79.2% of the shared variance between farmer attributes and service behaviour.
- Improved extension communication and digital infrastructure can enhance inclusive tribal agricultural development.

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Keywords: Canonical correlation analysis, Extension contact, Perception, Rythu Seva Kendras, Tribal farmers, Utilisation.

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ABSTRACT

The study aimed to examine the association between tribal farmers' profile characteristics and their perception and utilisation of *Rythu Seva Kendras* (a village-level agricultural service centres established by the Government of Andhra Pradesh to provide quality agricultural inputs and extension advisory services) in North Coastal Andhra Pradesh 2025–26 using Canonical Correlation Analysis for180 tribal respondents. The results of the 1st canonical function (U_1, V_1) revealed a very high canonical correlation of 0.890, square of correlation 0.792, eigenvalue 3.791, Wilks statistic 0.163 and significance 0.000*, indicating that nearly 79 per cent of the shared variance between farmers' profile characteristics and their perception -utilization behaviour was explained by the function, confirming a very strong and significant multivariate relationship. The second function (U_2, V_2) had a canonical correlation of 0.466, the squared canonical correlation of 0.217, the eigenvalue of 0.277 and Wilks' statistic of 0.783 ($p< 0.001$*), reflecting a comparatively weak and practically less meaningful relationship, given its low eigenvalue and high Wilks' lambda. The main elements affecting tribal farmers' perceptions of and use of RSK services were education, inventiveness, and extension interaction. Strengthening extension communication, digital infrastructure and digital literacy is advocated to improve the use of ICT-enabled services.

INTRODUCTION

Agriculture remains a major livelihood source in India, particularly in rural areas (Owolabi et al., 2026). A substantial proportion of farmers remain inadequately aware of technological advancement in agriculture (Sarnaik et al., 2020). Information dissemination facilitates agricultural development and technology adoption. In order to improve crop production, extension services must give farmers the necessary knowledge and assist them in optimising the use of limited resources (Jat et al., 2021). The global

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agricultural industry has transformed over the last couple of decades and the extension mechanism must keep pace and provide the farmers with improved management and decision-making capabilities (Singh et al., 2020). Non-governmental organisations facilitate agricultural development (Padhy et al., 2026).

In October 2019, the Agri Mission meeting discussed and recommended the establishment of an Agri Input Shop and a Village Knowledge Centre at the village level near village Secretariats, in addition to offering various government services, training for farmers, and capacity building on modern agricultural technology. Only pre-tested quality inputs of seeds, fertilisers and fungicides with a quality seal from the government shall be supplied at village level (Reddy, 2020). Farmers' knowledge & skills are derived from training, extension services and the use of technologies (Jaiswal et al., 2021). The Andhra Pradesh state has started facilitation centres (Rythu Seva Kendras, formally Rythu Bharosa Kendralu) within each village secretariat to supply the latest production technologies and quality inputs directly to farmers in their village. This provides easy and timely access to agro-inputs and farmer services for farmers through the Rythu Seva Kendras (RSKs)-kiosk and mobile application (Haritha et al., 2023). Rythu Seva Kendras (RSKs) have operated across Andhra Pradesh since kharif 2020 to improve agricultural services delivery (Saifuddin et al., 2023). To improve community and convergence, Agri Input Shop and Knowledge Centre were merged and renamed Dr YSR Rythu Bharosa Kendram now Rythu Seva Kendras (RSKs). With significant management and concerted efforts, 10,641 RSK (RBKs) were established by the government. As a one-stop shop for tested, high- quality agricultural inputs (such as seeds, pesticides and fungicides) and inputs for the confederated sector similar to feed and fodder, these centres facilitate dissemination of agricultural technologies among farming communities (Chowdary et al., 2022). RSKs would help the farmers at every stage, from purchasing seed to selling their crops (Babu et al., 2023; Anuhya et al., 2022). The Agriculture Department has employed 6758 villagers in accordance with this. They were put in RSKs and farmed by Agriculture Assistants (Babu et al., 2021).

Tribal farmers in North Coastal Andhra Pradesh are characterized by geographical remoteness, lower educational attainment, poor digital connectivity and limited access to institutional extension services. These constraints may influence their awareness, perception and utilisation of RSK services differently from the general farming population. Despite being an important target group for agricultural development programmes, empirical evidence on RSK service utilisation among tribal farmers remains limited. Therefore, understanding the factors associated with perception and utilisation of RSK services in tribal communities is essential for designing more inclusive and effective extension strategies. The majority of RBK/RSK studies (Chowdary et al., 2022; Haritha et al., 2023; Babu et al., 2023) have employed descriptive or bivariate analysis in the general farming population. Very few studies have been conducted on tribal farmers and no study has attempted to analyse the relationship between the profile characteristics of the tribal farmers and perception and utilization of RSK services using Canonical Correlation Analysis technique. This research gap in North Coastal region of Andhra Pradesh is filled up by this study.

METHODOLOGY

The present study was conducted in the tribal-dominant districts of North Coastal Andhra Pradesh viz. Parvathipuram Manyam, Srikakulam and Alluri Sitarama Raju in 2025-26 to gain insight into tribal farmers' perceptions and utilization of the services of Rythu Seva Kendras (RSKs). Two mandals were randomly selected from each district, for a total of six. Three RSKs and three tribal dominated villages under each RSK were identified from each selected mandal and ten tribal farmers were randomly selected from each of the villages. This resulted in a final sample of 180 tribal farmers studied under an ex-post facto research design. The study was confined to tribal farmers because they constitute a priority beneficiary group with unique socio-economic and geographical characteristics that may influence their perception and utilisation of RSK services differently from the general farming population. Primary data were collected from the respondents using a structured interview schedule. Canonical Correlation Analysis (CCA) was employed to analyse relationships between predictor and criterion variable sets using the collected data with IBM SPSS Statistics. Canonical correlation analysis is a multivariate statistical tool to analyse the relationship between two groups of variables simultaneously using a set of linear combinations called canonical variates (Keskin & Yasar, 2007; Pujitha et al., 2024). CCA was employed instead of simple correlation because it simultaneously analyses the relationship between multiple independent and multiple dependent variables, whereas simple correlation assesses only pairwise relationships. This approach enabled identification of the key profile characteristics jointly influencing tribal farmers' perception and utilisation of RSK services. This technique assists in the identification of socio-economic, communication and psychological factors affecting the effectiveness of RSK services for tribal farmers. The study included two sets of variables: 13 Independent variables (X) and 2 Dependent variables (Y). Where, x_1= Age, x_2= Education, x_3= Landholding, x_4= Annual income, x_5= Farming experience, x_6= Frequency of visit to RSK, x_7= Mass media exposure, x_8= Social participation, x_9= Achievement motivation, x_{10}= Innovative proneness, x_{11}= Scientific orientation, x_{12}= Risk orientation, x_{13}= Extension contact. Dependent variables y_1= Perception towards RSK services, y_2= Utilisation of RSK services. In the second set of analysis, we used 2 dependent variables and obtained 2 canonical correlations. (U_1, V_1) and (U_2, V_2). Before performing Canonical Correlation Analysis, the underlying assumptions were examined. Multicollinearity among the independent variables was assessed using Variance Inflation Factor (VIF) and tolerance values, and no evidence of serious multicollinearity was observed (VIF < 5; tolerance > 0.20). Canonical variates are linear combinations of the independent and dependent variables.

$$U_1 = a_{1I} x_1 + a_{12} x_2 + \ldots + a_{1i} x_i$$
$$U_2 = a_{21} x_1 + a_{22} x_2 + \ldots + a_{2i} x_i$$
$$U_{P=ai1.} X_1 + \ldots\ldots\ldots\ldots + a_{2i} X_i$$
$$V_1 = b_{1I} y_1 + b_{12} y_2$$
$$V_2 = b_{21} y_1 + b_{22} y_2$$

i refers to 13 independent variables; standardised canonical coefficients for x and y are denoted as $a_{1i,} b_{11,} b_{12...} a_{2i}$ and $b_{21}, b_{22.}$

Canonical correlation between (U_i, V_i) was estimated as :

The canonical correlation coefficient was estimated as:

$$r = \frac{Cov(U_i, V_i)}{\sqrt{Var(U_i)Var(V_i)}}$$

Wilks' Lambda statistics, eigenvalues, standardised canonical coefficients, canonical loadings, cross-loadings and redundancy indices were computed to assess the significance and intensity of the relationship between the two sets of variables. The variables with significant canonical loadings and cross-loadings were assumed to be the key contributors to the perception and utilisation of RSK services by the tribal farmers.

RESULTS

The canonical correlation analysis revealed (Table 1) two canonical functions between the independent variables and the perception and utilisation behaviour of tribal farmers towards RSK services. The first pair of canonical variables (U_1, V_1) had an extremely high canonical correlation ($\rho = 0.890$), demonstrating a high correlation between the two sets of variables. Squared canonical correlation (0.792) showed that 79.20 per cent of the variance was common between the independent and dependent variables. The high eigenvalue (3.791) and low Wilks' Lambda value (0.163) also indicated the high strength and significance of the first canonical function ($p < 0.001$).

The second pair of canonical variables (U_2, V_2) had a moderate correlation of 0.466 and 21.7 per cent of the variance. Although statistically significant ($p < 0.001$), the second function exhibited a low eigenvalue (0.277), indicating limited practical contribution and a high Wilks' Lambda value (0.783), which suggested less practical significance. The first canonical function accounted for the most important association between the two sets of variables overall.

The finding from Table 2, shows education and innovativeness exhibited stronger contributions to the first canonical variate based on coefficient magnitude. Among the dependent variables, perception demonstrated relatively stronger loading magnitude than utilisation, indicating greater association with the first canonical function. This indicates that education and innovative proneness were the key factors associated with perception and utilisation.

Achievement motivation exhibited the largest contribution (0.630) to the second canonical function, followed by farming experience (–0.491), social participation (–0.480), annual income (–0.363), and frequency of visits to RSK (–0.329). The signs of the standardized canonical coefficients should not be interpreted as indicating positive or inverse relationships because the orientation of canonical variates is arbitrary in Canonical Correlation Analysis. Instead, the magnitude of the coefficients reflects the relative contribution of variables to the canonical function. The canonical loadings and cross-loadings (Table 3) provide the appropriate basis for interpreting the direction and strength of the relationships. Among the dependent variables, perception showed a relatively stronger contribution than utilisation in the second canonical function.

Table 2. Standardised and unstandardized canonical coefficients of independent and dependent variables

Independent variable	Standardised Canonical Coefficient		Unstandardized Canonical Coefficient	
	U1	U2	V1	V2
Age	0.020	0.201	0.035	0.353
Education	-0.621	-0.126	-0.477	-0.097
Landholding	0.081	-0.030	0.134	-0.049
Annual Income	-0.038	-0.363	-0.058	-0.560
Farming experience	-0.111	-0.491	-0.206	-0.908
Frequency visit of RSK	-0.064	-0.329	-0.087	-0.448
Mass Media	-0.087	0.141	-0.063	0.102
Social Participation	-0.037	-0.480	-0.035	-0.454
Achievement Motivation	0.051	0.630	0.035	0.430
Innovative proneness	-0.277	0.289	-0.292	0.306
Scientific Orientation	-0.042	0.041	-0.039	0.038
Risk Orientation	-0.139	-0.255	-0.090	-0.165
Extension contacts	-0.131	-0.192	-0.074	-0.108
Dependent variable	U1	U2	V1	V2
Perception	-0.217	-0.469	-0.541	-1.167
Utilization	-0.117	0.238	-0.567	1.154

Table 3. Correlation between original variables and canonical variables

Independent variable	Set 1 canonical Loading		Set 2 Canonical cross Loadings	
	U1	U2	V1	V2
Age	0.294	-0.179	0.261	-0.083
Education	-0.948	0.106	-0.844	0.049
Landholding	-0.027	-0.058	-0.024	-0.027
Annual Income	-0.076	-0.288	-0.067	-0.134
Farming experience	-0.325	-0.425	-0.290	-0.198
Frequency visit of RSK	-0.105	-0.382	-0.093	-0.178
Mass Media	-0.098	0.100	-0.087	0.047
Social Participation	-0.127	-0.507	-0.113	-0.236
Achievement Motivation	-0.523	0.440	-0.465	0.205
Innovative proneness	-0.896	0.169	-0.797	0.079
Scientific Orientation	-0.445	0.093	-0.396	0.043
Risk	0.009	-0.143	0.008	-0.067
Extension contact	-0.838	0.078	-0.746	0.036
Dependent variable	U1	U2	V1	V2
Perception	-0.897	-0.441	-0.798	-0.206
Utilization	-0.907	0.420	-0.807	0.196

Table 1. Canonical correlation analysis of the profile characteristics and perception- utilisation behaviour towards RSK services.

Pair of canonical variates	Canonical correlation (ρ_i)	Square of correlation	Eigenvalue	Wilks statistics	Significance
U_1, V_1	0.890	0.792	3.791	0.163	0.000**
U_2, V_2	0.466	0.217	0.277	0.783	< 0.001**

The unstandardized coefficients also indicated perception, along with utilisation, to be the primary dependent variables for both canonical functions. Education and innovative proneness were the strongest contributors to the first canonical relationship, whereas achievement motivation, farming experience, social participation and annual income were the most important contributors to the second canonical relationship.

The correlation Table 3 expressed the variables with the highest correlation with the independent CV (U_1) were education (–0.948), innovative proneness (–0.896) and extension contact (–0.838) and were the three most important factors for the first CV function. The two variables with the largest canonical loading were the dependent variables, –0.907 for utilisation and –0.897 for perception, where these two variables defined the dependent canonical variate the most. The canonical cross-loadings also indicated that the education (–0.844), innovative proneness (–0.797), and extension contact (–0.746) had significant relationships with the dependent variate (V_1), thus supporting its significant contribution to perception and utilization.

Social participation (–0.507), farming experience (–0.425), times of visit to RSK (–0.382), and achievement motivation (0.440) were relatively more associated with the independent canonical variate (U_2) in the second canonical function. The items for perception exhibited moderate loading on the dependent side (–0.441), whereas the items for utilization had moderate loading (0.420) on the dependent side. In general, the first canonical function had the strongest and most meaningful association, mainly in relation to perception and utilisation, and was influenced by education, innovative proneness, and extension contact. The second canonical function had weak associations.

Table 4. Redundancy analysis showing the proportion of variance explained between independent and dependent variable sets

Canonical Variable	Set 1 by self	Set 1 by set 2	Set 2 by self	Set by set 1
1	0.239	0.189	0.814	0.644
2	0.075	0.016	0.186	0.040

The first canonical function was a redundancy analysis (Table 4) and accounted for the largest proportion of common variance among the two sets of variables. For the first function, Set 1 accounted for 23.9% of the variance within itself and 18.9% of the variance in set 2, while set 2 accounted for 81.4% of the variance within itself and 64.4% of the variance in Set 1. The values indicate that the relationship between the two sets of variables is strong and meaningful, in the sense of a multivariate relationship. The second canonical function, on the other hand, explained little variance. Only 7.5% and 1.6% of the variance of Set 1 was explained by Set 2, and only 18.6% and 4.0% of the variance of Set 2 was explained by Set 1. This implies that the second canonical function was of little practical use. The first canonical function accounted for the major and most significant relationship between the two sets of variables, whereas the second function had a relatively small effect in explaining the common variance.

DISCUSSION

The first canonical function demonstrated a strong multivariate association, the redundancy analysis showed that the independent variable set explained only 18.9% of the variance in the dependent variable set. This indicates that additional factors not included in the present study, such as institutional quality, accessibility of RSK services, farmers' trust, infrastructure availability and policy implementation, may also contribute to perception and utilisation behaviour. Therefore, the findings should be interpreted as representing important, but not exhaustive, determinants of RSK service utilisation. The second function, which played a part in the multivariate relationship, was comparatively small and consequently of little practical value. The findings are consistent with previous studies, with the observations made in the aforementioned RBK studies conducted in Srikakulam district, which showed that farmers with higher levels of extension contact, communication exposure and awareness had higher perception and utilisation of RBK services like e-crop booking, crop insurance, agro-advisory and others. Similarly, the study conducted by (Rao et al., 2024) revealed that education, innovative proneness and extension contact were the key factors determining the perception and utilisation of RSK services among tribal farmers. The results of this study emphasise the need to improve extension communication, digital awareness and capacity development programs to ensure farmers' effective involvement in institutional agricultural services. The present results also showed that perception and utilisation were significantly correlated with extension contact and information services, respectively. The utilisation of RSK services was higher in the tribal farmers with greater communication, exposure and interaction with extension personnel. Similar findings were reported by Chowdary et al. (2022) as farmers were very positive about and used e-crop booking, crop insurance, quality inputs and capacity-building programme services offered by the RBKs. The findings highlight the importance of extension interaction and awareness in improving the utilisation behaviour among tribal farmers.

Connectivity limitations, literacy constraints and digital exclusion influenced effective utilisation of RSK services among tribal farmers. While a few ICT -enabled services were available from the RSKs, many tribal farmers were not effectively able to access to advanced ICT services. Similar findings were reported in earlier RBK perception studies where there was a lack of awareness and availability of services like soil testing facility, smart TV interaction system, digital advisory services, etc., by the farmers. The present study also corroborates the observations of Saifuddin et al. (2023) who noted that the farmer–scientist interaction channels, as well as several ICT-enabled and information-related services including smart TV interaction systems, loan guidance services and advisory services combined with call centres were perceived as less effective by many farmers because of limited accessibility and awareness.

The findings also showed that educational attainment and innovativeness of tribal farmers, and their frequent contact with extension agencies were found to be associated with the effective perception and use of RSK services. However, increased access to information sources and institutional support led to more awareness

and uptake of agricultural services. The close linkage between extension contact and service uptake highlights the importance of extension workers and other actors at the frontline to facilitate technology transfer and empower farmers. Hence, expanding extension networks, upgrading the infrastructure for ICTs and expanding farmer-centric extension capacity building programs can significantly increase the access and effectiveness of RSK services, improving inclusive agriculture development in tribal areas. Thus, the findings reinforce the relevance of Diffusion of Innovations Theory in explaining variations in tribal farmers' perception and utilisation of RSK services.

CONCLUSION

The education, innovative proneness and extension contact were significantly associated with tribal farmers' perception and utilisation behaviour towards *Rythu Seva Kendra* services. The relationship between profile characteristics of tribal farmers and their perception-utilisation behaviour towards RSK services was found to be strong and significant by the use of Canonical Correlation Analysis. The farmers who were educated, innovative and more in contact with extension services had better awareness and utilization of services. Despite the availability of RSK services, limited digital literacy, poor internet connectivity and geographical isolation continue to constrain access to ICT-enabled advisory services. Therefore, improving digital infrastructure alone may not be sufficient unless accompanied by targeted digital literacy programmes and stronger village-level extension support. The results indicate that strengthening extension communication and building farmers' capacity to use digital agricultural services are particularly important for improving the effectiveness of RSK services in tribal communities.

DECLARATIONS

Ethics approval and informed consent: Throughout the study, the respondents were asked for their informed consent. The study was conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethical approval was waived by the Divisional Ethics Committee, Extension Division of Centurion University of Technology and Management, Paralakhemundi, Odisha, India.

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Research Article

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Women as a Decision Maker for Farm and Family: A Case of Lalitpur District of Nepal

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HIGHLIGHTS

- Women significantly influence household budgeting, child care, and educational decisions
- 57% women jointly participate with men in major farm decision

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ABSTRACT

Women play a vital role in agricultural production and household management in Nepal, yet their participation in decision-making often remains limited. Objective of this study was to examine the extent and nature of women's involvement in farm and family decisions in Godawari Municipality, Lalitpur District. A cross-sectional mixed-methods design was applied using survey data from 115 households and semi-structured interviews were one during June-July of 2025. Quantitative data were analysed using descriptive and inferential statistics, while qualitative data supported interpretation. Majority of women participate jointly i.e., 38% in crop selection, 47% for fertilizer use and >50% for irrigation use. Women also influence household decisions concerning budgeting, child care, and education. Training (r=0.67), family member support (r=0.72) and women involvement in community organization (r=0.32) were found to be positively and significantly associated with women participation in farm decisions. Despite increased awareness and access to training, women continue to face barriers such as unequal land ownership, cultural norms, and limited access to credit. Their participation nonetheless contributes positively to household economic conditions and empowerment. The findings highlight the importance of promoting gender-responsive agricultural policies and community-based initiatives that enhance women's leadership and equitable decision-making.

INTRODUCTION

Around the world, women make up almost half of the agricultural labour force, but they rarely share equal control over the land and resources they depend on (FAO, 2010). In recent years, migration of men to cities and foreign jobs has left more women managing farms on their own. This growing pattern, sometimes called the feminization of agriculture, has changed the daily rhythm of rural life (Momsen, 2011). Women handle sowing to marketing along with household chores and childcare. Despite these responsibilities, decision-making power often remains concentrated in men's hands. Deep-rooted traditions, illiteracy, and limited ownership of land make it difficult for women to influence how money is spent, what crops are planted, or how the harvest is used (Agarwal et al., 2003). As a result, even though women's work sustains rural families and contributes significantly to the national economy, their role is still viewed as "supportive" rather than central.

In Nepal, where more than two-thirds of the population relies on agriculture, women's contributions are immense. They handle most fieldwork planting, weeding, harvesting, and storing crops

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while men typically plough fields or manage marketing According to FAO (2019), nearly 74% of economically active Nepali women are engaged in agriculture and their participation in agricultural workforce is almost twice the South Asian average, yet very few own the land they work on and only four % old formal position in planning. The problem is that their work does not translate into decision-making power. Whether it's deciding what crops to plant, when to sell, or how to use the income, these choices are often made by men. Even within families, men tend to control major financial decisions while women focus on daily expenses and caregiving. The extent of women involvement was maximum in operations like transplanting, weeding, harvesting and storing (Nain & Kumar, 2010). This imbalance not only limit s women's empowerment but can also reduce productivity and innovation in farming. Women are involved in making agricultural decisions, farms are often more efficient, families are healthier, and children's education improves (Thapa, 2013). Singh et al. (2014) discussed women collectives roles in moving away from viewing farming strictly as a traditional way of life and transitioning it into a commercialized, profitable agribusiness. Further, building entrepreneurial capabilities among rural women may facilitate direct forward-marketing linkages (Singh et al., 2016). However, in many rural communities, women still struggle against social norms that treat them as secondary decision-makers. Illiteracy, cultural restrictions, and limited access to credit or training programs make it harder for them to take leadership roles. This shows a clear gap between participation and power; women contribute the most but decide the least. Bridging this gap is essential for genuine gender equality and sustainable development. Although existing literature highlights low decision-making power among rural women due to socio-cultural constraints and lower educational level, minimal research addresses urban and valley contexts in Nepal. Thus, this study addresses two main questions; Do gender roles in decision-making vary significantly by geographical region (rural vs. urban), what other key factors influence these gender dynamics?

METHODOLOGY

This study used a cross-sectional mixed-methods design that combined both quantitative and qualitative approaches (Timalsina et al., 2026). The numerical data was collected through surveys and also explored people's thoughts and experiences through open-ended questions. Using both methods provided a fuller picture of women's roles in decision-making rather than relying on numbers alone. The study was carried out between June and July 2025 when most households were busy with seasonal agricultural work. This timing helped the researcher observe decision-making during an active farming period, when choices about crops, labour, and spending was most visible.

The research took place in Godawari Municipality of Lalitpur District, located in Bagmati Province, Nepal. The municipality was chosen because it represents a mix of traditional farming communities and rapidly modernizing areas close to Kathmandu Valley. It is made up of several former village development committees such as Badikhel, Godamchaur, and Chapagaun. According to the 2021 national census, Godawari has a population of around 78,000 people, covering an area of about 96 square kilometres. Most residents rely on small-scale farming for income, cultivating vegetables, cereals, and fruits. Brahmin/Chhetri and Newar are the dominant ethnic groups, though Janajati and Magar communities also live in the area. The literacy rate (about 86%) is higher than the national average, which made communication and data collection easier.

The study focused on women engaged in both household and farming activities. Households cultivating more than ten kathas (H" 0.33 hectares) of land were chosen purposively to obtain sampling frame. A total of 115 women were selected using a random sampling approach by using Slovin's Formula ($n=N/1+Ne^2$, where N is population size), This method was chosen because it allowed the researcher to reach participants who were actively involved in farming while still maintaining randomness within that group. Respondents came from all 14 wards of the municipality, ensuring diversity in ethnicity, age, and economic status.

Primary data were collected directly from respondents through face-to-face interviews using a semi-structured questionnaire. Each interview lasted about 30 to 45 minutes, depending on how much the participant wished to share. Conducting personal interviews helped build trust and allowed participants to express their experiences in their own words. To ensure data reliability, the questionnaire was pre-tested with ten women from a nearby ward who were not included in the final sample. Their feedback helped refine unclear questions and adjust wording to match local understanding. The consistency of responses across similar questions was later checked during data entry. Triangulation between quantitative results and qualitative insights helped strengthen validity. For example, numerical data showing high female participation in crop decisions were cross-checked with women's own explanations of how those decisions were actually made at home.

The digital application 'mWater' Surveyor was used to record responses. This tool automatically stored data on a secure online server, minimizing human error in data entry. Secondary data such as population statistics, local development plans, and previous studies on gender and agriculture were obtained from the Central Bureau of Statistics (CBS), municipality offices, and academic journals.

After data collection, responses were exported from mWater into Microsoft Excel 2016 for cleaning and tabulation. Quantitative data were analyzed using SPSS version 26 to calculate frequencies, percentages, and averages. These descriptive statistics helped show how decision-making patterns differed across variables such as age, education, and income. Graphs and tables were created to present results clearly, while quotes and summaries from open-ended responses were used to give deeper insight into women's personal experiences. Inferential statistics such as chi-square test, and correlation analysis were performed to shows relationship among variables and their significance testing.

RESULTS

Women's participation in farm decision-making

One of the central findings is that decision-making in farms is gradually becoming more balanced. About 47% of all key

agricultural decisions were made jointly by men and women, while 39% were made solely by women and 14% by men. This is a major shift compared to earlier decades when men almost exclusively decided what to plant, when to sell, or how to use income. The trend toward shared decision-making reflects changes in education, migration, and women's participation in community organizations. Women now make significant decisions about crop selection, fertilizer use, pest management, irrigation, harvesting, and marketing. For instance, more than half of the respondents (52%) said they independently decided what crops to grow each season (Table 1). This independence is linked to practical experience women often spend more time in the fields and know what grows best in local conditions. Chi-square test for independence was conducted to examine whether women's participation in agricultural decision-making varied significantly across different types of household and farm decisions. This indicates that the distribution of power (whether decisions are made by women alone, jointly, or by men alone) depends significantly on the specific agricultural task at hand.

Budgeting and financial involvement

A large majority of women (nearly 80%) said they were actively involved in discussing the agricultural budget with their partners as shown in Figure 1. Only a small share (less than 10%) reported rarely or never being part of such discussions. This shows that women are not only labourers but also contributors to financial and planning decisions. However, full control over agricultural income remains limited. While women participate in discussions, major financial transactions such as purchasing land or large farm equipment are often finalized by men. Majority of respondent from Chapagaun explained: "We know how much we earn from vegetables and milk, but when it comes to buying fertilizer or selling land, our husband makes the final decision." Such experiences highlight the need to go beyond participation and focus on genuine decision power, where women's opinions translate into outcomes.

Table 1. Women's participation in agricultural decision-making

Type of Decision	Women Alone (%)	Jointly with Men (%)	Men Alone (%)	Chi-square test DF=10
Crop selection	52.2	38.3	9.5	P=0.042*
Fertilizer use	41.7	47.0	11.3	
Irrigation management	33.0	55.7	11.3	
Pest control	45.2	43.5	11.3	
Marketing and sales	37.4	46.1	16.5	
Use of agricultural income	29.6	54.8	15.6	

Note. "Jointly" indicates shared discussion and agreement between spouses or family members.

Access to training and extension services

About 68% of respondents had attended at least one agricultural training or extension program, mostly organized by local cooperatives or NGOs Figure 2. Training participation helped women gain technical skills in composting, vegetable farming, and livestock care. Those who attended training reported higher confidence and were more likely to make independent decisions. Yet, access was not equal for everyone. Women with young children or those from marginalized ethnic groups were less likely to participate, mainly because of time constraints and household responsibilities.

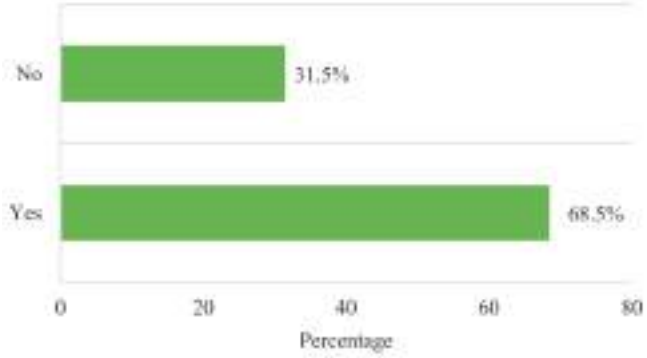
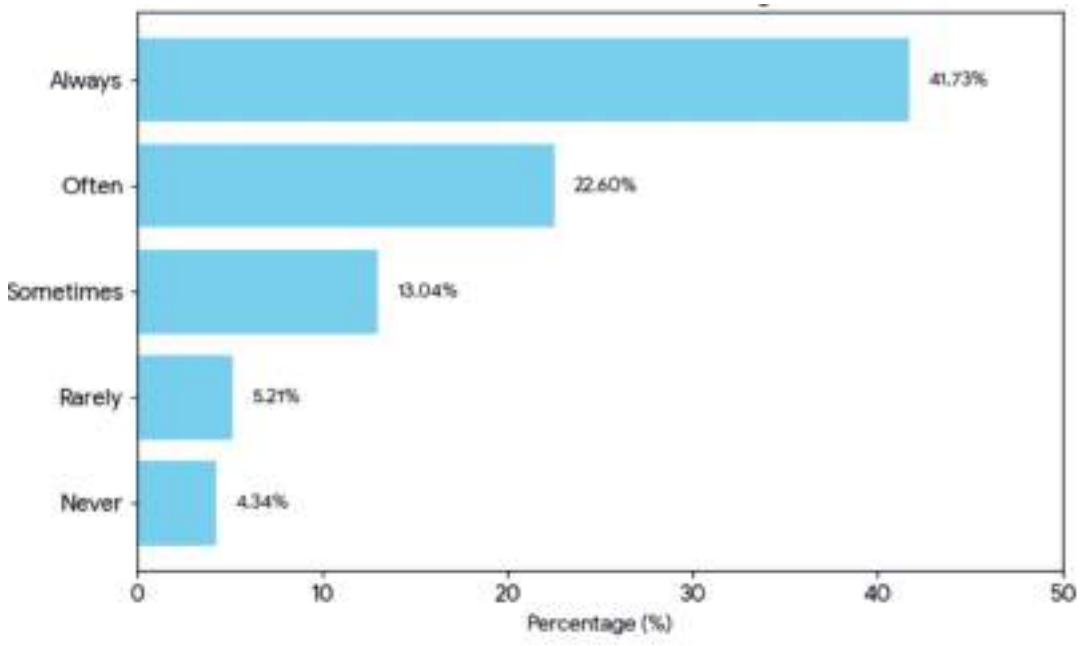


Figure 2. Respondent involved in training

Figure 1. Women involvement in financial decision

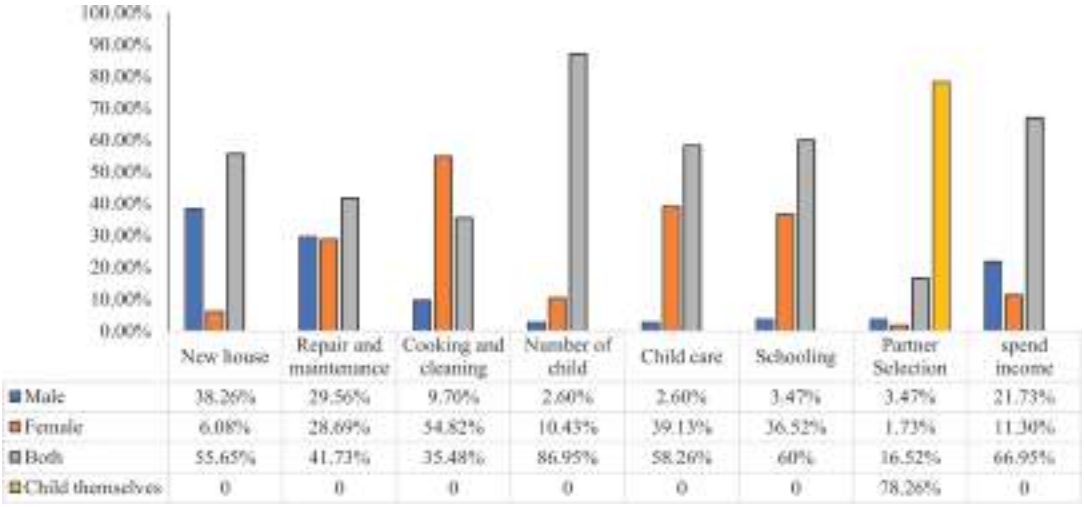


Women's role in family and household decision-making

In addition to farm work, women carry most of the responsibility at home cooking, cleaning, child care, and managing daily needs. The study found that women played an active role in nearly all household decisions, though the level of independence varied by type of decision. For everyday matters such as meal planning, schooling, and children's health care, women had strong decision-making power. Around 58% said they were the main decision-makers for child care, and 42% said they jointly made financial decisions about education with their partners. When it came to larger issues, like constructing or repairing a house or making long-term investments, decisions were usually made jointly. This trend toward shared decision-making indicates that mutual respect and cooperation are increasing within families. About 64% of respondents regularly discussed the household budget with their partners, showing that financial transparency is becoming more common as shown in Figure 3. This is a positive sign of evolving gender dynamics in rural families. However, not all decisions are equal. Many women admitted that when it comes to land registration or inheritance, men still hold authority. This reflects the slow pace of change in property rights and the need for legal reforms to ensure equal ownership opportunities for women.

Women's daily workload

The study revealed that women work long hours across multiple roles. On average, they spend about 4 hours a day on household chores, 3 hours on farming, 2 hours caring for livestock, and 2 hours on off-farm or income-generating activities Figure 4. This adds up to 11 hours of work per day, often without any formal recognition or pay. Men, on the other hand, spend more time on income-generating work but less on domestic tasks. The double burden balancing productive and reproductive roles remains a key barrier to empowerment. Despite this heavy workload, many women expressed pride in their ability to manage everything. Majority of participant shared: "Sometimes we feel tired, but when we see our children studying and the farm doing well, we feel strong." This sense of pride and resilience shows that empowerment is not only about formal power but also about self-worth and confidence.



	New house	Repair and maintenance	Cooking and cleaning	Number of child	Child care	Schooling	Partner Selection	spend income
Male	38.26%	29.56%	9.70%	2.60%	2.60%	3.47%	3.47%	21.73%
Female	6.08%	28.69%	54.82%	10.43%	39.13%	36.52%	1.73%	11.30%
Both	55.65%	41.73%	35.48%	86.95%	58.26%	60%	16.52%	66.95%
Child themselves	0	0	0	0	0	0	78.26%	0

Figure 3. Role of women in household decision making

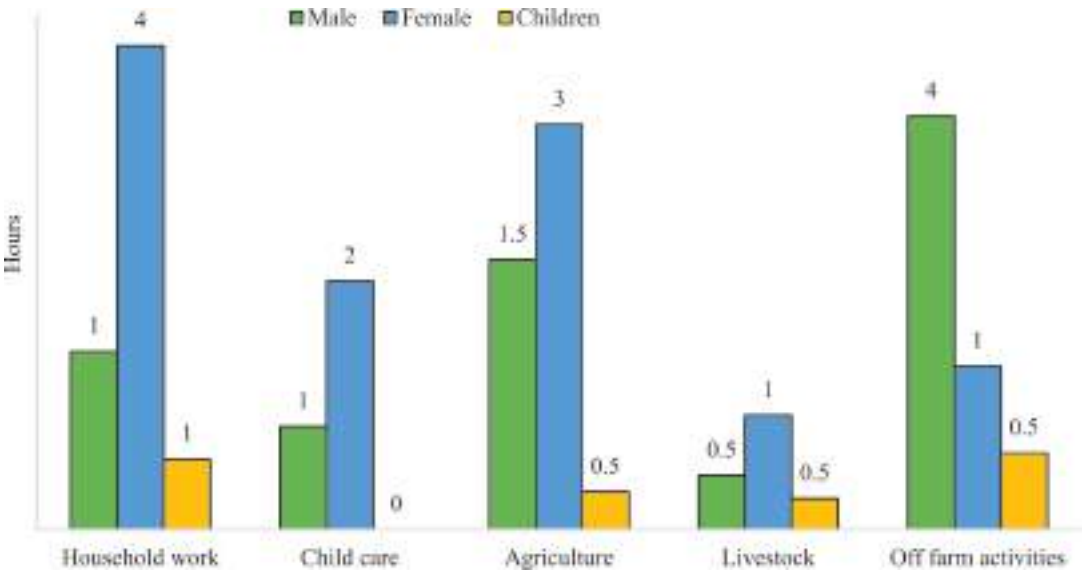


Figure 4. Women's daily average workload in hour (*Source:* Household Survey, 2024)

Perceived impacts of women's involvement

A significant 58% of respondents reported that their household's economic situation improved after they began participating more actively in decisions. Another 26% said they saw moderate improvement, while only 15% reported no change (Table 2). Most women attributed these positive outcomes to better planning and budgeting. When women were involved, families tended to save more and diversify income sources. For example, some women started side businesses such as poultry, vegetable nurseries, or handicrafts with small profits reinvested into farming. A Chi-square goodness-of-fit test revealed that this distribution was statistically significantly different from equal proportions χ^2 = 33.67**, $p < 0.001$, indicating a strong, positive perceived economic trend.

Table 2. Impact on household's economic situation due to involvement of women in decision-making

Impact on household's economic situation	Percentage	Score	Test statistics
Significantly improved	58.26	3	χ^2=33.67**
Improved	26.08	2	p<.001
No change	15.67	1	
Total	100		

Chi-square goodness-of-fit test evaluated against an equal proportion model across all response categories (df = 2 Median = 3, Interquartile Range (IQR) = 1.00 (Score range

Correlation between major factors with decision maker

Women's role in household decision-making was associated with access to training and extension services ($r = 0.67$, $p < 0.01$), family support ($r = 0.72$, $p < 0.01$), and membership in community organizations ($r = 0.32$, $p < 0.05$). Conversely, women's daily workload showed a significant negative correlation with decision-making role ($r = -0.42$, $p < 0.05$), indicating that heavier workloads may limit women's participation in household decisions as shown in Table 3.

Table 3. Pearson correlation between major factors that determine women decision maker

Variables	Pearson correlation (r) women as decision maker
Women daily work load	-0.42*
Training and Extension Service	0.67**
Support from family members	0.72**
Women membership to community organization	0.32*

Perceptions, opportunities, and challenges perception of importance

Almost two-thirds (65%) of respondents said that women's involvement in decision-making is "very important," while another 23% said it is "important." Only a small fraction (11%) remained neutral (Table 4). This strong consensus reflects growing awareness among women about their rights and the value of shared participation. Education and access to information have played key roles in shaping these attitudes.

Table 4. Perception regarding importance of women involvement in decision making

Perception	Frequency	Percentage
Very important	75	65.21
Important	27	23.47
Neutral	13	11.30
Total	115	100

Opportunities for women

The study identified several opportunities that help women strengthen their roles and were associated with women involvement in decision power. Support from family and community (43%), Membership in cooperatives or women's groups (39%), and Access to training and financial loans (around 30%) were major opportunities. Participation in cooperatives, in particular, gave women both a social network and an economic platform to share ideas and access credit. These local organizations serve as safe spaces where women learn leadership and negotiation skills.

Challenges

Even with progress, challenges persist. The most common issue mentioned was lack of access to land ownership (49%). Without land titles, women cannot use property as collateral for loans or gain official recognition as farmers. Other major barriers included cultural norms (20%), limited education or training (11%), and lack of resources (10%). Some also faced resistance from male partners (9%), especially in families where men viewed decision-making as a sign of authority (Table 5).

Table 5. Major challenges faced by women in decision-making (multiple responses)

Challenge	Percentage
Lack of land ownership	49.0
Cultural and social norms	20.0
Limited education/training	11.0
Lack of resources (credit, inputs)	10.4
Resistance from male family members	9.6

DISCUSSION

In Nepal majority of farm household and farm decision was governance by male. At present time this paradigm shifted towards female or jointly decision pattern. The shift is part of a broader "quiet transformation" where women's knowledge is increasingly valued in agricultural households. These findings are consistent with Chayal and Dhaka (2010) and Ghosh et al. (2021), who reported similar trends in India and other parts of South Asia. Education status, family type, age groups, training facility, women involvement in social organization are the factors associated with decision making. In context of Nepal social norms and gender roles strongly shape these dynamics, with women's participation in decision-making process. For example, married daughters not being

considered coparceners for parental property and women having limited influence in household decision-making (Ghimire et al., 2024). Alvi et al. (2021) suggested that creating flexible training schedules and childcare support can make programs more inclusive. These findings echo global evidence that women's empowerment enhances household well-being and community resilience (Annan et al., 2020). Empowered women tend to prioritize children's education and nutrition, creating a ripple effect of long-term development benefits. Maurya et al. (2026) reported that social networks and group involvement are important factors increasing women participation as well as decision making process. Despite of progressive improvement on women involvement on farm decision making there are lots of factors that hinder such improvements. Dhakal and Mishra (2022) reported that gender inequality in access to assets remains one of the main obstacles to women's empowerment in Nepal. Suradkar et al. (2013) also reported multiple repones for challenges such as poor economic status of family, no knowledge about improved facility, perplexity of time for farm and home activities, higher time consumption for household work, lack of confidence required to take decision, dominance of male member in family etc.

In Nepal, land is a valuable asset that represents not only economic security but also social status and political power (Rai et al., 2020). Although women have traditionally had limited access to land ownership, the introduction of the Joint Land Ownership (JLO) policy in 2011 has significantly improved women's access to land, leading to notable social and economic benefits, especially for those living in rural communities. Government and local authorities should encourage land registration in both spouses' names. This would give women legal recognition as farmers, allow them to access credit, and increase their decision-making power within households. Financial literacy programs can help women manage savings and investment more effectively. 100% respondent of Vegetable farmers of Chitwan Nepal agreed that financial support, credit, inputs subsidies significantly increased women participation in farm decision making (Shrestha et al., 2025).

Training programs should be scheduled at convenient times and locations for women, with childcare facilities where possible. Local extension workers need to adopt participatory methods that value women's existing knowledge and build technical skills in areas like soil management, irrigation, and entrepreneurship. Shrestha et al. (2015) also reported that training significantly boost the women participation in vegetable farming in Chitwan Nepal. Kumar and Nain (2013) and Pateriya et al. (2026) also reported that training only increased women involvement in farm decision making it's also minimize crop loss or maximize the profit.

Cooperatives provide a vital platform for collective learning, savings, and microcredit. Support for these groups through seed funding, capacity-building, and networking can amplify women's voices in community development. Maurya et al. (2026) reported that social networks and group involvement are important factors increasing women participation as well as decision making process. The social capital formation is enhanced in the society with participation in SHGs, which consequently reduces the vulnerability of women folk and develop wellbeing in the society (Das et al., 2018). Shrestha et al. (2025) also reported that support from family, relatives and spouse promote the women involvement in decision making. Lasting change depends not only on empowering women but also on reshaping men's attitudes. Community awareness campaigns should highlight the shared benefits of joint decision-making and shared domestic responsibilities.

CONCLUSION

Women are no longer seen only as "helpers" in agriculture; they are cultivators, planners, and decision-makers whose choices directly influence household well-being. Most respondents reported taking part in decisions about crop selection, fertilizer use, livestock care, and household budgeting. Many of these decisions are now made jointly between men and women, showing that family dynamics are slowly becoming more cooperative. Education, training, and the formation of women's groups have all played key roles in building this confidence. In conclusion women's empowerment in rural Nepal is a process, not an event. It grows through education, awareness, and daily negotiation within families. Each small decision a woman makes whether choosing a crop, joining a cooperative, or budgeting for her children's education adds to her sense of agency. Over time, these micro-level changes can lead to large-scale social transformation.

DECLARATIONS

Ethics approval and informed consent: Before starting each interview, the researcher clearly explained the purpose of the study and asked for verbal consent. Participants were informed that their answers would remain confidential and would be used only for academic purposes. They were free to skip any question or stop the interview at any time. No personal identifiers were included in the final dataset. The study adhered to the ethical guidelines set by the Institute of Agriculture and Animal Science (IAAS), Tribhuvan University.

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Extension Support and Peer Influence on Climate-Smart Agriculture Adoption among Indonesian Rice Farmers

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HIGHLIGHTS

- Extension support strengthens farmers' behavioral intention and perceived ease of using climate-smart agriculture.
- Behavioral intention is the strongest direct predictor of realized CSA adoption among Indonesian smallholder rice farmers.
- Peer influence primarily improves perceived ease of use, highlighting the importance of farmer-to-farmer learning in CSA diffusion.

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Keywords: Agricultural extension, Behavioural intention, Climate-smart agriculture, Peer influence, Technology acceptance model.

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ABSTRACT

Extension support and peer learning are widely promoted to accelerate climate-smart agriculture (CSA), but their relationships with farmers' cognitive evaluations and realized adoption remain insufficiently understood. This study examined CSA adoption among Indonesian smallholder rice farmers using a TAM-informed exploratory framework. A cross-sectional survey during 2025 involved 342 farmers in Sukra District, Indramayu Regency, West Java and Praya District, Central Lombok Regency, West Nusa Tenggara. Data were analyzed using partial least squares structural equation modelling. Extension support was positively associated with behavioural intention and perceived ease of use, while peer influence strongly predicted perceived ease of use but not behavioural intention. Farmer characteristics were associated with perceived ease of use but not behavioural intention. Behavioural intention was the strongest direct predictor of CSA adoption, followed by attitude toward CSA, whereas perceived ease of use had no significant direct relationship with adoption. The model explained 31.5% of the variance in adoption and demonstrated positive predictive relevance, although its out-of-sample predictive accuracy was limited. These findings indicate that extension should combine participatory demonstrations with farmer-to-farmer learning to strengthen operational confidence and intention to adopt CSA.

INTRODUCTION

Climate variability increasingly threatens rice-based farming, especially smallholders dependent on seasonal stability and limited production assets. Droughts, floods, and irregular rainfall disrupt planting, reduce yields, and threaten household income, compelling farmers in developing countries to adopt resilient yet productive practices (Acevedo et al., 2020; Hansen et al., 2018; Shilomboleni et al., 2024). These combined pressures make adaptation a production, livelihood, and environmental imperative for rice systems increasingly exposed to climatic shocks. Climate-Smart Agriculture (CSA) responds by integrating productivity, adaptation, and sustainable resource management (Islam et al., 2022; Mpala & Simatele, 2024; Vatsa et al., 2023; Zheng et al., 2024), while seeking

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to increase farm income, strengthen livelihood and ecosystem resilience, and reduce agricultural greenhouse gas emissions (Ma & Rahut, 2024).

Agricultural extension facilitates CSA diffusion by transferring knowledge, demonstrating applications, and reducing uncertainty, although its effects on adoption remain mixed (Rezaei-Moghaddam & Salehi, 2010; Lipper et al., 2017; Aggarwal et al., 2018: Shitu et al., 2018). In Karawang and Subang, government extension did not affect farmers' resilience capacity in one survey (Azhari et al., 2025a), whereas a larger survey identified extension implementation as a strong predictor of resilience and farm sustainability (Azhari et al., 2025b). This divergence may reflect extension capacity: Indonesian services remain production-oriented, while needs assessment, participatory facilitation, and business planning receive limited attention (Amanah et al., 2026). Peer learning also informs adoption through observation and farmer-group discussion, consistent with Social Learning Theory (Bandura, 1977). Explaining their joint influence therefore requires examining how farmers interpret information and evaluate technologies.

The Technology Acceptance Model (TAM), grounded in the Theory of Reasoned Action, explains adoption through cognitive evaluation and behavioral intention (Ajzen & Fishbein, 1980; Davis, 1989). Perceived usefulness and perceived ease of use are central determinants of attitude, intention, and technology use (Davis, 1989; Venkatesh et al., 2003; Venkatesh & Davis, 2000). In agriculture, experience, training, and social interaction shape these evaluations; extension and peer learning may therefore strengthen operational confidence and intention rather than constitute adoption itself (Ejigu & Yeshitela, 2024; Genius et al., 2014; Gemtou et al., 2024).

This study uses a TAM-informed exploratory framework for realized CSA adoption, positioning extension support, peer influence, and selected farmer characteristics as antecedents of perceived ease of use and behavioral intention. Perceived usefulness was excluded because no independent item validly measured it. The noncanonical Behavioral Intention → Attitude path is interpreted only as an exploratory cross-sectional association, not a causal sequence (Davis et al., 1989; Venkatesh & Bala, 2008; Ajzen & Schmidt, 2020).

Empirical models integrating extension, peer influence, cognitive evaluation, intention, and realized CSA adoption remain limited, particularly in rice-based systems (Mohr & Kühl, 2021; Rezaei-Moghaddam & Salehi, 2010). Smallholder studies more often apply the theory of planned behavior (Atta-Aidoo et al., 2022), while food-security technology reviews examine barriers without a cognitive model (Weisenfeld & Wetterberg, 2015). Using two Indonesian rice regions, this study tests relationships between behavioral intention, ease of use, attitude, and CSA adoption; examines extension, peer, and farmer-characteristic relationships with cognition; and evaluates out-of-sample predictive performance.

METHODOLOGY

Fieldwork was conducted during August–September 2025 in Sukra District, Indramayu Regency, West Java, and Praya District, Central Lombok Regency, West Nusa Tenggara. A cross-sectional survey applied a TAM-informed exploratory framework incorporating extension support, peer influence, and selected farmer characteristics as antecedents of farmers' cognitive evaluations and realized CSA adoption.

The population comprised 2,400 active rice farmers registered in formal farmer groups, which facilitate extension, information exchange, and learning. Because registration does not necessarily indicate active participation (Helmi et al., 2019), this sampling-frame limitation was considered when interpreting generalizability. Using Slovin's formula with a 5% margin of error (Slovin, 1960), 342 respondents were equally allocated between locations (171 each) and selected through proportional stratified random sampling at farmer-group level.

Trained enumerators conducted face-to-face interviews. The pilot-tested questionnaire adapted technology-acceptance and agricultural-adoption measures (Davis, 1989; Venkatesh & Bala, 2008; Zarei et al., 2022). Perceptual items used five-point Likert scales. Perceived ease of use and peer influence were reflective; extension support, selected farmer characteristics, and CSA adoption were formative. Behavioral intention and attitude were single-item constructs; the latter captured perceived benefits relative to previous practices. Their reliability and convergent validity could not be assessed (Diamantopoulos et al., 2012). Perceived usefulness was excluded because no item validly measured it. Adoption captured the number and duration of implemented CSA practices.

Data were processed using IBM SPSS Statistics 27.0 for descriptive analysis and SmartPLS 4.1.1.2 for model estimation and prediction. PLS-SEM was selected to estimate predictive models containing reflective and formative constructs (Hair et al., 2022; Sarstedt et al., 2022). Reflective measurement was evaluated using outer loadings, Cronbach's alpha, composite reliability, average variance extracted, and the heterotrait–monotrait ratio (Henseler et al., 2015). Formative measurement was assessed using outer weights, outer loadings, and variance inflation factors below 5. Structural assessment examined inner collinearity, path coefficients, R^2, and f^2 based on Cohen's (1988) benchmarks. Statistical significance was evaluated using 5,000 bootstrap subsamples and bias-corrected and accelerated confidence intervals. Predictive performance was assessed using blindfolding Q^2, ten-fold PLSpredict with ten repetitions, linear-model benchmarks (Shmueli et al., 2019), and SRMR, consistent with Indonesian rice research (Azhari et al., 2025b).

RESULTS

Assessment of the reflective measurement model

Perceived Ease of Use and Peer Farmer Influence were evaluated as reflective constructs. The three indicators of Perceived Ease of Use showed strong outer loadings, ranging from 0.933 to 0.953. The two indicators of Peer Farmer Influence had loadings of 0.660 and 0.954.

Composite reliability exceeded 0.70 for both reflective constructs, and their average variance extracted exceeded 0.50, supporting internal consistency and convergent validity. Cronbach's alpha for Peer Farmer Influence was 0.577; however, composite reliability reached 0.800. Given that the construct contained only two indicators, composite reliability was used as the primary internal-consistency criterion.

Table 1. Indicator loadings in the CSA adoption model

Variable	Indicator	Outer loading
Agricultural Extension Support	Extension Module	0.759
	Frequency of Extension Visits	0.579
	Extension Worker Influence	0.707
	Intensity of Adoption Encouragement	0.831
Attitude toward CSA	Relative Advantage	1.000
CSA Adoption Level	Number of CSA Types Implemented	0.880
	Duration of CSA Use	0.570
Selected Farmer Characteristics	Activeness in Farmer Groups	0.902
	Farmer Education	0.585
Behavioral Intention	Intention to Adopt CSA	1.000
Perceived Ease of Use	Ease of Implementation	0.939
	Ease of Observation	0.953
	Ease of Testing	0.933
Peer Farmer Influence	Farmer Colleagues	0.954
	Farmer Figure	0.660

Source: Processed field data, 2025

Note: Loadings for formative indicators are supplementary; formative assessment is based primarily on outer weights and indicator collinearity.

Behavioral Intention and Attitude toward CSA were each measured using a single indicator. The attitude item operationalized an overall evaluation of CSA benefits relative to previous practices. Internal consistency and convergent validity could therefore not be assessed for either construct. Agricultural Extension Support, Selected Farmer Characteristics, and CSA Adoption Level were evaluated separately as formative constructs and were excluded from reflective reliability and validity assessment.

Discriminant validity between Perceived Ease of Use and Peer Farmer Influence was supported by an HTMT ratio of 0.550, with a 97.5% bootstrap upper bound of 0.657, below the threshold of 0.85 recommended by Henseler et al. (2015). HTMT was not assessed for pairs involving single-item or formative constructs.

Assessment of the formative measurement model

Agricultural Extension Support, Selected Farmer Characteristics, and CSA Adoption Level were assessed as formative constructs. All indicator variance inflation factors ranged from 1.013 to 2.045, remaining below the threshold of 5 and indicating no critical collinearity. All outer weights were positive and statistically significant at $p < 0.001$. Within Agricultural Extension Support, Intensity of Adoption Encouragement had the largest weight ($w = 0.465$), followed by Frequency of Extension Visits ($w = 0.354$), Extension Module ($w = 0.319$), and Extension Worker Influence ($w = 0.235$). Farmer-group activeness contributed more strongly to Selected Farmer Characteristics than formal education ($w = 0.824$ and 0.439, respectively). For CSA Adoption Level, the number of implemented practices had a larger weight than duration of use ($w = 0.827$ and 0.477, respectively). These results support indicator relevance and the absence of critical collinearity (Hair et al., 2022). Convergent validity through redundancy analysis could not be assessed because the instrument did not include independent global criteria for the formative constructs.

Structural model results

All inner VIF values were below 3.0, indicating that lateral collinearity did not materially affect the structural estimates. The model explained 44.6% of the variance in Behavioral Intention, 28.6% in Perceived Ease of Use, 18.9% in Attitude toward CSA, and 31.5% in CSA Adoption Level.

Behavioral Intention was the strongest predictor of CSA adoption ($\beta = 0.524$, $p < 0.001$), followed by Attitude toward CSA ($\beta = 0.186$, $p = 0.001$). Perceived Ease of Use was not significantly related to adoption ($\beta = –0.057$, $p = 0.457$), but it was strongly

Table 2. Measurement model evaluation: Cronbach's alpha, composite reliability, and AVE

Construct	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Perceived Ease of Use	0.936	0.959	0.887
Peer Farmer Influence	0.577	0.800	0.673

Source: Processed field data, 2025

Table 3. Heterotrait–monotrait (HTMT) ratios for the reflective constructs

Construct pair	HTMT	97.5% bootstrap upper bound	Below 0.85 threshold
Perceived Ease of Use – Peer Farmer Influence	0.550	0.657	Yes

Source: Processed field data, 2025

Table 4. Formative measurement model: indicator collinearity, outer weights, and outer loadings

Construct	Indicator	VIF	Outer weight	t	p	Outer loading
Agricultural Extension Support	Extension Module	2.045	0.319	7.82	<0.001	0.759
	Frequency of Extension Visits	1.301	0.354	6.48	<0.001	0.579
	Extension Worker Influence	1.607	0.235	5.68	<0.001	0.707
	Intensity of Adoption Encouragement	1.788	0.465	11.61	<0.001	0.831
Selected Farmer Characteristics	Activeness in Farmer Groups	1.032	0.824	12.50	<0.001	0.902
	Farmer Education	1.032	0.439	4.58	<0.001	0.585
CSA Adoption Level	Number of CSA Types Implemented	1.013	0.827	17.31	<0.001	0.880
	Duration of CSA Use	1.013	0.477	7.68	<0.001	0.570

Source: Processed field data, 2025

associated with Behavioral Intention ($\beta = 0.581$, $p < 0.001$) and Attitude ($\beta = 0.458$, $p < 0.001$).

Extension support was positively related to Behavioral Intention ($\beta = 0.145$, $p = 0.006$) and Perceived Ease of Use ($\beta = 0.146$, $p = 0.004$). Peer influence was positively associated with Perceived Ease of Use ($\beta = 0.348$, $p < 0.001$) but not Behavioral Intention ($\beta = –0.023$, $p = 0.716$). Selected Farmer Characteristics were related to Perceived Ease of Use ($\beta = 0.172$, $p = 0.001$) but not Behavioral Intention ($\beta = 0.059$, $p = 0.157$). Behavioral Intention was not significantly associated with Attitude toward CSA ($\beta = –0.037$, $p = 0.638$).

An R^2 of 0.315 indicates that the model leaves approximately two-thirds of the variation in CSA adoption unexplained. Factors not included in the model—such as land tenure, credit access, irrigation reliability, input and output prices, and local group norms—may account for additional variation. The results therefore demonstrate meaningful cognitive and institutional associations but do not provide a complete explanation of CSA adoption.

Effect sizes and explanatory power

The largest structural effect was observed for Perceived Ease of Use on Behavioral Intention ($f^2 = 0.434$), followed by Behavioral Intention on CSA Adoption Level ($f^2 = 0.232$) and Perceived Ease of Use on Attitude toward CSA ($f^2 = 0.150$). Peer Farmer Influence had a small-to-medium effect on Perceived Ease of Use ($f^2 = 0.127$). Extension support had small effects on Behavioral Intention ($f^2 = 0.024$) and Perceived Ease of Use ($f^2 = 0.019$). The remaining effects were small or negligible. These results indicate that operational simplicity is most strongly associated with intention, while intention contributes most strongly to realized adoption.

Model fit and predictive assessment

Blindfolding produced positive Q^2 values for Behavioral Intention (0.424), CSA Adoption Level (0.241), Attitude toward CSA (0.179), and Perceived Ease of Use (0.152), indicating predictive relevance (Hair et al., 2022). PLSpredict also produced positive Q^2predict values ranging from 0.085 to 0.186. However, the PLS-SEM model generated slightly higher RMSE values than the linear-model benchmark for all available indicators, indicating low out-of-sample predictive power according to Shmueli et al. (2019). The SRMR values for the saturated and estimated models were 0.108 and 0.127, respectively, exceeding the conventional threshold of 0.08. Thus, the model demonstrates in-sample explanatory relevance but limited approximate fit and out-of-sample predictive accuracy.

DISCUSSION

Extension support was positively associated with both behavioral intention and perceived ease of use. This finding suggests that extension may contribute to CSA adoption by strengthening farmers' readiness to act and reducing uncertainty about implementation. Extension therefore functions as an enabling institutional mechanism rather than constituting adoption itself. This interpretation is consistent with diffusion-oriented perspectives

Table 5. Structural path estimates

Structural Path	Path Coefficient	T Statistics	P Value	Significance
Agricultural Extension Support → Behavioral Intention	0.145	2.738	0.006	Significant
Agricultural Extension Support → Perceived Ease of Use	0.146	2.872	0.004	Significant
Attitude toward CSA → CSA Adoption Level	0.186	3.285	0.001	Significant
Selected Farmer Characteristics → Behavioral Intention	0.059	1.415	0.157	Not Significant
Selected Farmer Characteristics → Perceived Ease of Use	0.172	3.596	0.001	Significant
Behavioral Intention → Attitude toward CSA	–0.037	0.470	0.638	Not Significant
Behavioral Intention → CSA Adoption Level	0.524	7.486	0.001	Significant
Perceived Ease of Use → Attitude toward CSA	0.458	6.612	0.001	Significant
Perceived Ease of Use → CSA Adoption Level	–0.057	0.744	0.457	Not Significant
Perceived Ease of Use → Behavioral Intention	0.581	11.921	0.001	Significant
Peer Farmer Influence → Behavioral Intention	–0.023	0.363	0.716	Not Significant
Peer Farmer Influence → Perceived Ease of Use	0.348	7.611	0.001	Significant

Source: Processed field data, 2025

Table 6. Inner variance inflation factors and effect sizes of structural paths

Structural path	Inner VIF	f^2	Effect size (Cohen, 1988)
Agricultural Extension Support → Behavioral Intention	1.565	0.024	Small
Agricultural Extension Support → Perceived Ease of Use	1.535	0.019	Small
Attitude toward CSA → CSA Adoption Level	1.233	0.041	Small
Selected Farmer Characteristics → Behavioral Intention	1.345	0.005	Negligible
Selected Farmer Characteristics → Perceived Ease of Use	1.304	0.032	Small
Behavioral Intention → Attitude toward CSA	1.727	0.001	Negligible
Behavioral Intention → CSA Adoption Level	1.729	0.232	Medium
Perceived Ease of Use → Attitude toward CSA	1.727	0.150	Medium
Perceived Ease of Use → CSA Adoption Level	1.986	0.002	Negligible
Perceived Ease of Use → Behavioral Intention	1.400	0.434	Large
Peer Farmer Influence → Behavioral Intention	1.513	0.001	Negligible
Peer Farmer Influence → Perceived Ease of Use	1.343	0.127	Small–medium

Source: Processed field data, 2025

Table 7. Approximate model fit, predictive relevance (Q^2), and PLSpredict results

Endogenous construct / indicator	Q^2 (Blindfolding)	Q^2predict	RMSE (PLS-SEM)	RMSE (LM)	Difference (PLS–LM)
Behavioral Intention	0.424	0.152	0.664	0.603	0.061
Perceived Ease of Use	0.152	–	–	–	–
• Ease of Implementation	–	0.117	0.9	0.895	0.005
• Ease of Observation	–	0.186	0.894	0.892	0.002
• Ease of Testing	–	0.142	0.899	0.892	0.007
Attitude toward CSA	0.179	0.139	0.817	0.805	0.011
CSA Adoption Level	0.241	–	–	–	–
• Number of CSA Types Implemented	–	0.085	0.985	0.975	0.01
• Duration of CSA Use	–	n.a.	n.a.	n.a.	n.a.
SRMR (Saturated model)	0.108	–	–	–	–
SRMR (Estimated model)	0.127	–	–	–	–

Source: Processed field data, 2025

emphasizing the informational and facilitative roles of agricultural advisory services (Rezaei-Moghaddam & Salehi, 2010). Evidence from West Java similarly shows that extension effects depend on implementation and interaction with farmers' human and social capital (Azhari et al., 2025a).

Peer influence was strongly associated with perceived ease of use but not behavioral intention. Observing neighboring farmers and discussing CSA practices within farmer groups may help farmers understand how a practice is implemented, tested, and adjusted under local conditions. Such interaction may improve operational confidence without necessarily creating a commitment to adopt. This pattern is consistent with Social Learning Theory, which emphasizes learning through observation and interaction (Bandura, 1977; Gerba et al., 2015; Ding et al., 2022; Shitu et al., 2024), and with evidence that social interaction is particularly relevant to farmers' assessments of technological feasibility (Genius et al., 2014).

Behavioral intention was the strongest predictor of realized CSA adoption, while attitude had a smaller positive relationship with adoption. Perceived ease of use was not directly associated with adoption, although it was strongly related to both intention and attitude. These findings are broadly consistent with TAM: operational simplicity can strengthen readiness and favorable evaluation, but actual implementation requires a sufficiently strong commitment to act. For smallholders, that commitment may also depend on resource availability, expected returns, and exposure to production risk (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). Evidence from smallholder systems in West Sumatra supports this interpretation: farmers there adopted diversified cropping and crop-livestock arrangements, practices widely framed as adaptation to production and climate risk, mainly to stabilise income and maintain cash flow while awaiting the main harvest, whereas environmental motives were reported by only a small share of respondents (Utami et al., 2020). Operational simplicity may therefore be necessary but not sufficient, because adoption ultimately depends on whether a practice is judged capable of securing household income.

The findings support extension strategies combining participatory demonstrations with farmer-to-farmer learning. Demonstration plots can make implementation procedures and outcomes observable, while peer interaction can provide context-specific knowledge about operational constraints. Extension workers therefore need competencies in needs assessment, participatory facilitation, and business planning, rather than relying primarily on production-oriented information delivery (Amanah et al., 2026). However, the modest explanatory and predictive performance indicates that cognitive and institutional factors should be complemented by economic and structural conditions in future models.

Several limitations should be recognized. The cross-sectional design supports associations rather than causal or temporal

conclusions. The Behavioral Intention → Attitude path differs from the canonical TAM sequence and should be interpreted as exploratory. Perceived usefulness was not included because no independent item validly measured the construct. Behavioral intention and attitude were measured with single items, and the attitude item represented perceived benefits relative to previous practices; consequently, their internal consistency and convergent validity could not be assessed. Convergent validity of the formative constructs could not be examined through redundancy analysis because independent global criteria were unavailable. Adoption was self-reported, and perceptions may have been influenced by previous adoption experiences. The study covered only two rice-producing areas and used farmer-group registers as its sampling frame, which may under-represent farmers belonging to inactive groups (Helmi et al., 2019). The model also excluded land tenure, credit access, irrigation reliability, prices, and other structural constraints. These limitations restrict generalization and help explain the model's limited out-of-sample predictive accuracy.

CONCLUSION

Among 342 rice farmers in Sukra and Praya, extension support was positively associated with behavioral intention and perceived ease of using CSA, while peer influence was primarily associated with perceived ease of use. Behavioral intention was the strongest predictor of realized adoption, followed by attitude, whereas perceived ease of use had no significant direct relationship with adoption. These findings indicate that extension and peer learning contribute differently to CSA acceptance: extension strengthens readiness to adopt, while farmer-to-farmer interaction builds operational confidence. Extension programs should therefore combine participatory demonstrations, locally documented outcomes, and peer-learning activities. Nevertheless, the model's moderate explanatory capacity and limited out-of-sample predictive accuracy indicate that future studies should incorporate economic, institutional, and resource-related constraints and employ longitudinal designs to clarify the transition from intention to sustained CSA adoption.

DECLARATIONS

Ethics approval and informed consent: The study was approved by the Research Ethics Committee, Universitas Pendidikan Indonesia, under ethical approval No. 101/UN40.K/PT.01.01/2025. All participants provided informed consent before participating in the study.

Data availability statement: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. The data are not publicly available because they contain information that could compromise participant confidentiality.

Software used: Data were analyzed using SmartPLS 4.1.1.2 (SmartPLS GmbH, Oststeinbek, Germany) for partial least squares structural equation modeling (PLS-SEM) and IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA) for descriptive statistical analysis.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that during the preparation of this work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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APPENDIX

Table A1. Constructs, indicators, measurement items, and sources

Construct	Indicator	Measurement Item	Scale	Adapted From
Agricultural Extension Support	Extension Module	Number of CSA training topics received and completeness of technical extension materials.	5-point ordinal scale	Zarei et al. (2022); contextualized for Indonesian CSA extension
	Frequency of Extension Visits	Frequency of extension worker visits during each cropping season.	5-point frequency scale	Zarei et al. (2022)
	Extension Worker Influence	Extent to which extension workers influence farmers' decisions to adopt CSA technologies.	5-point Likert	Zarei et al. (2022)
	Intensity of Adoption Encouragement	Frequency with which extension workers directly encouraged CSA adoption during the past two years.	5-point frequency scale	Zarei et al. (2022)
Peer Farmer Influence	Farmer Colleagues	Number of farmer group members adopting CSA and frequency of CSA discussions during farmer group meetings.	5-point ordinal/ frequency scale	Zarei et al. (2022); Social Learning Theory
	Farmer Figure	Frequency of following recommendations from lead farmers and perceived influence of successful model farmers.	5-point Likert	Zarei et al. (2022)
Selected Farmer Characteristics	Activeness in Farmer Groups	Level of participation in farmer group activities.	5-point participation scale	Developed for this study
	Farmer Education	Highest level of formal education completed.	Ordinal categories	Developed for this study
Perceived Ease of Use	Ease of Implementation	CSA technologies are easy to implement.	5-point Likert (1 = Strongly disagree to 5 = Strongly agree)	Davis (1989); Venkatesh & Bala (2008)
	Ease of Observation	The results of CSA implementation are easy to observe.	5-point Likert	Davis (1989); Venkatesh & Bala (2008)
	Ease of Testing	CSA technologies are easy to trial before full adoption.	5-point Likert	Davis (1989); Venkatesh & Bala (2008)
Behavioral Intention	Intention to Adopt CSA	Likelihood of adopting CSA technologies in the next cropping season.	5-point Likert	Davis (1989); Venkatesh & Bala (2008)
Attitude toward CSA	Relative Advantage	CSA technologies provide greater benefits than previous farming practices.	5-point Likert	Davis (1989); Rogers (2003)
	Number of CSA Types	Total number of CSA technologies currently adopted.	Count/index	Adapted from Zarei et al. (2022)
CSA Adoption Level	Duration of CSA Use	Year in which the farmer first adopted CSA technologies.	Years of adoption	Adapted from Zarei et al. (2022)

Research Article

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Understanding the Adoption Behaviour of Climate-smart Agriculture Practices among Farmers in Saran, Bihar

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HIGHLIGHTS

- Pest risk and advisory management recorded the highest adoption index (51.09) among the five CSA components in Saran district
- Annual income (r = 0.537**) and knowledge (r = 0.425**) were the strongest correlates of CSA adoption.
- Seven principal components with eigenvalues >1 collectively explained 67.26% of total variance
- Family type was the only socio-demographic variable significantly associated with CSA adoption behaviour (H = 4.24, df = 1, p = 0.039).

ARTICLE INFO

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ABSTRACT

Climate Smart Agriculture (CSA) represents a transformational approach that integrates agricultural productivity, climate change adaptation, and mitigation objectives. The study was conducted in Saran district of Bihar during 2025–26 to assess the adoption behaviour of CSA practices and to identify the socio-economic and psychological factors influencing such adoption. A multi-stage random sampling technique was employed to select 160 respondents from 16 villages across four blocks. Data were collected through a pre-tested structured interview schedule and analysed using Pearson's correlation coefficient, Principal Component Analysis (PCA), and the Kruskal-Wallis H test. Results revealed that pest risk and advisory management recorded the highest adoption index (51.09), while sustainability, income, and environmental practices were least adopted (40.54). Annual income (r = 0.537), knowledge (r = 0.425), and mass media exposure (r = 0.287) emerged as the most significant correlates of adoption. PCA yielded seven meaningful components explaining 66.84% of the total variance. Family type was the only categorical variable significantly associated with adoption behaviour (H = 4.24, p < 0.05). The study underscores the pivotal role of knowledge enhancement, income support, and media-based communication in promoting CSA adoption among smallholder farmers in Bihar.

INTRODUCTION

Agriculture remains the backbone of India's rural economy, sustaining nearly 58 per cent of the country's workforce and contributing significantly to national food security (Birthal et al., 2015). Climate change, however, poses an escalating threat to agricultural productivity, particularly in the Indo-Gangetic Plains where erratic monsoons, prolonged droughts, recurrent floods, and extreme temperature events increasingly jeopardise crop yields and farmers' livelihoods (Khatri-Chhetri et al., 2017). Bihar, one of India's most agrarian and climatically vulnerable states, is acutely exposed to these stresses due to its dependence on rain-fed

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agriculture, fragmented land holdings, and limited institutional infrastructure. In this context, climate smart agriculture (CSA) has emerged as a globally recognised paradigm that simultaneously enhances productivity, strengthens adaptive capacity, and reduces greenhouse gas emissions from agricultural systems (Food and Agriculture Organisation [FAO], 2013; Shitu & Nain, 2024).

CSA encompasses a spectrum of technology-based and management practices including improved soil health management, water-efficient irrigation techniques, integrated pest management, climate-resilient crop varieties, conservation agriculture, and sustainable income diversification strategies. Despite demonstrated benefits, the adoption of these practices by smallholder farmers remains dismal across South Asia, primarily due to capital constraints, inadequate knowledge, limited access to extension services, and socio-cultural barriers (Nayak et al., 2025). Understanding the determinants of adoption behaviour is therefore critical for designing context-specific extension strategies and evidence-based policy interventions.

Adoption behaviour has been extensively studied in the extension education literature. Yadav et al. (2013) reported that education, land holding, and extension contact significantly influenced technology adoption among farmers in Rajasthan. Kumar et al. (2026) found knowledge to be the primary predictor of adoption among natural farming in Uttar Pradesh. Mishra et al. (2025) demonstrated that annual income and mass media exposure were robust determinants of adoption of CSA practices in flood-prone areas and also emphasised the role of family structure and social participation in shaping adoption decisions. Despite this substantial and growing international evidence base, empirical studies specifically examining CSA adoption in the Gangetic alluvial, flood-prone districts of Bihar as distinct from the better-studied hill and drought-prone regions of South Asia remain scarce; this represents a geographical and context-specific gap in the extension literature that the present study addresses, while also contributing methodologically by jointly applying correlation, exploratory PCA, and non-parametric group comparison within a single behavioural-adoption framework.

The Saran district of Bihar was selected as the study area for its predominantly agrarian character and exposure to multiple climate stressors, including annual Ghaghara River flooding and recurrent moisture stress during the kharif season. The district also exhibits significant heterogeneity in socio-economic conditions, making it suitable for analysing the multidimensional determinants of adoption behaviour. The present investigation was therefore undertaken with the specific objectives of: (i) assessing the component-wise adoption level of CSA practices; (ii) examining the relationship between selected independent variables and adoption behaviour; (iii) identifying underlying dimensions of independent variables through PCA; and (iv) determining whether adoption behaviour differed significantly across categorical socio-demographic groups.

METHODOLOGY

The present study was conducted in Saran district of Bihar during 2025-26. The district was purposively selected owing to its predominantly agrarian character and exposure to recurrent climate stress. A combined purposive-cum-multistage random sampling design was employed. In the first stage, four blocks Manjhi, Ekma, Baniyapur, and Jalalpur were purposively selected from Saran district based on their representativeness of the district's diverse agro-climatic and socio-economic landscape. In the second stage, four villages were randomly selected from each block (sampling frame: complete list of revenue villages obtained from the block development office), yielding 16 villages. In the third stage, 10 respondents were randomly selected from each village using a simple random sampling procedure from the village voter/farmer list, resulting in a total sample of 160 respondents. The sample size of 10 respondents per village was fixed to balance adequate within-village representation against the logistical feasibility of administering a detailed structured schedule across 16 villages within the study period. The respondents were adult farmers engaged in agricultural activities and were interviewed using a pre-tested structured interview schedule.

Adoption was taken as the dependent variable, operationally defined as the extent to which farmers adopted recommended agricultural practices. The adoption level was assessed for the same 5 aspects and 24 issues, using a scoring system of fully adopted (2 points), medium adopted (1 point), and not adopted (0 points). The highest attainable score for both knowledge and adoption was 48 (24 multiplied by 2). An adoption index was developed.

$$\text{Adoption index} = \frac{\text{Total score achieved}}{\text{Total achievable score}} \times 100$$

Data were analysed using R Studio (version 4.5.2). A total of eighteen (18) independent variables were entered into the Principal Component Analysis, consistent with the reported Bartlett's test degrees of freedom (df = 18×17/2 = 153). Prior to PCA, all continuous variables were standardised (z-scores) to ensure comparability of scale. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity were applied to assess the factorability of the data (Kaiser, 1970; Bartlett, 1950). Components with eigenvalues exceeding 1.0 were retained following Kaiser's criterion (Kaiser, 1960), and varimax rotation was applied. Factor loadings of 0.40 or above were considered significant. The Kruskal-Wallis H test, a non-parametric equivalent of one-way ANOVA, was employed to test for significant differences in CSA adoption across categories of discrete socio-demographic variables. A significance level of $p<0.05$ was adopted throughout.

RESULTS

Component-wise adoption of CSA practices

Table 1 presents the component-wise adoption indices of CSA practices among the sampled farmers, arranged in descending order of adoption. Pest risk and advisory management recorded the highest adoption index (51.09, rank I), followed by crop management and agronomical practices (48.61, rank II), soil health and nutrient management (47.50, rank III), and water management and moisture conservation (46.93, rank IV). Sustainability, income, and environmental practices recorded the lowest adoption index (40.54, rank V). suggesting that practices with long-term and diffuse environmental benefits, such as crop residue management and agroforestry, were least internalised by farmers, likely due to their perceived complexity and delayed returns.

Table 1. Component-wise adoption behaviour of CSA practices among respondents

S. No.	Component wise	Adoption Index	Rank
1	Pest risk and advisory management	51.09	I
2	Crop management and agronomical practices	48.61	II
3	Soil health and nutrient management	47.50	III
4	Water management and moisture conservation	46.93	IV
5	Sustainability, income and environmental practices	40.54	V

Principal component analysis

Before conducting PCA, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was computed at 0.577. This value falls in the "mediocre" range on Kaiser's (1974) guideline and is below the commonly recommended minimum threshold of 0.60 for confirmatory factor analysis; it is therefore explicitly acknowledged here as a methodological limitation, and the PCA results that follow are presented as exploratory rather than confirmatory. Bartlett's Test of Sphericity yielded $\chi^2(153) = 728.04$, $p < 0.001$, confirming that the correlation matrix was significantly different from an identity matrix and that the data were nonetheless minimally factorable.

Table 2 presents the total variance explained by the extracted principal components, recalculated against the full set of 18 variables entered into the analysis. Seven components with eigenvalues exceeding 1.0 were retained following Kaiser's criterion (Kaiser, 1960). PC1 had the highest eigenvalue of 2.7356, accounting for 15.20% of variance (2.7356 ÷ 18). The cumulative variance explained by all seven components was 67.26%, which is now consistent with the rotated cumulative proportion reported in the final column, correcting a discrepancy in the originally reported unrotated cumulative percentage. After varimax rotation, the SS loadings for each component ranged from 1.3265 (PC7) to 2.2681 (PC3), suggesting moderately well-defined factor structures. Variables with rotated factor loadings ≥ 0.40 in absolute value were considered substantively significant and retained for interpretation.

Kruskal-wallis H test results

The Kruskal-Wallis H test was applied to examine whether adoption behaviour differed significantly across different categories of seven socio-demographic variables (Table 3). Among all variables tested, family type was the only variable that produced a statistically significant difference in CSA adoption ($H = 4.24$, $df = 1$, $p = 0.039$). This suggests that farmers belonging to joint families demonstrated comparatively higher adoption levels than those in nuclear families. All other tested variables gender ($H = 0.28$, $p = 0.595$), caste ($H = 4.14$, $p = 0.247$), religion ($H = 0.16$, $p = 0.688$), education ($H = 6.97$, $p = 0.138$), marital status ($H = 0.58$, $p = 0.447$), and occupation ($H = 0.01$, $p = 0.921$) — were non-significant at the five per cent level of probability.

Table 3. Kruskal-Wallis H test results for CSA adoption across categorical variables

Variable	df	H Statistic	p-value	Significance
Gender	1	0.2825	0.5951	NS
Caste	3	4.1359	0.2472	NS
Religion	1	0.1617	0.6876	NS
Education	4	6.9662	0.1377	NS
Family Type	1	4.2406	0.0395	*
Marital Status	1	0.5790	0.4467	NS
Occupation	1	0.0098	0.9213	NS

H = Kruskal-Wallis test statistic; df = degrees of freedom (number of groups –1); * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; NS = Not Significant ($p \geq 0.05$). Technology adoption was used as the dependent variable.

Correlation between adoption behaviour and independent variables

Table 4 presents the correlation coefficients between CSA adoption and the continuous and binary independent variables (caste and religion, being multi-category nominal variables, are reported separately in Table 3). Annual income exhibited the strongest positive and highly significant correlation with adoption ($r = 0.537$, $p < 0.01$), underscoring the importance of financial capacity in enabling farmers to invest in CSA technologies. Knowledge was the second most influential correlate ($r = 0.425$, $p < 0.01$), consistent with the conventional extension view that knowledge is a precursor to behavioural change. Mass media exposure ($r = 0.287$, $p < 0.01$) also showed a significant association, reflecting the role of information dissemination channels in adoption decisions. Age ($r = 0.192$, $p < 0.05$) and education ($r = 0.167$, $p < 0.05$) were positively but modestly correlated with adoption. Gender, family size, marital status, occupation, farming experience, scientific orientation, and

Table 2. Total variance explained by principal components

PC	Eigenvalue	% Variance	Cum. %	SS Loadings	Prop. Var.	Cum. Prop.
PC1	2.7356	15.20%	15.20%	1.8156	10.09%	10.09%
PC2	2.1519	11.96%	27.16%	1.9295	10.72%	20.81%
PC3	1.9604	10.89%	38.05%	2.2681	12.60%	33.41%
PC4	1.7567	9.76%	47.81%	1.7532	9.74%	43.15%
PC5	1.2962	7.20%	55.01%	1.4374	7.99%	51.14%
PC6	1.1467	6.37%	61.38%	1.5763	8.76%	59.90%
PC7	1.0591	5.88%	67.26%	1.3265	7.37%	67.26%

KMO Measure = 0.5770, Bartlett's Test = $\chi^2(153) = 728.04$, $p < 0.001$

Table 4. Correlation between adoption behaviour and independent variables

Variable	Correlation with CSA Adoption (r)
Age (Continuous)	0.192*
Gender (Binary)[a]	-0.042
Education (Continuous)	0.167*
Family Size (Continuous)	-0.144
Marital Status (Binary)[a]	0.060
Occupation (Binary)[a]	-0.008
Farming Experience (Continuous)	0.153
Scientific Orientation (Continuous)	0.095
Land Holding (Continuous)	0.093
Annual Income (Continuous)	0.537**
Mass Media Exposure (Continuous)	0.287**
Knowledge (Continuous)	0.425**

* $p < 0.05$; ** $p < 0.01$. [a] Binary variables analysed using point-biserial correlation (mathematically equivalent to Pearson r for dichotomous data). Caste and Religion (multi-category nominal variables) are reported in Table 3 (Kruskal-Wallis H test) rather than here.

land holding did not show statistically significant correlations with adoption behaviour in this sample; this should be interpreted cautiously as an absence of significant bivariate association within this dataset, rather than as evidence that these variables are not relevant drivers of CSA adoption more generally, particularly given the modest sample size and the exploratory nature of the wider analysis.

DISCUSSION

Pest risk and advisory management recorded the highest adoption index among the five CSA components, indicating farmers' preference for practices offering immediate, perceptible economic benefit and low production risk. This is consistent with Aryal et al. (2018) and Khatri-Chhetri et al. (2017), who found that Indo-Gangetic Plain farmers, including in Bihar, consistently prioritise CSA technologies offering quick, tangible returns over those with diffuse, long-term environmental benefits. The comparatively low adoption of sustainability, income, and environmental practices such as agroforestry and crop residue management suggests these are perceived as labour-intensive and slower to pay off, consistent with Rogers' (2003) emphasis on relative advantage and observability as key drivers of an innovation's diffusion.

Exploratory PCA identified seven components explaining 67.26% of total variance, suggesting that the independent variables underlying CSA adoption are multidimensional; however, given the modest KMO (0.577), this factor structure should be treated as preliminary until the components are substantively labelled and validated on a larger, more factorable dataset. Multidimensional adoption behaviour has similarly been reported by Aryal et al. (2018) and Finizola e Silva et al. (2024), who found household attributes, market access, institutional support, and climate risk jointly explain CSA adoption intensity across South Asian and African smallholder contexts respectively. Effective CSA scale-up appears to depend on the interaction of extension, finance, institutions, and farmer capacity rather than any single socio-economic variable in isolation (Thottadi & Singh, 2024), reinforcing a systems approach to extension education that integrates advisory services, institutional support, and capacity building.

Among categorical variables, family type alone was significantly associated with adoption behaviour; joint-family structures may offer more available labour and shared decision-making that reduce the perceived risk of adopting new technologies, though this direction requires confirmation from group-wise descriptive statistics. The absence of a significant association for caste, religion, and gender should not be over-interpreted as evidence that social cleavages no longer shape adoption; it may equally reflect this sample's composition, coding of these variables, or limited statistical power, and expanding access to ICT-based advisory services and Krishi Vigyan Kendras may still be contributing to more inclusive extension outreach (Sonu & Jha, 2026).

Annual income showed the strongest positive association with CSA adoption, followed by knowledge and mass media exposure, suggesting that financial capacity remains an important facilitating factor: farmers with greater income may be better able to absorb the risk of adopting costlier technologies such as quality seed, improved irrigation, and climate-resilient varieties (Sonu & Jha, 2025a, 2025b). These associative patterns should not, however, be read as proof of a causal financial determinant without multivariable control for confounding factors. Knowledge's second-ranked association reinforces Rogers' (2003) view that knowledge acquisition is the first stage of the innovation-decision process; a farmer aware of the practice's benefits is better positioned to evaluate and adopt it. Mass media exposure was also significantly and positively associated with adoption, consistent with the documented role of mobile-based agro-advisory platforms and digital extension services in strengthening climate-smart farming awareness in India, since such platforms deliver tailored advisory messages directly to farmers on climate-smart practices (Ghanghas et al., 2015; Kumar et al., 2022; Thottadi & Singh, 2024; Singh et al., 2025). Collectively, these associations point to knowledge-building extension education, expanded mass-media and ICT-enabled advisory access, and improved institutional credit as priority levers for stimulating CSA adoption in eastern India.

CONCLUSION

CSA adoption among farmers in Saran district was most strongly associated with annual income, knowledge of recommended practices, and mass media exposure, with family type as the only significant structural correlate among the socio-demographic variables tested. Pest risk management practices showed the highest adoption, while sustainability-oriented practices lagged considerably, reflecting farmers' preference for CSA options offering quick, tangible returns. Exploratory PCA suggested a multidimensional structure underlying adoption, though this requires further validation given the modest sampling adequacy observed. Extension systems in Bihar could usefully prioritise knowledge-intensive, income-linked, and media-supported interventions such as farmer field schools, income-diversification schemes, and local-language mass media as potential, rather than proven, levers for narrowing the adoption gap. Key limitations include the cross-sectional design, modest KMO value, and single-district scope;

future longitudinal, multi-district research incorporating qualitative methods is recommended to validate these associations.

DECLARATIONS

Ethical approval and consent to participate: The study was conducted in accordance with principals laid out in Helinski Declaration 1964 and its modifications. Ethical approval was waived by the departmental Review Board of Department of Agricultural Extension Education, ANDUA&T Kumarganj, Ayodhya, UP. Informed consent was sought from all the participants.

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Research Article

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Weather-Based Prediction of Sorghum Yield in Hamirpur District

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HIGHLIGHT

- The PCA-ANN model performed optimally for prediction of sorghum yield at the calibration stage with Adjusted R^2 of 0.94.
- ANN model performed optimally for prediction of sorghum yield at the validation stage with Adjusted R^2 of 0.94.
- Hybrid PCA-ANN model is clearly better and consistent in comparison to the simple ANN, LASSO, Ridge Regression and SMLR models in weather-based yield prediction of sorghum crop in Hamirpur district.

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ABSTRACT

The study was conducted during 2024-25. Five multivariable models were tested for the sorghum yield prediction in Hamirpur district of the Bundelkhand region, India namely Artificial Neural Network (ANN), PCA with Artificial Neural Network (PCA-ANN), Least Absolute Shrinkage and Selection Operator (LASSO), Ridge Regression, and Stepwise Multiple Linear Regression (SMLR). Average meteorological data of different crop phenological stages were used as predictor variables to build the models. The coefficient of determination (R^2), root mean square error (RMSE) and mean absolute error (MAE) were used to evaluate the model's performance. The five models were compared, and the PCA-ANN model was found to have the highest prediction accuracy, suggesting the dimensionality reduction process of PCA improved predictive ability of the ANN model. The PCA-ANN model had the highest predictive performance, with low prediction errors (MAE = 0.33 q ha^{-1} and RMSE = 0.50 q ha^{-1}) during the calibration process. The evaluation metrics ranked the forecasting performance of the models in the order: PCA-ANN>ANN>SMLR>LASSO>Ridge Regression. PCA, along with ANN, has emerged as a powerful and reliable technique for sorghum yield prediction under the influence of changing climate and can prove useful for farmers in the region of Bundelkhand for decision support.

INTRODUCTION

The climate of the Bundelkhand region in India is extremely sensitive to climatic fluctuations and is characterised by recurrent droughts, erratic rainfall, land degradation, a mono-cropping system, poverty and large-scale migration (Kalia et al., 2021). Since irrigation facilities are still scarce and limited, crop production is highly sensitive to variations in monsoon rainfall in this region, which mainly relies on monsoon rains for cultivation (Pathak et al., 2024). Due to the semi-arid region of Hamirpur district, oilseeds, pulses and coarse cereals are the major crops. Sorghum is one of the most appropriate cereal crops for semi-arid regions as it possesses a drought tolerance trait and can yield stable crops under moisture-constrained conditions (Singh et al., 2018). The crop grows in a

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series of definite phenological stages, the time to maturity being from 90-120 days, depending to a large degree on environmental conditions. India ranks third in production of sorghum after the USA and Nigeria. The total sorghum production in the country was estimated at around 4.03 MT during 2023-2024, with Maharashtra having the highest production, followed by Karnataka, TN, Rajasthan and MP (Jadhav et al., 2025).

Agro-meteorological variables are of great significance in crop performance. Phenological weather indices, incorporating weather features with crop development phases, have been proven to be useful indicators for better yield prediction (Singh et al., 2025). These indices can also be used to better estimate yield, water use, disease and pest occurrence, etc., assisting in the management of crops in a climate-resilient way. Agro-meteorological indicators also help farmers and decision-makers to optimise the use of resources and agricultural planning in the face of climate variability and uncertainty (Ransing et al., 2014; Garde et al., 2015; Yadav et al., 2021). Accurate crop yield predictions are crucial for achieving food security, market planning, and efficient agricultural management. Historically, statistical modelling has been a prevalent approach to estimating crop yields by developing relationships among crop yield, weather parameters, soil properties, and management practices (Maurya et al., 2025; Tripathi et al., 2023). The conventional methods (e.g., multiple linear regression and pre-harvest forecasting models) are simple and easy to understand, but they are limited in their ability to explain the relationships between these weather variables, their interactions, and the growth of crops, which causes their forecasting accuracy to be low. Conventional methods are straightforward and intuitive, but may assume linearity and/or a priori relationships among weather parameters and crop development. In practice, the weather factors like temperature, precipitation, humidity, solar radiation and soil moisture are highly interdependent, and the impact on crops is often characterised as being nonlinear and interactive. Furthermore, the sensitivity of crops to these variables will be different at different growth stages, and extreme conditions may lead to stress, which will affect crop growth and yield. These complex interactions and nonlinear relationships, and dynamic crop responses, may not be captured by conventional methods, leading to lower forecasting accuracy (Khan & Kumar, 2025; Setiya et al., 2022). In recent years, machine learning techniques have emerged that can offer strong alternatives to yield prediction. The machine learning models have therefore been found to be better at predicting various crops like pigeon pea, rice, sorghum, and wheat (Sridhara et al., 2020; Sridhara et al., 2023; Satpathi et al., 2023; Aravind et al., 2022). Although these developments have been made, very few studies have focused on hybrid approaches combining dimensionality reduction techniques with machine learning (Setiya et al., 2022) to enhance prediction accuracy, and most of the studies conducted have been limited to either weather variables or vegetation indices alone. The present study compares performance of the statistical and machine learning models to forecast sorghum yield in Hamirpur district based on weather indices.

METHODOLOGY

The Kharif sorghum yield data were collected from the Spider Statistics Journal Uttar Pradesh, published by the Department of Economics and Statistics, on sorghum yield for 31 years from 1991-92 to 2021-22. Also, data on weather conditions were gathered from the NASA POWER (https://power.larc.nasa.gov/data-access-viewer/). Daily weather data are used to obtain mean phenological values. Weighted and unweighted weather indices were derived using this mean phenological value. Unweighted weather indices have been obtained through aggregations of single weather variables or when interactions between them were taken into account. As an alternative, to calculate the weighted weather indexes, multiply each weather variable by the dependent variable or by the interaction of each weather variable with its coefficient. The five weather variables were combined in various combinations with other variables to produce weather indices. This results in a total of 10 pairs, which means there are 20 weather indices overall. The formulas used (Satpathi et al., 2023) to calculate weather indices, both weighted and unweighted, are shown in Equations (1) and (2) below

Unweighted weather indices:

$$Z_{mn} = \sum_{r=1}^{q} X_{mr}, Z_{mm'n} = \sum_{r=1}^{q} X_{mr} X'_{m'r} \quad \text{... (1)}$$

Weighted weather indices:

$$Z_{mn} = \sum_{r=1}^{q} p^{n}_{mr} X_{mr'}, Z_{mm'n} = \sum_{r=1}^{q} p^{i}_{mm'r} X_{mr} X_{m'r} \quad \text{... (2)}$$

Here, q represents the total number of phenological stages under study.

The term X_{mr} refers to the value of the mth weather variable, while $X_{m'r}$ is the value of the m'^{th} weather variable. r_{mr} and $r_{mm'r}$ denote the correlation coefficients between yield and the mth weather variable, or the product of the mth and variable m'^{th} weather variable, during the rth phenological stage. When n=0, it indicates unweighted weather indices; when n=1, it indicates weighted weather indices. Thirty weather indices were produced by using the above procedure (Satapathi et al., 2023). Using time series data on phenological weather indexes and sorghum yield, three multivariate models were developed for this study. The models were tested and trained on these datasets. Five models, ANN, PCA-ANN, LASSO, Ridge Regression and SMLR were used in this study.

To assess the model performance, we used Adjusted R^2 (adjusted coefficient of determination), root mean square error (RMSE), mean absolute error (MAE), percentage error (PE), normalized root mean square error (nRMSE), and model efficiency (EF). We compared the models based on their adjusted R-squared values. These statistical measurements have the following formulas.

$$nRMSE = \frac{100}{M}\sqrt{\frac{\sum_{i=1}^{j}(x_i - \hat{x}_i)^2}{m}} \quad \text{... (3)}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{j}(x_i - \hat{x}_i)^2}{m}} \quad \text{... (4)}$$

$$MAE = \frac{\sum_{i=1}^{j}|x_i - \hat{x}_i|}{m} \quad \text{... (5)}$$

$$Adj.R^2 = 1 - \frac{(m-1)(1-R^2)}{(m-q-1)} \quad \text{... (6)}$$

$$Percentage\ Error = \left(\frac{x_i - \hat{x}_i}{x_i}\right) \times 100 \quad \text{... (7)}$$

Here, x_i is the actual value, and $\hat{x}_i$ is the predicted value for each i from 1 to j. The symbols x_i and $\hat{x}_i$ represent the average of the actual and predicted values, respectively. The σ_x and $\sigma_{\hat{x}}$ are the standard deviations of the actual and predicted values. M is the average of all actual values, m is the total number of observations, and q is the number of predictors in the model.

RESULTS

Tables 1 demonstrate the summary results of the model performance in Hamirpur district. ANN had the highest overall predictive accuracy. The model has been validated, and it has the best prediction accuracy with the highest adjusted R^2 (0.94), lowest MAE (0.38 q ha^{-1}), RMSE (0.46 q ha^{-1}), and model efficiency (EF = 0.89), and good generalisation capability. The PC-ANN demonstrated the best calibration adjusted R^2 (0.94), indicating a very good fit to the calibration set. The ability of the model to capture the variation between the observations and the predictions (adjusted R^2 = 0.85, RMSE = 0.58 q ha^{-1}, EF = 0.83) was slightly lower than that of the ANN model, showing that dimensionality reduction with PCA did not increase the accuracy of the model. SMLR showed moderate performance with a validation adjusted R^2 of 0.88, RMSE of 0.72 q ha^{-1} and EF of 0.74. It showed some improvement in performance over the regularised linear models, but not as high an accuracy as the ANN-based approaches. LASSO and Ridge Regression yielded somewhat inferior prediction accuracy. Both models showed relatively high values for the validation adjusted R^2 (0.83 and 0.90, respectively), but higher RMSE (1.58 and 1.81 q ha^{-1}, respectively) and negative EF values (-0.21 and -0.58, respectively), which suggested that these models were less efficient in predicting the response variable.

As per the results shown in Table 2, there were significant differences between the models by the prediction error analysis. The error range for the Ridge Regression model was the most narrow (-79.86% to 14.02%), suggesting that there was less variation in prediction errors within this model, though it was less efficient in predicting the target variable as seen during validation. The error range of the PCA-ANN model was also comparatively smaller (-80.84% to 18.81%), than that of standard ANN model. The prediction errors of the ANN model were between -120.76% and 16.52%. Its minimum error was larger than those of PCA-ANN and Ridge Regression but it showed that it has the highest validation accuracy in terms of adjusted R^2, RMSE, MAE, and Nash–Sutcliffe efficiency, which means that it has a better overall prediction. The largest error range was observed in the LASSO model with a range ranging from -195.80% to 20.36% and in the SMLR model with a range from -205.34% to 25.96%. The large negative errors show that some observations were underestimated, which shows less stability in the predictions by the models than ANN-based models.

To evaluate and compare the predictive performance of the ANN, PCA-ANN, LASSO, Ridge Regression and SMLR models, the Taylor diagram (Figure 1) was used by simultaneously assessing the correlation coefficient, standard deviation, and centered root mean square error (CRMSE). The ideal model was used as a reference point as it has a correlation coefficient of 1.0, the same standard deviation as the observed data, and a centered RMSE of 0. The reference point (Observed) is the ideal model that has a correlation coefficient of 1.0, the same standard deviation as the observed data and a centered RMSE of 0. When evaluated, PCA-ANN is the closest to the reference point, implying it best captures the observed variability, with good correlation and lowest centered RMSE. This is consistent with its better calibration performance (Adjusted R^2 = 0.94 and EF = 0.94), indicating that PCA achieved good dimensionality reduction and model fitting by eliminating data redundancy and redundancy of parameters in the calibration process. The ANN model also showed a good correlation with the observed data with slightly low standard deviation than the observations and a slightly larger centered RMSE than the PCA-ANN model. However, its nearness to the reference point suggests good calibration capabilities. The SMLR model was found to be moderately correlated with the observations with lower correlation coefficient and lower standard deviation compared to ANN based models. As a result, it had a higher centered RMSE indicating it

Table 1. Quantitative measurements made during calibration and validation for Hamirpur

Model	Calibration					Validation				
	Adjusted R^2	MAE (q ha^{-1})	RMSE (q ha^{-1})	nRMSE (%)	EF	Adjusted R^2	MAE (q ha^{-1})	RMSE (q ha^{-1})	nRMSE (%)	EF
ANN	0.87	0.58	0.76	8.00	0.86	0.94	0.38	0.46	10.00	0.89
PCA-ANN	0.94	0.33	0.50	55.00	0.94	0.85	0.38	0.58	12.00	0.83
LASSO	0.51	1.22	1.58	21.00	0.42	0.83	1.46	1.58	17.00	-0.21
Ridge Regression	0.537	1.19	1.63	21.78	0.39	0.90	1.59	1.81	19.63	-0.58
SMLR	0.53	1.10	1.43	19.15	0.53	0.88	0.64	0.72	7.82	0.74

Table 2. Information on the models used and the error percentage for Hamirpur

Model	Equation	Error percentage
ANN	No of hidden layers: 5	-120.76% to 16.52%
PCA-ANN	9; No of PC's: 5	-80.84% to 18.81%
LASSO	Y = 7.486 + 0.513 × Z11 + 0.269 × Z31 + 0.18 × Z251 + 0.206 × Z341	-195.80% to 20.36%
Ridge Regression	Y = 7.826 - 0.036 × Z10 + 0.123 × Z11 - 0.002 × Z20	-79.86% to 14.02%
SMLR	Y = 21.237 + 1.775 × Z11 + 0.014 × Z251 + 1.895 × Z31	-205.34% to 25.96%

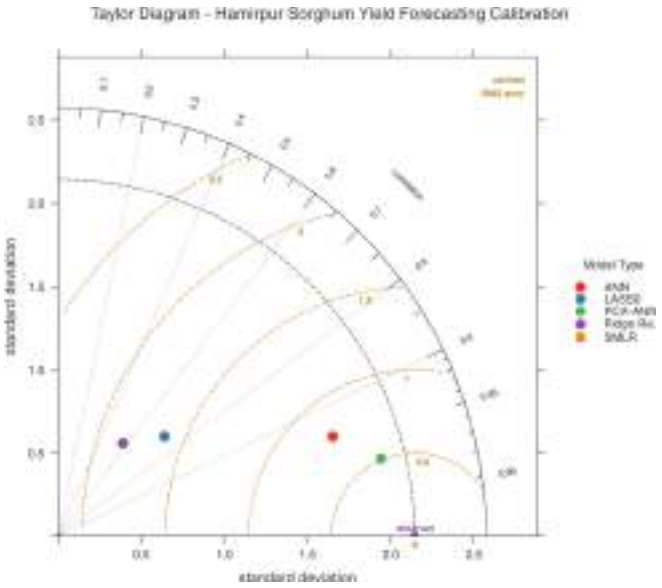


Figure 1. Taylor diagram for calibration

was less able to capture the observed variability. Both LASSO and Ridge Regression are found further away from the reference point, and have relatively smaller standard deviations and correlation. The higher RMSE values of their centered values suggest that they are less in agreement with the observed data and less able to calibrate as compared to the ANN-based approaches.

The performance of the validation was shown by the Taylor diagram in Figure 2. In all the models tested, the ANN model is closest to the reference point, which shows the greatest correspondence with the observed sorghum yield. It has a high correlation coefficient (about 0.94), standard deviation near that of the observed data and the lowest centered RMSE, indicating that it is the best model to reproduce the magnitude and variability of the observed yields. Validation statistics between these observations are in line with those for ANN, which had the highest adjusted R^2

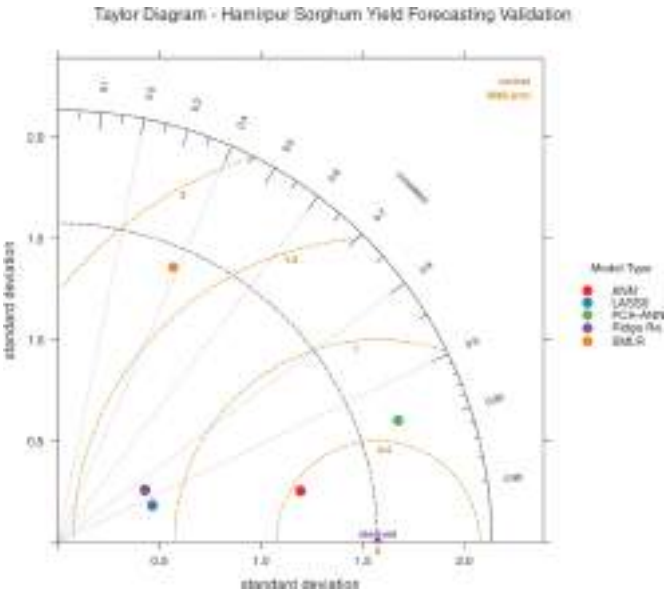


Figure 2. Taylor diagram for validation

(0.94), lowest RMSE (0.46 q ha^{-1}) and highest model efficiency (EF = 0.89). It can be seen that the PCA-ANN model is located slightly away from the reference point than ANN model, which means the correlation is slightly lower with a centered RMSE slightly higher than that of ANN. It was equally able to encompass the range of the observed data but its predictive ability was somewhat less than that of the ANN model in line with the statistical validation results. The SMLR model had moderate performance as it had a lower correlation coefficient and larger centered RMSE than the ANN based models. Also, its standard deviation was lower than the standard deviation of the observations, which indicated that it underestimated the yield variation of sorghum. The LASSO and Ridge Regression are the two farthest from the reference point, having comparatively low correlation coefficients, and very low standard deviations with higher centered RMSE values. performance, as they were not as effective as a constant (the observed mean) predictor.

DISCUSSION

The study tested the five models to forecast sorghum yield namely: ANN, PCA-based artificial neural network (PCA-ANN), LASSO, Ridge Regression and SMLR models. The outcomes indicated that the machine learning models, specifically ANN, achieved better performance over linear regression-based approaches in predicting Sorghum yield as compared to the other linear models. The PCA-ANN model had the highest predictive performance, with low prediction errors (MAE = 0.33 q ha^{-1} and

RMSE = 0.50 q ha^{-1}) during the calibration process. This is because the dimensionality reduction process used in PCA-ANN reduces the multicollinearity of the predictor variables and retains most of the information of the original dataset. PCA can decrease the redundancy of vegetation indices, which are highly correlated, allowing the neural network to learn the more stable relationships in model training. The result is in line with the previous studies that indicate that using the PCA with ANN yields better calibration accuracy due to reducing the dimensions of the input and noise (Aravind et al., 2022; Setia et al., 2022; Khan & Kumar, 2025; Singh et al., 2025). While PCA-ANN gave the best calibration statistics, the ANN model gave the highest validation accuracy (adjusted R^2 = 0.94, RMSE = 0.46 q ha^{-1}, MAE = 0.38 q ha^{-1} and EF = 0.89), which showed better generalisation to the independent set. Improved validation performance indicates that the ANN was able to estimate the complex and nonlinear relationships among the spectral indices and sorghum yield without dimensionality reduction. Neural networks can model complex interactions between the predictor variables that are not well captured by linear regression models. Therefore, ANN showed high prediction accuracy for the observations not previously seen, which demonstrates the robustness of the ANN for practical yield forecasting (Satpathi et al., 2023). The regression-based models, on the other hand, had relatively low predictive power. LASSO and Ridge Regression are two useful regularisation methods to reduce model complexity and multicollinearity, but they are based on the assumption that the relationship between predictor variables and crop yield is mostly linear. Many factors interact and affect sorghum yield, which means yield response is highly nonlinear, making linear modelling

challenging. This restriction is seen in their lower adjusted R^2 values in their calibration and higher RMSE values and negative Nash–Sutcliffe efficiency (EF) for their validation. The poor prediction of the observations by the regression models compared to the mean observed yield (indicated by negative EF) suggests that the regression models may not be ideally suited for this application (Das et al., 2022; Khan & Kumar, 2025). The SMLR model seemed to outperform LASSO and Ridge Regression models and was still worse than ANN-based models. The stepwise regression only retained a subset of the vegetation indices that were significant in the prediction equation, which made the equation easier to understand and interpret. However, the limited predictive utility of this model may have been because nonlinear or interactive variables were not included. SMLR thus performed moderately well in terms of validation accuracy (adjusted $R^2 = 0.88$ and EF = 0.74), suggesting that linear relationships accounted for some of the yield variability but not all, as the crop growth dynamics were complex (Sridhara et al., 2020; Yadav et al., 2021).

CONCLUSION

ANN is the most useful and precise predictive model for forecasting sorghum yield in the conditions of the present study. While the PCA method was found to have reduced data redundancy and improved calibration performance, it did not improve the predictive performance on new data. Hence, the use of an ANN model is recommended for operational yield prediction of sorghum using the multispectral remote sensing data, and a PCA-ANN model may be useful where there is a need to reduce the number of computations or the availability of the predictor data sets are highly correlated. In general, the study revealed that the hybrid models, like the PCA-ANN, are more applicable to weather prediction in areas such as the Bundelkhand with erratic weather conditions. These models provide farmers, researchers and policy makers with the practical tools for controlling and planning agricultural output in the face of changing environmental conditions.

DECLARATIONS

Ethical approval and consent to participate: This study did not require ethical approval or consent to participate, and all the authors agree.

Availability of supporting data: Supporting data will be available upon request from the first and corresponding authors.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that create any potential conflict of interest. No conflict of interest among the authors.

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Research Article

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Determinants of Rural Youth Perception towards Agricultural Participation: Evidence from Kannur District, Keralam

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HIGHLIGHTS

- Youth engagement in agriculture was mostly motivated by education and agricultural information.
- Mass media and extension contact strongly improved favourable perceptions towards agriculture.
- Economic motivation led youths to consider agriculture as a viable means of earning a living.

ARTICLE INFO

Keywords: Youth employment, Career aspiration, Path analysis, Rural livelihood, Institutional support, Extension contact, Economic motivation.

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ABSTRACT

The study was conducted during the years 2025-2026 in Payyannur Block of Kannur district, Keralam to understand the perceptions of the youths about their participation in agriculture. A total of 120 youths from rural areas were selected randomly following a multi-stage random sampling procedure. The primary data were collected by using a pre-tested structured interview schedule. Path analysis was used to estimate the direct effects of socio-personal, socio-economic, communication and psychological variables on the participation of the youths in agriculture. It was found that the model developed accounted for 83.90 per cent of variation in participation. Out of the selected variables, education, occupation, land holding, mass media exposure, economic motivation, extension contact and religion had significant positive direct effects on the participation. Education was found as the most important variable influencing participation. However, the variables like caste, marital status, family size, family type, annual income, social participation, risk orientation did not have any significant direct effects. From these results, it can inferred that enhancing access to education, the spread of agricultural information, extension services, and economic incentives can lead to positive attitudes and higher involvement of young people in rural agriculture.

INTRODUCTION

Agriculture remains one of the key industries that contribute to food security, jobs, livelihood in India. In spite of technological progress, and the introduction of various policies, the sector is still experiencing a decline in youth participation. Rapid urbanization, education levels, migration, job diversification, availability of comparatively safe non-agricultural jobs have considerably changed career priorities of rural youth making agriculture unpopular profession among them (Geza et al., 2021). It raises serious problems related to sustainability of agriculture, availability of future professional farming generation. Young people are endowed

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with such qualities as energy, creativity, adaptability to new technologies and entrepreneurial spirit which would allow them to change agriculture and make more effective, competitive industry. They are necessary for development of climate-smart agriculture, technological innovations, value creation and agribusiness (Dutta et al., 2022). Taking into account this potential, various government and development organizations have developed special programs aimed at encouraging young people to become involved in agriculture through promotion of entrepreneurship, skill acquisition and other forms of support. Yet, efficiency of such programs is highly dependent on the perception of agriculture by rural youth (Kote et al., 2024).

Perception is one of the key determinants of occupational choice and intention. Several socio-personal, socio-economic, communication, institutional factors affect perception of rural youth towards their involvement in agriculture. These factors include education, farm experience, occupation of the family members, ownership of land, extension service access, and exposure to successful agricultural enterprises. Good perceptions of profitability, innovation, entrepreneurship, social status lead to agricultural participation; on other hand, labour-intensive nature, risk and lower economic returns make agriculture unattractive to rural youth as a career (Henning et al., 2022). According to most recent findings, youth have greater inclination towards income stability, career opportunities and innovation than traditional activity of agriculture. In south part of India, many farmers usually encourage young generation to get involved in other occupations other than farming due to production risk, weather changes, labour shortage, instability of income earned by farming (Nandi et al., 2022). Research indicates that better extension services, entrepreneurial skills and market access boost the confidence and participation in agriculture (Singh et al., 2014; Singh et al., 2016; Sreelakshmi et al., 2024). Further, positive attitude towards farming, extension linkage, achievement motivation, and agricultural skills positively influence youth participation, whereas migration intentions and preference for non-farm activities discourage participation in agriculture (Maurya et al., 2021). Besides, agricultural policies targeted youth, agriprenurship programs, technological innovations play roles in making agriculture more attractive occupation (Nain et al., 2019; Rana et al., 2024).

Keralam is unique in terms of agriculture with its ageing farmers, diminishing cultivation areas, scarcity of labour, occupational diversification. Changing dynamics are visible in Kannur district, where rural youth tend to choose occupations other than agriculture, despite having immense opportunities for agriprenurship, sustainability in agriculture sector. While there have been several studies on youth participation in agriculture, there is lack of empirical literature regarding perceptions of rural youth in Keralam. This study attempts to investigate role of socio-personal, socio-economic, communication, psychological determinants of rural youth perception towards agricultural participation.

METHODOLOGY

The research study was carried out in 2025–2026 in Payyannur Block, which is part of Kannur district in the state of Keralam, India. Exploratory research design was employed, as the research study dealt with the factors affecting perception of the youths towards agriculture without manipulating the independent variables. Payyannur Block was chosen purposefully due to its high population of rural youth and predominance of agricultural activities. The population of the study consisted of rural youths aged between 18 and 35 years residing in the selected villages in Payyannur Block. Multistage sampling technique was used in selection of the samples. Payyannur Block was chosen purposively in the first stage. In the second stage, villages with a high number of youths and agricultural activities were selected. A sample size of 120 rural youths was selected randomly in the third stage. Primary data were collected through an interview schedule which was well-prepared and tested before being applied in relation to the objectives of the study. The interview schedule comprised of statements and questions on social/personality, socio-economic, communication, and psychological attributes of the respondents as well as items that pertained to their involvement in agriculture. The perception statements were measured using a five -point Likert scale, while the categorical and quantitative variables were measured using the appropriate scales. A structured interview schedule was developed for the study with the consultation of subject matter specialist through judges' opinion. Primary data obtained were edited, coded, categorized, and arranged in tables for analysis. Path analysis was applied to measure the impact of the selected independent variables on youth involvement in agricultural production as well as the extent to which each independent variable influences the dependent variable. The relationship among variables was segmented into direct impacts through the use of standardized path coefficients, hence measuring the impact of each explanatory variable. Coefficient of determination (R^2) was utilized in determining the percentage of variability in the youth involvement influenced by path model while the residual effect represented the impact of other variables which were not considered in the analysis. Statistical significance of the measured path coefficients was tested at the 5 per cent and 1 per cent probability levels. Analysis was conducted using IBM SPSS Statistics. Multidimensional Scaling (MDS) was employed to examine perceptual relationships among the statements measuring rural youth's perception towards participation in agriculture.

RESULTS

Results from the path analysis are presented in Table 1. Path analysis was conducted to establish the direct influences of the selected socio-personal, socio-economic, communication, and psychological variables on youth involvement in agriculture. The path model fit accounted for 83.90 per cent of the total variability in youth involvement in agriculture ($R^2 = 0.839$), implying that the selected independent variables were able to explain the variability in the dependent variable satisfactorily. The residual 16.10 per cent of the variability in the dependent variable could be explained by other factors that were not included in the current study. The high value of R^2 showed that the model had satisfactory explanatory power. Of the fourteen explanatory variables considered for the model, seven variables showed statistically significant positive direct effect, while the remaining seven variables were insignificant. Education had the greatest standardized direct effect ($\beta = 0.279$)

Table 1. Estimated path coefficients of determinants of rural youth perception towards agricultural participation

Variable	Estimate	Std.Err	z-value	P(>|z|)	Std.lv	Std.all
Religion (X1)	1.475	0.727	2.029	0.042	1.475	0.078*
Caste (X2)	-0.575	0.376	-1.527	0.127	-0.575	-0.059
Education (X3)	1.312	0.254	5.169	0.000	1.312	0.279**
Marital status (X4)	0.541	0.370	0.712	0.200	0.200	0.014
Family size (X5)	0.787	0.552	1.426	0.154	0.787	0.055
Family type (X6)	0.768	0.611	1.257	0.209	0.768	0.049
Occupation (X7)	0.724	0.162	4.461	0.000	0.724	0.201**
Land holding (X8)	0.658	0.230	2.864	0.004	0.658	0.138*
Annual income (X9)	0.112	0.289	0.388	0.698	0.112	0.015
Mass media exposure (X10)	0.380	0.088	4.310	0.000	0.380	0.224**
Economic motivation (X11)	0.201	0.056	3.584	0.000	0.201	0.165**
Social participation (X12)	-0.057	0.058	-0.975	0.330	-0.057	-0.038
Risk orientation (X13)	0.042	0.040	1.037	0.300	0.042	0.040
Extension contact (X14)	0.252	0.073	3.464	0.001	0.252	0.193*

*Significant at the 5% level ($p < 0.05$); **Significant at the 1% level ($p < 0.01$)

Estimate = Regression coefficient; Std. Err = Standard error; z-value = Wald test statistic; P(>|z|) = Probability value (*p*-value); Std.lv = Standardized latent variable estimate; Std. all = Completely standardized estimate.

and was highly statistically significant at one per cent level of probability ($p < 0.01$), thus making it the best predictor of youth involvement in agriculture. This was followed by mass media exposure ($\beta = 0.224$), occupation ($\beta = 0.201$), extension services ($\beta = 0.193$), economic motivation ($\beta = 0.165$) and land holdings ($\beta = 0.138$), which were statistically significant at one percent level. Religion showed a relatively smaller standardized path coefficient ($\beta = 0.078$) but was still statistically significant at five percent level ($p < 0.05$). The positive path coefficients revealed that increase in these variables would result in increased involvement of youth in agriculture. From among all the important factors, it was revealed that education proved to be the most dominant factor, followed by mass media exposure, occupation, and extension contact. The results suggested that educational qualifications, availability of agricultural information, and frequent interactions with extension services played an important role in the improvement of youth involvement in agricultural practices. An effective agricultural extension and advisory services significantly enhances farmers awareness and perception towards agriculture (Krithika & Karthikeyan, 2023). A similar trend was also witnessed in the study conducted by Henning et al. (2022), who found out that positive perceptions, availability of information, and institutional support had increased youth interest in their involvement in agricultural activities. Similarly, Haldar et al. (2022) found out that rural youths had been actively involved in agriculture when they had good access to agricultural resources and information.

The analysis also pointed out that caste ($\beta = -0.059$), marital status ($\beta = 0.014$), family size ($\beta = 0.055$), family type ($\beta = 0.049$), annual income ($\beta = 0.015$), social participation ($\beta = -0.038$) and risk orientation ($\beta = 0.040$) did not have any statistically significant or showed any direct effect on the participation of youth in agriculture because the p-value of these independent variables was greater than the five percent level of significance. The effects of caste and social participation were negative as shown by the standardized path coefficient, but they were statistically non-significant. In the same way, the effects of marital status, family size, family type, annual income and risk orientation were positive but statistically insignificant. Generally, the path analysis showed that 50.00 per cent of the variables used to explain the youth participation in agriculture had significant impact on the youth participation in agriculture while the other 50.00 per cent had no statistically significant direct impact on youth participation in agriculture. Education, mass media exposure, occupation, extension services, economic incentives, land ownership and religion were the main factors affecting youth participation in agriculture. The coefficient of determination also revealed that the selected variables accounted for a reasonable amount of variance observed in youth participation in agriculture. The path model, therefore, was able to properly show the direct impacts of the selected explanatory variables.

The path diagram revealed that Education (X3) exerted the highest positive direct effect (0.30) on rural youths' perceptions towards participating in agriculture, indicating that educational attainment was the most influential factor shaping favourable perceptions towards agricultural participation. This was followed by Mass Media Exposure (X10) (0.24), Extension Contact (X14) (0.19), Occupation (X7) (0.18), Economic Motivation (X11) (0.16)

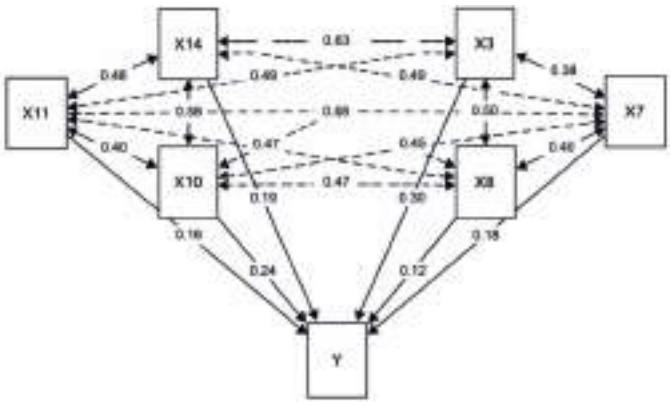


Figure 1. Path Analytical Model of Significant Determinants of Youths' Perceptions towards Participating in Agriculture.

and Land Holding (X8) (0.12). The positive path coefficients indicated that an increase in these variables would result in a corresponding improvement in the perception of rural youth towards participating in agriculture. The findings suggest that better educational opportunities, wider exposure to agricultural information, regular interaction with extension agencies, greater involvement in farming-related occupations, stronger economic aspirations and improved access to land collectively contribute to developing a more favourable perception of agriculture among rural youth.

The diagram further illustrated the interrelationships among the significant explanatory variables. Among them, Extension Contact (X14) and Education (X3) exhibited the strongest positive association (0.63), suggesting that rural youth maintaining frequent contact with extension personnel were more likely to possess better educational awareness and understanding of agricultural technologies and opportunities. A similarly strong association was observed between Extension Contact (X14) and Mass Media Exposure (X10) (0.58), indicating that extension services and communication media complemented each other in enhancing agricultural awareness among rural youth. Moderate positive associations were also observed between Extension Contact and Land Holding (0.49), Education and Land Holding (0.50), Education and Occupation (0.38), Mass Media Exposure and Land Holding (0.47), Education and Mass Media Exposure (0.47), and Occupation and Land Holding (0.40). These positive interrelationships indicate that improvements in one factor are accompanied by improvements in other related factors, ultimately contributing to favourable perceptions towards participating in agriculture. Overall, the path diagram demonstrates that rural youths' perceptions are influenced not only by the direct effects of individual variables but also by the combined interaction of educational, communication, institutional and socio-economic factors.

The Multidimensional Scaling technique (MDS) was used to identify the perceptual relationships between the statements. In Dim1, 52.17 per cent of the variance was explained, whereas 8.27 per cent of the variance was explained in Dim2, which together explains 60.44 per cent of the variance. The dominance of dimension 1 indicates that it is the most important dimension for differentiating respondents' perception of the statements. From the MDS plot, distinct clustering of the statements could be seen. All positive statements were found to form clusters, signifying a high level of similarity in the respondents' perceptions. S1, S2, S4, S17, and S18 formed a cluster that showed similar perceptions on the part of respondents. There was another positive cluster of S3, S5, S6, and S10. However, the negative statements showed higher dispersion in perceptual space. Statements S7, S9, and S14 constituted a separate cluster located in the lower-right part of the map; this was due to their high similarity. Similarly, S8 and S19 formed a group located in the upper-right quadrant; this showed that respondents viewed the statements as similar concepts. Statement S11 was quite isolated among all other statements; it demonstrated unique perceptions as opposed to other negative statements. Generally, the MDS map shows clear distinction between positive and negative statements, which proves that respondents could clearly distinguish favourable and unfavourable perceptions. The grouping proves high similarity within the group and high dissimilarity between groups, which means the validity of the conceptual structure of statements used in the research. Moreover, the findings indicate that the youth in rural areas have clear perceptions about their involvement in agriculture, and favourable perceptions are more reliable than unfavourable perceptions. Such perceptions show that although youths are aware of the chances and gains of agriculture, their worries about the constraints of agriculture differ widely from one individual to another. Thus, improvement in extension education, availability of agricultural information, and role models in agriculture can help build up favourable perceptions and motivate youth in agriculture.

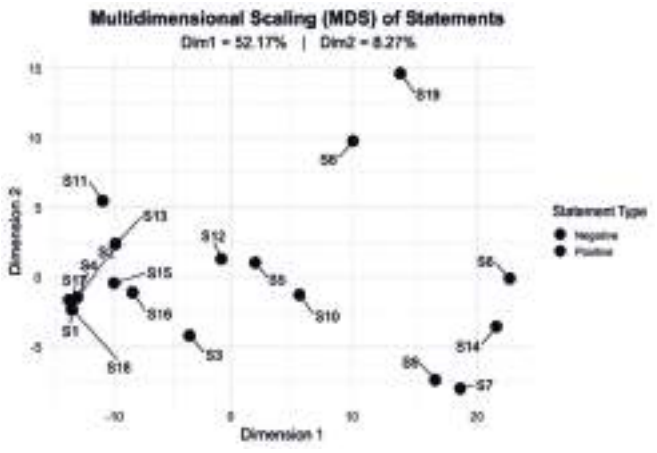


Figure 2. MDS map showing perceptual relationships between positive and negative statements

DISCUSSION

As per the current study, youth involvement in agriculture is considerably affected by education, occupation, land ownership, exposure to mass media, economic incentives, extension contacts, and religion, while caste, marital status, family size, family type, annual income, social participation, and risk taking attitude have no significant influence at all. This implies that rural youth participation is gradually becoming affected by factors like education, information, and institutions rather than any traditional socio-demographic variables. This signifies that gradually agriculture is getting recognized by the youth as a knowledge-intensive as well as economically viable profession. Education proves to be the most important factor influencing youth participation in agriculture. Youth with better education levels tend to be able to understand new techniques in agriculture, gather information scientifically, and recognize entrepreneurial opportunities in the field of agriculture, similar findings were reported by Modak et al. (2018) while reporting entrepreneurial competencies of post graduate students. Education also increases their decision-making ability and makes them regard agriculture as a profession rather than a mere family profession. A similar finding is made by Owolabi et al. (2026) where it is observed that youth studying agriculture at the undergraduate level showed favourable perceptions and participated actively in agricultural practices.

Exposure to mass media plays a significant positive role in youth participation as well. Availability of information through TV, mobile and social media increases the awareness about new

technological inputs in farming, government schemes and marketing facilities available. Information through media makes the rural youth more aware about modern methods in agriculture. The results of the study have been found in consonance with the findings of Geethalakshmi et al. (2024) in which it was found that digital and online media play an important role in the dissemination of agricultural information and behavioural change among rural communities. Occupational status and land holdings also positively contribute to youth participation. If the youth are already involved in agriculture or are from an agricultural family, they definitely get more opportunities for participating in agriculture and land holding provides them with the basic means for cultivation. However, their contribution is relatively less than that of education and mass media exposure, showing that just physical inputs alone are not enough for ensuring youth participation in agriculture.

Contact with extension services is yet another important variable affecting participation. Regular contacts with extension staff will result in better availability of scientific inputs, technical help, and institutional support, and consequently will increase confidence of rural youth towards taking up agricultural activities. Owolabi et al. (2026), where it has been stated that consistent practical involvement and institutional guidance greatly contribute to increasing the participation of students in agriculture activities. Even though in their research, authors took up university students, nevertheless, the significance of technical help stated by them supports the current findings. Economic motivation is also an important variable for participation. Youth having a perception about profitability of agricultural activities and expecting better economic gains through agriculture are more likely to take up agricultural pursuits. This reflects increasing transition of agriculture from being a traditional occupation to being an entrepreneurship. Singh et al. (2026) have also reported the same findings stating that the entrepreneurship behaviour among rural youth is significantly related with economic motivation, innovation and business orientation.

However, religion exerts considerable, yet relatively weak, and positive influence on youth participation, which indicates that socio-cultural values continue to influence career choice. Roy et al. (2024) emphasized necessity of creating an adequate method of analysis to improve the quality and scientific relevance of extension research in agriculture. However, some factors such as caste, marital status, family size, family structure, income level, socio-cultural involvement and risk orientation do not play any role whatsoever. It means that socio-demographic characteristics mentioned above are not enough to encourage youth participation provided that education, communication and motivation are taken into consideration. These findings shows light on previous studies done by Jatav (2024) which explains, agriculture as career choice is becoming more and more economic rather than socio-economic status. Generally, findings shows youth participation in agriculture becomes increasingly knowledge-based, information-based and economically motivated. Consequently, implementation of high-quality agricultural education, increase in application of mass media and extension services and encouragement of entrepreneurship program will have a positive impact on youth participation in agriculture.

CONCLUSION

Youth involvement in agriculture depends on their education, mass media exposure, occupation, extension activities, economics, landownership, and religion, thereby indicating that socio-personal, socio-economic, communication, and psychological variables play an important role in influencing youth involvement. Knowledge, information, institutions, and economic incentives have more weightage than demographic characteristics. It can therefore be inferred that by improving education, extension activities and access to reliable agricultural information, as well as promotion of entrepreneurship and communication, youth involvement can be increased in Keralam state. However, the study was limited to Payyannur Block of Kannur District, Keralam therefore, the findings may not be generalized to other regions. Further studies covering different geographical regions and larger samples are recommended to better understand rural youths' perceptions towards agriculture.

DECLARATIONS

Ethics approval and informed consent: The study was approved by the Departmental Advisory Board of Department of Agricultural Extension, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu-603201, Tamil Nadu, India as the part of research programme of first author and was duly cleared for the principals explained in Helsinki 1964 declaration and its modifications. The study was undertaken with due considerations All participants provided informed consent before participating in the study.

Data availability statement: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that during the preparation of this work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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Research Article

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Bibliometric Analysis of Climate-Resilient Agricultural Technologies for Water-Secure Farming

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HIGHLIGHTS

- Agricultural technology has become interdisciplinary, with climate-resilient technologies emerging as a rapidly growing research field.
- Research increasingly focused on climate adaptation, water management, and AI-driven precision agriculture between 2021 and 2026.
- Publications grew annually by 26.14%, peaking in 2025, with India, China, and the United States leading.

ARTICLE INFO

Keywords: Climate-resilient agriculture, Water security, Irrigation efficiency, Drought mitigation, Smart irrigation, Bibliometric analysis, Water-food nexus.

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ABSTRACT

Agriculture in rainfed and water stressed regions is highly vulnerable to climate change due to a number of reasons. The study examined the global development of climate-resilient agricultural technology research from 2021 to 2026, focusing on water security, water-use efficiency, drought alleviation, soil moisture management, and water–food linkages. A bibliometric approach was used in the Scopus database. After applying the filters on year, language and keywords, 1233 documents in English language were excluded in the final set of data. The findings revealed that the number of publications has increased significantly over the years with a rate of 26.14% and a sharp increase in research output since 2023, with the peak year being 2025. The top contributing countries were India, China and the United States while top journals were found to be Science of the Total Environment, Journal of Environmental Management and Agricultural Water Management. Dominant research themes included climate change, food security, drought, irrigation, water scarcity, remote sensing, artificial intelligence, and smart irrigation. The findings provide evidence for guiding research priorities, fostering international collaboration, and supporting evidence-based policies that strengthen climate adaptation, water resource management, and sustainable agricultural development worldwide.

INTRODUCTION

Agriculture in rainfed and water-stressed regions is especially vulnerable because farmers often have limited access to irrigation, climate information, credit, insurance, storage, and technical support. Recent studies report that climate variability affects crop growth, soil fertility, water availability, and food security, thereby making adaptation-oriented agricultural research a central scientific and policy concern (Karri & Nalluri, 2024; Mehra et al., 2024; Nam et al., 2026; Roy et al., 2025; Singh et al., 2026). Ground water depletion, erratic and scanty rainfall, increase in water demand, low water use efficiency, high cost technologies, lack of awareness, training and infrastructure are the major problems in the water secure farming and technologies (Dhaarna & Kashyap, 2025; Qi et al., 2024; Hussen et al., 2026).

There is a growing volume of literature for climate-resilient agriculture in agricultural science, environmental management, water resources, sustainability science and digital technology. Research

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in remote sensing, artificial intelligence, machine learning, smart irrigation, and precision agriculture reflects a growing transition from traditional adaptation approaches to technology-driven, resource-efficient water management practices in agriculture. Concurrently, the adoption of these technologies is uneven, due to the high upfront costs for technology, poor extension service, lack of digital connectivity for many smallholder farmers, and inadequate institutional coordination. The mismatch between technological development and field-level application indicates the need to better understand research structures globally and where future research should be focused (Javed et al., 2025; Ma et al., 2024; Wonneberger et al., 2025; Lekha et al., 2026).

Policy-wise, knowledge of the global research landscape in climate-resilient agricultural technologies is needed to design appropriate adaptation strategies. Bibliometric evidence can help to inform policy decisions on priority areas, including water-efficient irrigation, digital agriculture, climate-smart agriculture, and capacity building. The outputs and results of the global research networks can help guide strategic investments, enhance the linkages between research institutes and agricultural agencies, and enable the transfer of scientific advances to the farm level. Thus, knowledge of the research development timeline in this area can be relevant for structuring technological development and fitting it to the water security and sustainable agricultural policies (Dhawi & Aleidan, 2024; Miller et al., 2024; Oswald-Spring & Jaramillo-Monroy, 2025).

The quantitative mapping of publication growth, influential sources, productive countries, author and institutional cooperation, citation impact and evolution of keywords make the bibliometric approach well suited for further analysis and usage. The analysis may provide a means to deduce a major theme, new technologies, areas of research need, and collaboration trends from a vast pool of literature. It uncovers unique situations, providing researchers and stakeholders with valuable perspectives for future exploration and engagement in related fields (Roy et al., 2024). It also enables evidence-based planning by identifying the mismatch between the current research priorities and the preparedness for drought, irrigation efficiency, water conservation and climate adaptation. Therefore, the present study examines global research on climate-resilient agricultural technologies from 2021 to 2026, with emphasis on water security, irrigation efficiency, drought mitigation, soil-moisture management, smart irrigation, and the water-food nexus.

METHODOLOGY

A bibliometric research design was used to examine global publications on climate-resilient agricultural technologies during 2021 to 2026. The Scopus database was selected as the primary data source because of its extensive coverage of peer-reviewed articles, review papers, book chapters, conference proceedings, and interdisciplinary literature spanning agriculture, environmental science, water resources, climate science, and sustainability. The search query is : (TITLE-ABS-KEY (“Climate resilient” OR “Water security”) AND TITLE-ABS-KEY (“agriculture”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (EXACTKEYWORD, “Agriculture”) OR LIMIT-TO (EXACTKEYWORD, “Drought”) OR LIMIT-TO (EXACTKEYWORD, “Water Security”) OR LIMIT-TO (EXACTKEYWORD, “Irrigation”) OR LIMIT-TO (EXACTKEYWORD, “Climate-resilient Agriculture”) OR LIMIT-TO (EXACTKEYWORD, “Climate Resilient Agriculture”) OR LIMIT-TO (EXACTKEYWORD, “Environmental Impact”)) AND PUBYEAR > 2020 AND PUBYEAR < 2027. Once the year, language, keyword, and subject relevance filters were applied, 1,233 documents remained. Comma-separated values (CSV) files of the bibliographic records were obtained from Scopus. The exported file was subsequently verified for missing fields, duplicate records, inconsistent spelling of author keywords and names of countries, sources and institutions. Minor inconsistencies were fixed for better visualization and descriptive statistics of the network.

RESULTS

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework was employed to facilitate a transparent, systematic, and reproducible process for selecting relevant literature. In bibliometric research, the PRISMA flow diagram strengthens the reliability and transparency of the analysis by presenting a clear account of the records identified, screened, excluded, and ultimately included at different stages of the literature search and selection process.

The analysis process is demonstrated in Figure 1. Biblioshiny and VOSviewer software were used for analysing the dataset. Descriptive bibliometric statistics such as annual production growth, source productivity, document type distribution, authorship pattern, citation impact, co-authorship level, and international collaboration statistics were calculated using the reference processing software Biblioshiny. The keyword co-occurrence network, country

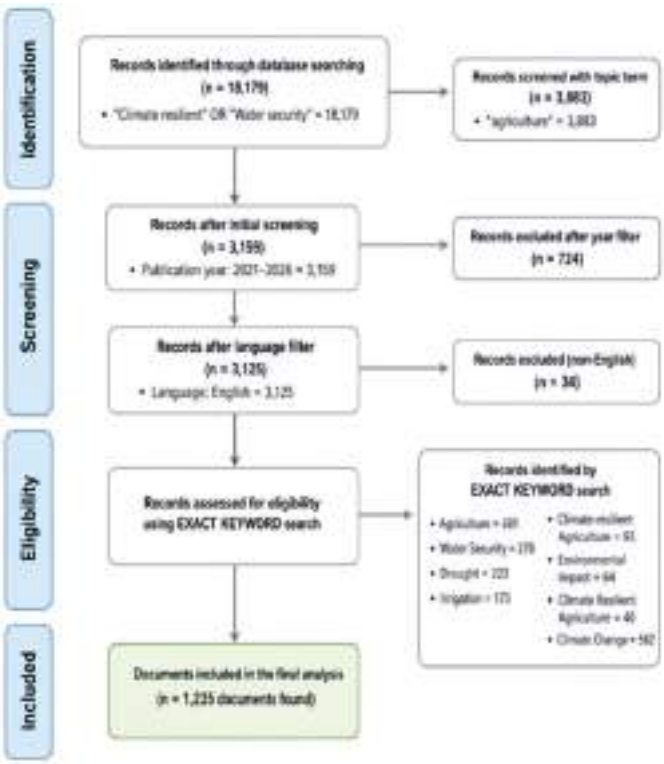


Figure 1. PRISMA

collaboration network, institutional collaboration network, author collaboration network and source-level network were created and visualised using VOSviewer (Vosviewer, 2026). Occurrence thresholds were scaled to the size of the network being considered to prevent the inclusion of meaningless, uninterpretable clusters. The findings were analyzed to detect patterns of publication, the leading countries, sources of influence, collaboration networks, key words, new research areas, and the direction of future research in the field of water-secure and climate-resilient agriculture.

A total of 1,233 documents published across 637 sources were included in the final dataset covering 2021–2026. The field recorded a growth rate of 26.14%, with an average document age of 1.69 years and an average of 11.39 citations per document. A total of 234,597 references, 7,326 Keywords Plus and 3,621 author keywords were included in the dataset. A total of 5,573 authors contributed to the research field, with an average of 5.31 co-authors per document. The collaborative nature of the field was reflected in a high rate of international co-authorship, at 37.79 per cent. The most common document types are articles, followed by reviews, book chapters and conference papers. The main bibliometric profile is presented in Table 1.

The trend of annual publications was evident and had increased throughout the study period. Publication output rose from 88 articles in 2021 to 107 in 2022 and 137 in 2023. It further increased to 185 articles in 2024 and reached the highest level of 435 articles in 2025. When the data were extracted there were 281 articles published in the year 2026. The trend showed that after 2023, research activity has greatly increased, reflecting a growing recognition of the importance of studies on climate adaptation, drought mitigation, irrigation efficiency, water-resource management, and sustainable agriculture. The annual output is given in Table 2.

Table 1. Dataset Bibliometric Profile

Indicator	Result
Timespan	2021 to 2026
Sources	637
Documents	1,233
Annual growth rate	26.14%
Average citations per document	11.39
References	234,597
Keywords Plus	7,326
Author keywords	3,621
Authors	5,573
Single-authored documents	72
Co-authors per document	5.31
International co-authorship	37.79%

Table 2. Annual Publication Output

Year	Articles
2021	88
2022	107
2023	137
2024	185
2025	435
2026	281

The country-wise results revealed that India had the largest number of publications with 245 articles, followed by China with 162 articles and the USA with 87 articles. India contributed 206 single-country publications and 39 multiple-country publications, whereas China recorded 93 single-country and 69 multiple-country publications. At the source level, *Science of the Total Environment* received the highest number of citations (706), followed by *Journal of Environmental Management* (645) and *Agricultural Water Management* (560). The results of the keyword analysis indicated that there was a focus on research themes related to climate change, food security, sustainable agriculture, drought, irrigation, water scarcity, remote sensing, artificial intelligence, machine learning, and smart irrigation. The summary of these results is shown in Table 3.

DISCUSSION

The results suggest that now agricultural technology research has become an interdisciplinary field, and climate-resilient agricultural technology is an emerging and fast-growing research field. The surge in publications since 2023 highlights the rising importance of climate adaptation, food security, and sustainable water management. The focus on drought stress, heat tolerance, soil-water conservation and climate-smart crop management by recent studies on agriculture align well with this trend (Antala et al., 2025; Sugumar et al., 2024; Teferi et al., 2025). The high frequency of water-related terms validates that water availability, water use for irrigation, groundwater conservation and water-food link are four important aspects of agricultural resilience.

The impact of other journals of related interest to environmental management and agricultural water management also

Table 3. Key Findings

Indicator	Major result	Interpretation
Leading countries	India: 245; China: 162; United States: 87	Asian countries contributed prominently, with moderate international collaboration.
Influential sources	Science of the Total Environment: 706 citations; Journal of Environmental Management: 645; Agricultural Water Management: 560	High-impact studies appeared in environmental, water, and agriculture journals.
Dominant keywords	Climate change, food security, sustainable agriculture, drought, irrigation, water scarcity	Research concentrated on adaptation and water-resource challenges.
Emerging keywords	Remote sensing, precision agriculture, machine learning, artificial intelligence, smart irrigation	Digital tools became central to crop-water monitoring and decision support.
Collaboration pattern	37.79 percent international co-authorship; 5.31 co-authors per document	The field was collaborative but required stronger institutional integration.

reflects that water management is not limited to crop science but is also a component of water-resource planning and sustainability studies. The dominance of India, China, and the United States again indicates that research activity is limited to countries where large-scale agriculture is practiced, the developed scientific infrastructure is present, and the climate is largely exposed. But the outcomes of the collaboration also indicate that international cooperation is still unbalanced. The percentage of single country publications, particularly India, is relatively high and reflects the good productivity of the country but points to the need to build more extensive international research collaborations.

This is crucial because climate risks, drought preparedness and water scarcity are transboundary issues that are characterized by the need for sharing data, comparative field studies, and coordinated institutional networks. Research on water security and social organization also indicates that technical solutions work better when they are complemented by local governance, the participation of farmers, and coordination of policies (Dhawi & Aleidan, 2024; Miller et al., 2024; Oswald-Spring & Jaramillo-Monroy, 2025).

The composition of keywords brings out the transition from the previous days' adaptation from past to present, to the present and digital and data-driven agriculture. The terms used in this article suggest increased attention to real-time monitoring, crop water-stress assessment, irrigation planning and decision making support: remote sensing, machine learning, artificial intelligence, precision agriculture, and smart irrigation. In line with the findings of other studies done showing rising application of satellite data, predictive models and digital tools in agricultural modernization and water resource assessment (Arefin et al., 2026; Pandey et al., 2025; Qi et al., 2024). However, that has yet to become a reality in the real world. Smallholder farmers can be limited in access by high costs and limited connectivity, extension services, and lack of digital literacy. Therefore, future research should combine technological innovation with affordability, training, field validation, local adaptation, and policy support so that climate-resilient technologies can move from scientific development to farm-level implementation.

Integrated climate-resilient agricultural approach using artificial intelligence, remote sensing, Internet of Things (IoT)-based monitoring, precision irrigation, and socio-economic evaluations should be further explored in future studies. Developing inclusive innovation ecosystems that support smallholders, enhancing capacity-building and digital literacy initiatives is warranted (Barman et al., 2026) Particular efforts should be undertaken to create low-cost and farmer-friendly solutions that are applicable to smallholder farming systems. Emerging technologies must be tested for effectiveness, scalability, and sustainability through long-term field research, regional adaptation studies, and policy-oriented research.

CONCLUSION

The evidence shows that research is increasingly centered on water security, drought mitigation, irrigation efficiency, soil-moisture management, smart farming, and the water-food relationship. The strongest publication growth after 2023 confirms the rising global importance of resilient and water-secure agriculture. Scientific leadership is limited to a small number of countries, and there is still a need to increase cooperation between both regions and institutions, and disciplines. Future research needs to focus more on these farmers-level factors such as farmer-level adoption, affordable digital instruments, field validation, and policy supports to ensure the adoption of these technologies and transform them into resilient agricultural systems. Areas identified as emerging trends in the literature include: Artificial Intelligence, Machine Learning, Remote sensing, Precision agriculture, Smart irrigation systems and Digital decision-support tools. Researches on field-level validation, cost-effective technology improvement, farmer's behaviour on technology adoption, adaptation strategies in regional level and interdisciplinary studies for better results are required.

DECLARATIONS

Ethical statement/approval: This study used publicly available bibliographic records and did not involve human participants, animals, or confidential information.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability statement: As the data was fetched from publicly available records only analyzed data will be available upon request from the corresponding authors.

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Comparative Impact Analysis of Fruit and Vegetable Preservation Training on Rural Women in Haryana

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HIGHLIGHTS

- Trained women scored 32.75 out of 42 on adoption, against 20.60 for women who never attended a course.
- Education, socio-economic status, information sources and economic motivation raised adoption; age pulled it down.
- Most trainees showed moderate impact and food security carried the highest mean score of the six dimensions.
- Labelling, registration and advertising ranked last even after training, pointing to a gap in entrepreneurial support.

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Keywords: Adoption, Entrepreneurial skills, Food security, Krishi Vigyan Kendra, Post-harvest losses, Value addition.

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ABSTRACT

Post-harvest losses in fruits and vegetables ran high in India, and preservation at the household level gave rural women a way to cut those losses while adding to family income. Krishi Vigyan Kendras in Haryana ran vocational courses on preservation, but little was known about what the courses left behind. The study was carried out during 2025 in Sirsa, Hisar, Jind and Bhiwani and set out to compare adoption between trained and untrained rural women and to measure the impact of training on beneficiaries. Following an ex post facto design, 80 trained and 80 untrained women were interviewed personally with a structured schedule. Weighted mean scores, correlation, regression and an independent samples t-test were applied. Trained women scored far higher on adoption ($t = 37.54$; $p<0.01$), with 71.25 per cent in the medium and 28.75 per cent in the high category. Education, socio-economic status, information sources and economic motivation went with higher adoption, while age worked against it. Labelling, registration and advertising stayed at the bottom even among trained women. Food security recorded the highest mean impact score. Training built technical skill, but the market side needed support of its own.

INTRODUCTION

Fruits and vegetables carry much of the vitamin, mineral and fibre load of an ordinary Indian diet. India grows them in quantity and horticulture now counts among the faster-moving parts of the farm sector (AABMI & MANAGE, 2021). The trouble begins after harvest. Somewhere between 30 and 40 per cent of the produce is lost every year to careless handling, transport, storage and marketing (Kumar et al., 2017). National estimates put fruits and vegetables at the top of the loss table among all commodity groups (Jha et al., 2015). Cold storage is scarce, supply chains are broken into too many hands and market links stay thin, so the losses hold regardless

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of how much a grower knows (Negi & Anand, 2015). Preservation cuts into the problem directly. It slows spoilage, holds nutrients and stretches supply into the lean months (Bathla et al., 2018) and where it takes root, it opens income at the village level (Roy et al., 2013).

Women sit at the centre of food systems across the developing world (World Bank, 2017). In pickle and cashew processing they make up close to 90 per cent of the workforce (Sabharwal & Panwar, 2015) and globally they spend 85 to 90 per cent of their food-related hours on preparing, processing and preserving (FAO, 2011). Much of that work still follows methods handed down at home rather than tested in a laboratory and spoilage follows (Pandey et al., 2017). Training is meant to close that gap (Kulvir & Shivani, 2022). Kaur and Garg (2016) and Kaur and Kaur (2019) found a good share of trainees putting their new skills to use at home. In the farm sector, family size, land size, turnover and annual income directly determine success (Kobba et al., 2021). Rana (2017) noted a gain in social and economic confidence afterwards. Purohit et al. (2015) and Johnson (2015) tied training to better efficiency and to empowerment more broadly. Group-based work has lifted income, savings and awareness among women in allied sectors (Rajkumar et al., 2024) and training built around stated needs is treated as a pillar of value chain development (Nath et al., 2025; Arun Kumar & Nain, 2025).

Haryana grows fruits and vegetables on a wide scale (Department of Industries and Commerce, Government of Haryana, 2018) and its Krishi Vigyan Kendras hold preservation courses for rural women year after year. What those courses leave behind has rarely been measured. Three objectives shape the present work: to set the adoption of preservation practices by trained women against that of untrained women, to trace how selected socio-personal and psychological variables relate to adoption and to gauge the impact of training across six areas of the beneficiaries' lives. Two null hypotheses follow from these. The first holds that adoption does not differ between trained and untrained women. The second holds that the selected independent variables bear no significant relation to adoption or to impact.

METHODOLOGY

Haryana provided the setting and the fieldwork ran through 2025. An ex post facto design suited the situation, since the trainings were already over and the investigator could not manipulate any of the independent variables. Four districts entered the sample on the strength of their area and production under fruits and vegetables, namely Sirsa, Hisar, Jind and Bhiwani. Women who had attended a preservation course at the local Krishi Vigyan Kendra between 2021-2022 and 2023-2024 made up the participant population. Trainee registers held by each Kendra served as the sampling frame. Twenty names were drawn from every district without replacement using a random number table, which gave 80 participants. For the non-participant group, village lists were obtained from the panchayat and the local extension functionary in the same villages that the trainees came from and 20 women were drawn at random from each district. Each of them confirmed at the time of the interview that she had never attended a preservation course, which took the sample to 160.

A structured interview schedule was built around the objectives and tried out on a non-sample group of respondents. Internal consistency proved satisfactory (Cronbach's alpha = 0.84). Subject-matter specialists went through the content for validity before the schedule was finalised and every response was collected face to face. Both groups answered on age, marital status, family type, education, socio-economic status, land holding, training experience, use of information sources, extension contacts, innovativeness, economic motivation and adoption of preservation practices. Adoption covered 14 practices, each rated as fully adopted, partially adopted or not adopted and scored 3, 2 and 1. Weighted mean scores were worked out practice by practice and ranked, while summated scores placed respondents in low, medium and high categories against the mean and standard deviation of the pooled sample. Impact questions went only to the participants, who alone had the exposure needed to answer them and covered food security, skill development, economic empowerment, personal impact, social impact and family impact. Analysis rested on frequency, percentage, weighted mean score, rank order, Pearson's coefficient of correlation, multiple regression and an independent samples t-test.

RESULTS

Adoption level of participants and non-participants regarding preservation practices

Trained women stood well ahead of untrained women on all fourteen practices (Table 1). Their top three were preserving during the harvesting season, keeping preserved products covered and starting with fresh produce. Registration of products for marketing and advertising sat at the bottom. Untrained women ordered the practices in much the same way but scored lower throughout, their best score going to the use of fresh fruits and vegetables. The gap between the two groups ran widest on the technical practices, sterilization and the correct use of preservatives, colours and flavours in particular, where trained women stood more than a full point ahead. It ran narrowest on the three commercial practices. Labelling, registration and advertising ranked last in both groups and both groups sat close to the floor of the scale. Every non-participant returned the lowest possible score on registration, so the small gap there reflects that floor as much as anything the training did or did not achieve.

Table 2 placed 28.75 per cent of participants in the high adoption category and 71.25 per cent in the medium category, with none in the low category. Non-participants split the other way, 46.25 per cent falling in the low category and the rest in the medium category, with no one reaching the high category. Mean adoption stood at 32.75 for participants against 20.60 for non-participants and the independent samples t-test returned a significant difference ($t(158) = 37.54$, $p<0.01$, Cohen's $d = 5.93$).

Relationship between selected variables and adoption level

Seven variables correlated positively and significantly with adoption among participants, namely education ($r=0.374$), information sources ($r=0.348$), socio-economic status ($r=0.342$), economic motivation ($r=0.335$), training experience ($r=0.319$), family type ($r=0.310$) and land holding ($r=0.290$), as set out in Table 3.

Table 1. Adoption level of participants and non-participants regarding preservation practices

Statements	Participants WMS	Rank	Non-participants WMS	Rank
Preservation during harvesting season	2.96	I	2.09	II
Use of fresh fruits and vegetables	2.83	III	2.10	I
Use of stainless-steel utensils	2.66	V	1.83	V
Use of ingredients in correct proportion	2.48	VIII	1.63	VI
Preparation within suggested time frame	2.39	IX	1.09	X
Use of right amount of preservatives, colours and flavours	2.54	VI	1.13	IX
Preserved products are not kept open	2.90	II	2.04	III
Packets of preserved products are properly sealed	2.53	VII	1.61	VII
Sealed packets are kept in airtight containers	2.71	IV	1.85	IV
Sterilization of stored preserved products	2.34	X	1.14	VIII
Packaged preserved products are properly labelled	1.63	XII	1.03	XIII
Registration of products for marketing	1.26	XIV	1.00	XIV
Advertising the products to increase demand	1.59	XIII	1.04	XII
Consideration of total production cost	1.95	XI	1.05	XI

WMS = weighted mean score (maximum score 3).

The same variables mattered for non-participants, though socio-economic status led there (r=0.521). Age carried a weak negative sign in both groups. Marital status, extension contacts and innovativeness fell short of significance either way. Taken together the eleven predictors accounted for 41.2 per cent of the variance in adoption among participants, while the ten available for non-participants accounted for 46.1 per cent. Both models were significant, F(11,68)=4.33 and F(10,69)=5.90 (p<0.01).

Table 2. Comparison of adoption level between participants and non-participants

Category (score range)	Participants (%)	Non-participants (%)
Low (up to 20.25)	0.00	46.25
Medium (20.25 to 33.10)	71.25	53.75
High (above 33.10)	28.75	0.00
Mean	32.75	20.60
Standard deviation	2.39	1.64

t(158) = 37.54**; mean difference = 12.15; standard error of difference = 0.32; Cohen's d = 5.93; **significant at p<0.01 (independent samples t-test, 2-tailed).

Table 3. Relationship between selected variables and adoption level

Variables	Correlation coefficient (r) of participants	Correlation coefficient (r) of non-participants
Age	-0.172	-0.142
Marital status	0.215	0.118
Family type	0.310**	0.319**
Education	0.374**	0.254*
Socio-economic status	0.342**	0.521**
Land holding	0.290**	0.287**
Training experience	0.319**	NA
Information sources	0.348**	0.235*
Extension contacts	0.140	0.210
Innovativeness	0.099	0.192
Economic motivation	0.335**	0.251*
R square	0.412	0.461
Adjusted R square	0.317	0.383
F-value (df)	4.33** (11,68)	5.90** (10,69)

*Correlation significant at p<0.05 (2-tailed); **correlation significant at p<0.01 (2-tailed); NA = not applicable as non-participants had no training exposure.

Impact of training on participant rural women

Most participants landed in the medium band on every one of the six impact dimensions, from 56.25 per cent on family impact to 72.50 per cent on personal impact (Table 4). Food security carried the highest mean at 18.36 and economic empowerment the lowest at 9.66. Standard deviations stayed close across dimensions, which suggested fairly uniform responses. Social impact drew the largest share into the high category at 25.00 per cent, while economic empowerment and food security drew the smallest at 8.75 per cent each.

Table 5 showed education (r=0.959), information sources (r=0.775), socio-economic status (r=0.400), economic motivation (r=0.362), extension contacts (r=0.285), training experience (r=0.272) and land holding (r=0.255) correlating positively and significantly with overall impact. Age ran the other way (r=-0.301). Marital status, family type and innovativeness showed no significant relation. Education returned the strongest coefficient of any variable in the study.

DISCUSSION

The distance between the two groups points towards the training. Participants have practised under supervision and practice is what turns instruction into habit, whereas the untrained women work from methods picked up informally without that grounding (Pandey et al., 2017). How far the design can carry that reading is another matter. An ex post facto study cannot separate the training from the women who chose it. Those who enrol at a Kendra may already be more motivated, better exposed or better supported at home than those who stay away and some part of the gap belongs to that difference rather than to the course. With no baseline reading on the participants, the untrained group works as a comparison group and nothing stronger. Similar gaps between beneficiaries and non-beneficiaries turn up in other women-centred programmes (Pandey & Kritika, 2026). Samantaray et al. (2020), Bora and Deka

Table 4. Distribution of participants across dimensions of training impact

Category	Food security	Skill development	Economic empowerment	Personal impact	Social impact	Family impact
Low (<Mean-SD)	21.25	20.00	21.25	13.75	15.00	23.75
Medium (Mean±SD)	70.00	68.75	70.00	72.50	60.00	56.25
High (>Mean+SD)	8.75	11.25	8.75	13.75	25.00	20.00
Mean	18.36	12.70	9.66	13.09	10.29	9.89
SD	1.94	1.60	1.57	1.49	1.62	1.70

Figures denote percentage of participants; SD = standard deviation.

Table 5. Relationship between selected variables of participants and impact of training

Variables	Correlation coefficient (r)
Age	-0.301**
Marital status	0.177
Family type	0.080
Education	0.959**
Socio-economic status	0.400**
Land holding	0.255*
Training experience	0.272*
Information sources	0.775**
Extension contacts	0.285*
Innovativeness	0.073
Economic motivation	0.362**

*Correlation significant at p<0.05 (2-tailed); **correlation significant at p<0.01 (2-tailed).

(2021) report trained women at a moderate level of adoption against a low level among the untrained, while Fatima and Nishad (2017) and Anju and Dahiya (2021) find both groups preserving but the trained group doing so more thoroughly.

The correlates hold few surprises. Schooling and a stronger economic position widen a woman's access to scientific information and her willingness to act on it. Joint families seem to free up the time and the hands that a new practice demands. For the untrained group, land and access to information appear to stand in, at least partly, for the training they never received. The negative pull of age fits Hada and Bansal (2017), Buraka Kanthisri and Sreenivasarao (2018) and Dharshini Priya et al. (2026), all of whom find younger and better-schooled women more responsive to extension programmes. The regression figures deserve a lighter reading than the correlations. Eleven predictors against eighty cases work out to about seven cases per predictor, short of what the method usually asks for and education, socio-economic status and information sources overlap in what they measure. The individual coefficients are therefore indicative rather than settled.

The weak spot lies inside the trained group itself. Labelling, registration and advertising remain the least adopted practices even after training, which says the course builds the technical hand better than the commercial one. Not all of that sits with the trainer. Labelling and registration need packaging suppliers, testing facilities and organised outlets, and rural Haryana is thin on all three (Negi & Anand, 2015). The clustering of respondents in the medium impact band, with family impact and economic empowerment at the lower end, tells a similar story, since confidence and knowledge come first and money later. Hardly anyone reaches the high category on any dimension, which argues for refresher contact rather than a single course (Bharath et al., 2024). The correlation of 0.959 between education and impact towers over everything else in the study and is unlikely to be a plain bivariate relationship. Several impact items turn on information seeking and record keeping, both of which depend on schooling, so the two scales probably overlap in what they capture and the coefficient is not read here as an effect size. The wider picture matches Poshiya et al. (2019), Kumar and Sharma (2018), Sindhu (2019) and Kumar (2025) who describe trained women preserving surplus, feeding their families more evenly through the year and finding a fresh line of income.

CONCLUSION

Trained rural women adopt preservation practices well ahead of untrained women and the lead holds across almost all fourteen practices studied. The pattern fits a training effect, though the design leaves room for self-selection, so the result reads as a strong association rather than settled proof of cause. On the six impact dimensions mostly, trained women show moderate change, strongest in food security and weakest in economic empowerment and family impact. Scientific training therefore does useful work but stops short of the market. Short hands-on modules on labelling, registration and marketing, backed by links to packaging and certification services, would carry it further. Whether these gains last, and whether entrepreneurship support closes the commercial gap, is worth following up.

DECLARATIONS

Ethics approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Extension Education, CCSHAU, Hisar, India waived the ethical approval. The purpose of the study was explained to every respondent, prior informed consent was obtained, participation was voluntary and the responses were kept anonymous and used solely for research purposes.

Conflict of interest: The authors declare that they have no conflict of interest, financial or non-financial, in relation to the subject matter of this manuscript.

Data availability statement: Data is available upon reasonable request from the first author as well as corresponding author.

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Market Participation and Income Distribution among Women Cassava Marketers in Anambra and Imo States, Nigeria

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HIGHLIGHTS

- Women marketers exhibited high participation in cassava marketing activities, experience significantly increased market participation.
- Market associations enhanced women's marketing involvement.
- Digital marketing participation remained very low and extension support can reduce marketing inequality among women.

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ABSTRACT

Marketing of Cassava is a major livelihood activity of the rural women in South-East Nigeria, yet the differences in market participation and income distribution exist. This study examined income distribution and market participation among women processed cassava marketers in Imo and Anambra States, Nigeria during the 2025 marketing season. A multistage sampling technique was used to select 368 respondents from eight major market through the use of a structured questionnaire. Data were analyzed using descriptive statistics, the Gini coefficient, participation index, multiple regression, and probit regression models. The pooled Gini coefficient of 0.39 showed moderate income inequality and the overall market participation was high (82.64%) in product regulation, standardization, value addition, cooperative sales management, stakeholder decision-making, and price advocacy. The marketing experience ($P<0.01$) and market association membership ($P<0.01$) significantly increased market participation. Education ($P<0.01$) significantly influenced income distribution in Anambra, while marketing experience and marital status significantly influenced income distribution in Imo State and the pooled sample. Strengthening extension education, entrepreneurial capacity, and market institutions can enhance participation and income equality.

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INTRODUCTION

Cassava (*Manihot esculenta Crantz*) remains a strategic food security and income-generating root crop in sub-Saharan Africa, assisting millions of rural households through production, processing, and marketing activities. Globally, cassava production has increased steadily, with annual growth surpassing 3%, making it one of the fastest growing food crops in tropical regions (Obot et al., 2023). Africa contributes a substantial proportion of global cassava production, with Nigeria being recognised as one of the leading producers. Beyond its role as a staple crop, cassava has developed into an important commercial commodity that aids agro-processing enterprises, employment generation, and rural economic development through activities such as processing, aggregation, distribution, and marketing (Udemezue et al., 2019).

The increasing commercialization of cassava has created opportunities for rural entrepreneurs to participate in increasing agricultural value chains. Subsequently, the ability of small-scale marketers to benefit from these opportunities is influenced by access to productive resources, financial services, marketing information, infrastructure, and institutional support. Limited access to these resources may limit enterprise growth, decline competitiveness, and add to variations in economic results among market participants (Eerdewijk & Danielsen, 2015; Gebre et al., 2021). These challenges show the importance of effective value chain governance mechanisms that promote inclusive participation and equitable distributions of benefits among marketers. Agricultural commercialization and entrepreneurship are increasingly recognized as pathways for improving rural livelihoods by enhancing market integration, value addition, income generation, and economic empowerment (Nain et al., 2019; Kademani et al., 2020). Entrepreneurial capabilities, innovation adoption, and access to market linkages influenced the performance of agricultural enterprises (Gupta et al., 2023; Licciardo et al., 2023). Similarly, socioeconomic characteristics such as education, experience, institutional membership, access to information shape participation and performance in agricultural markets (Ajah et al., 2022). Extension education plays important role in assisting commercialization through the provision of technical knowledge, market intelligence, entrepreneurial skills, and networks to institutional resources. Raghavendra et al. (2023) reported that awareness and participation in electronic agricultural marketing systems are significantly influenced by access to information and institutional support, while Sangappa et al. (2023) showed that strengthening value chain linkages through farmer organizations facilitates market access and income opportunities among agricultural actors.

Evidence from CGIAR-related research further shows that women's empowerment within agricultural value chain is influenced by access to markets, training, extension services, and supportive institutions (Quisumbling et al., 2021). Furthermore, Banerjee et al. (2014), in a World Bank study, reported that unequal access to productive resources and agricultural services contributes to persistent gender differences in agricultural performance among women farmers in Africa.

Although, past studies have examined cassava production, profitability, and market participation in Nigeria, limited empirical evidence exists on the relationship between market participation and income distribution among women processed cassava marketers. Existing studies have largely focused on the determinants of participation, profitability, or marketing efficiency, with limited attention to how differences in market participation translate into income differences among women entrepreneurs. Understanding this relationship is essential for formulating policies and extension interventions that promote inclusive commercialization and equitable livelihood results.

METHODOLOGY

The study was carried out in Imo and Anambra States, South-East, Nigeria. These states were selected purposively due to their active participation in cassava value chain activities. Anambra lies between latitudes 5°38′N and 6°47′N and longitudes 6°36′E and 7°21′E of the greenwich meridian, with 21 Local Government Areas (LGAs) across four agricultural zones (Awka, Anambra, Aguata, and Onitsha). it has a projected population of 5,720,035 and about 4,416 km^2 land area, with approximately 70% arable land (NBS, 2021). Imo State lies between latitudes 5°12′N and 5°56′N and longitudes 6°38′E and 7°25′E of Greenwich meridian, consisting of 27 LGAs and a projected population of 5,265,082 (Imo State Government, 2021). Agriculture dominates livelihoods in both states, with cassava marketing being highly visible.

A multistage sampling procedure was adopted. In stage one, four major markets were purposively selected from each states based on marketing intensity. In Anambra, Eke Awka, Nkwo Nnewi, Nkwo Ogbe-Ihiala, and Eke Ekwulobia were selected, while Ekeukwu Owerri, Eke Okigwe, Afor Ogbe, and Ahiazu Mbaise International Market were selected in Imo State.

The sample was determined using Cochran's (1977) sample size formula for finite population. A 95% confidence level (Z = 1.96), 5% margin error (e = 0.05), and an assumed population proportion of 0.50 were adopted because no prior estimate of target characteristic was available. The initial sample size was estimated as:

$$n_o = \frac{Z^2\, P(1-P)}{e^2} \quad \text{... (1)}$$

Where, n_o = initial sample size, Z = 1.96 at the 95% confidence level, P = 0.50, e = 0.05.

Since the sample frame consisted of 922 registered women cassava marketers, the finite population correction was applied:

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}} \quad \text{... (2)}$$

Where, N = 922. The calculated sample size was proportionately allocated among the chosen markets, leading to 368 respondents. Proportionate random sampling was used to select 186 respondents from Anambra State and 182 respondents from Imo State.

Primary cross-sectional data were collected in the 2025 marketing season with the use of structured questionnaire covering socioeconomic characteristics, income levels, marketing experience, participation intensity, and income distribution factors. The questionnaire was validated by Agricultural Economics experts and achieved a Cronbach's alpha of 0.90, indicating high reliability.

Descriptive statistics (frequencies, percentages, and means) were used for preliminary analysis. Income inequality was measured using the Gini coefficient adopted from Anyaegbu et al. (2020). the model is specified as follows:

$$G.C = 1 - \sum_{i=1}^{n} F_i P_i \quad \text{... (3)}$$

Where, *G.C* = Gini Coefficient, F_i = Proportion of women cassava marketers' income in the ith Class (Naira), and P_i = Cumulative Proportion of women cassava marketer's income in the ith Class (Naira). i = i^{th} women processed cassava marketers in the study area.

The Gini coefficient was used to assess the degree of income inequality among women processed cassava marketers. The coefficient ranges from 0 to 1, with values closer to 0 indicating greater income equality and values closer to 1 indicating higher inequality. The categorization of inequality levels was based on the criteria proposed by Ahlin and Jeong (2021).

The level of market participation among women processed cassava marketers was evaluated using the participation Index (PI), which expresses the ratio of an individual's actual participation score to maximum obtainable participation score. The approach adopted in related participation studies, the index is expressed as:

$$P_i = \frac{ACP_i}{TOP_i} \quad \text{... (4)}$$

Where, PI_i = Participation Index, ACP_i = Actual Participation (Score), *TOP* = Total Participatory Level Obtainable (Score).

Higher Participation Index values indicate greater involvement in cassava marketing activities, while lower values reflect limited participation.

A binary Probit regression model was employed to identify socioeconomic factors influencing income inequality among women cassava marketers. The Probit model was preferred because it assumes a cumulative normal distribution of the latent response variable and is widely applied when the dependent variable is dichotomous. Although Logit and Probit models often produce similar results, the Probit specification provides efficient estimates under the assumption of normally distributed error terms and has been widely adopted in agricultural economics studies. The model as used by Nathan and Rosli (2016) was adopted for this study and the model is specified as;

Y = (1, if the respondent belongs to the high - income inequality
0, if the respondents belongs to a low - income inequality)

$$Y_i = \beta X_i + \varepsilon_i \quad \text{... (5)}$$

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \varepsilon_i \quad \text{... (6)}$$

Y = Income Inequality (1, high income inequality; 0, otherwise),

Respondents were classified into the high-income inequality category using the predetermined income threshold adopted in this study (mean monthly income). This binary transformation enabled estimation of the probability that respondents belonged to the higher income inequality category as a function of their socioeconomic characteristics.

β is the estimated vector of parameters, and X_i is the vector of observed nonrandom explanatory variables.

Where, i = Number of Independent Variables, β_0 = Constant Term, $\beta_1 - \beta_9$ = Regression Coefficients, X_1 = Marital Status of the Processed Cassava women marketers (1, Married; 0, Otherwise), X_2 = Size of Households (Total Number of Persons), X_3 = Level of Education (Years),

X_4 = Marketing Experience (Years), X_5 = Amount of Credit accessed (Naira), X_6 = Membership of Market Association (1, Member; 0, Otherwise), X_7 = Age (Years), X_8 = Distance to Market (Proxied by Time spent in getting to the market in hours), X_9 = Level of Market Participation (1, Participated, 0, Otherwise) and U_i = Error Term.

Multiple Regression Analysis, following Onoja et al. (2013), was used to determine the factors influencing the level of market participation among women processed cassava marketers in the study area. Four alternative functional forms (Linear, Semi-log, Double-log, and Exponential) were estimated to identify the most appropriate empirical specification. The lead equation was selected based on a combination of statistical and econometric criteria, including the magnitude of the adjusted coefficient of determination (Adjusted R^2), overall significance of the F-statistic, statistical significance of individual regression coefficients, conformity of coefficient signs with a priori expectations, and economic interpretability. The model satisfying these criteria most adequately was selected for discussion. The model is specified as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon_i \quad \text{... (7)}$$

Where, Y_i = Participation Index (Number), X_1 = Educational Level (Years), X_2 = Years of Experience (Years), X_3 = Age of Farmer (Years), X_4 = Household Size (Units), X_5 = Membership of Market Association (1, Member; 0, Otherwise), X_6 = Amount of Credit Accessed (₦), and X_7 = Income (₦), εi = Errors Term.

To ensure the validity and reliability of the estimated regression model, several post-estimation diagnostic tests were conducted. Multicollinearity among the explanatory variables was assessed using the Variance Inflation Factor (VIF), with VIF values below 10 showing the absence of serious multicollinearity. Homoscedasticity of the residuals was examined using the Breusch-Pagan/Cook-Weisberg test, while the normality of the residuals was evaluated using the Shapiro-Wilk test. Independence of the errors in the multiple regression models was assessed using the Durbin-Watson statistic, with values close to 2 showing no evidence of serial correlation. For the probit regression model, goodness-of-fit was evaluated using the Log Likelihood, Log likelihood Ratio (LR) Chi-square statistics, McFadden's Pseudo R^2, and classification accuracy. The LR Chi-square test was used to assess the overall significance of the model, while the Pseudo R^2 measured the explanatory power of the model. Classification accuracy was computed as the percentage of correctly classified observations based on the estimated probabilities.

RESULTS AND DISCUSSION

Marketers in Imo State recorded a higher mean income of ₦ 167,265.10, Anambra State recorded ₦ 136,000.52 and the pooled

Table 1. Income Distribution and Gini Coefficient of Women Cassava Marketers

State	NR	MMI (₦)	CMI (₦)	Gini coefficient	Level of inequality
Imo	182	167,265.1	398,250.24	0.42	High inequality
Anambra	186	136,000.52	377,779.22	0.36	Moderate inequality
Pooled	368	151,459.63	388,447.50	0.39	Moderate inequality

Source: Field Survey Data, 2025 <0.31 (Low Inequality), 0.31 – 0.40 (Moderate Inequality), 0.41 – 0.50 (High Inequality), NR (Number of respondents), MMI (Mean Monthly Income), CMI (Cumulative Mean Income)

Figure 1. Income Distribution using Lorenz curve for processed cassava women marketers in the study area (pooled)

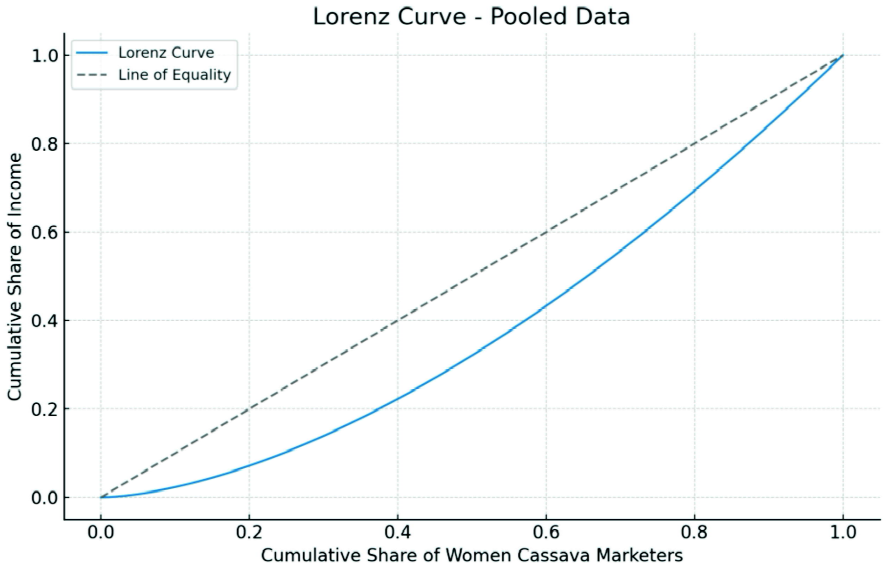


Table 2. Categorization of Level of Participation

Imo	Participation Index Range	Participation Level	Frequency	Percentage
	0.00 – 0.39	Low Participation	0	0.00
	0.40 – 0.69	Moderate Participation	16	8.79
	0.70 – 1.00	High Participation	166	91.21
Total			182	
Anambra	0.00 – 0.39	Low Participation	4	2.15
	0.40 – 0.69	Moderate Participation	47	25.27
	0.70 – 1.00	High Participation	135	72.58
Total			186	
Pooled	0.00 – 0.39	Low Participation	4	1.04
	0.40 – 0.69	Moderate Participation	63	16.32
	0.70 – 1.00	High Participation	301	82.64
Total			368	

Source: Field Survey, 0.00 – 0.39 (Low Participation), 0.40 – 0.69 (Moderate Participation), 0.70 – 1.00 (High Participation)

Table 3. Marketing Activities Participation by Processed Cassava Women Marketers in Imo and Anambra States

Marketing Activity Name	Imo Mean Participation	Imo State Participation Level	Anambra Mean Participation	Anambra State Participation Level	Mean Participation	Remark
Cassava Product Regulation	3.6	Heavily Participated	2.8	Fairly Participated	3.2	Heavily Participated
Cassava Quantity Regulation	2.9	Fairly Participated	1.9	Infrequently Participated	2.4	Fairly Participated
Cassava Product Standardization	3.4	Heavily Participated	3.0	Heavily Participated	3.2	Heavily Participated
Price Violator Taskforce Committee	2.9	Fairly Participated	2.4	Fairly Participated	2.7	Fairly Participated
Stakeholder Decision Making	3.4	Heavily Participated	3.4	Heavily Participated	3.4	Heavily Participated
Cassava Marketing Committee	3.6	Heavily Participated	2.9	Fairly Participated	3.3	Heavily Participated
Committee on Use of Standard Measurement	2.6	Fairly Participated	2.2	Fairly Participated	2.4	Fairly Participated

Table 3 contd...

Marketing Activity Name	Imo Mean Participation	Imo State Participation Level	Anambra Mean Participation	Anambra State Participation Level	Mean Participation	Remark
Value Addition Practices	3.4	Heavily Participated	3.2	Heavily Participated	3.3	Heavily Participated
Market Access Coordination	2.4	Fairly Participated	2.4	Fairly Participated	3.0	Fairly Participated
Financial and Digital Platforms	1.8	Infrequently Participated	1.8	Infrequently Participated	1.8	Infrequently Participated
Market Survey and Exploration	2.6	Fairly Participated	2.5	Fairly Participated	2.6	Fairly Participated
Cooperative Sales Management	3.6	Heavily Participated	3.4	Heavily Participated	3.5	Heavily Participated
Transport and Packaging Management	2.6	Fairly Participated	2.4	Fairly Participated	2.5	Fairly Participated
Market Price Advocacy	3.6	Heavily Participated	3.0	Heavily Participated	3.3	Heavily Participated
Quality Assurance Monitoring	2.6	Fairly Participated	2.0	Fairly Participated	2.3	Fairly Participated

Source: Computed from Field Survey (2025) Heavily Participated = 3.0 <above, Fairly Participated = 2.0 – 2.9, Infrequently Participated = 1.0 – 1.9, μ= Mean Value

Table 4. Determinants of Level of Market Participation by Women Cassava Marketers

Explanatory Variable	Anambra State				IMO State			
	+Linear	Exponential	Double-Log	Semi-Log	Linear	Exponential	+Double-Log	Semi-Log
Constant	0.965	-0.096	0.768	1.533	0.970	-0.068	0.143	1.233
	(6.905)	-(0.495)	(0.919)	(2.287)	(7.701)	-(0.507)	(0.248)	(2.287)
Education	0.005**	0.008*	0.097	0.068	0.004	0.005	0.083	0.068
	(1.753)	(1.737)	(1.294)	(1.253)	(1.155)	(1.325)	(1.436)	(1.253)
Marketing Experience	0.005**	0.003**	0.083**	-0.049	-0.003	-0.003	-0.058	-0.049
	(2.367)	(2.166)	(2.836)	-(1.243)	-(0.727)	-(0.847)	-(1.373)	-(1.243)
Age	-0.006**	-0.007**	-0.263*	0.015	0.001	0.001	0.019	0.015
	-(2.390)	-(2.052)	-(1.606)	(0.133)	(0.246)	(0.221)	(0.157)	(0.133)
Household Size	-0.002	-0.002	-0.005	-0.096**	-0.013**	-0.011**	-0.087**	-0.096**
	-(0.431)	-(0.264)	-(0.118)	-(2.475)	-(2.180)	-(1.805)	-(2.102)	-(2.475)
Market Association	0.086**	0.090*	0.040	0.032	0.026	0.040*	0.043*	0.032
	(2.514)	(1.881)	(0.787)	(1.270)	(1.082)	(1.534)	(1.606)	(1.270)
Amount of Credit	-0.00000041**	-0.0000006.1**	-0.081*	0.012	0.000000065	0.000000073	0.013	0.012
	-(2.080)	-(2.225)	-(1.943)	(0.914)	(0.639)	(0.674)	(0.894)	(0.914)
Farm Income	0.000000027**	0.00000034**	0.044*	-0.033*	-0.00000014	-0.00000016*	-0.032*	-0.033*
	(2.340)	(2.091)	(1.551)	-(1.687)	-(1.453)	-(1.578)	-(1.527)	-(1.687)
R^2	0.503	0.485	0.453	0.469	0.597	0.637	0.760	0.800
Adj R^2	0.471	0.453	0.414	0.431	0.223	0.264	0.393	0.434
F Statistics	6.404**	5.714**	3.897**	4.390**	1.597*	1.710*	2.069**	2.186**
Observation	186				182			

Source: Field Survey Data Analysis, 2025 P< 0.05 = * and P < 0.01 = ** +Lead Equation Values in parentheses are the t ratio

Table 5. Pooled Data on Level of Market Participation by Women Cassava Marketers

Explanatory Variable	Linear	Exponential	Double-Log	+Semi-Log
Constant	0.990	1.365	0.441	-0.056
	(9.942)	(3.288)	(0.839)	-(0.430)
Education	0.012	0.143	0.197	0.017
	(5.161)	(4.097)	(4.442)	(5.815)
Marketing Experience	0.005	0.057	0.078	0.006**
	(2.476) **	(3.282)	(3.548)	(2.413)
Age	-0.006	-0.246	-0.316	-0.008
	-(3.553)	-(2.986)	-(3.029)	-(3.510)
Household Size	-0.006	-0.017	-0.012	-0.005
	-(1.327)	-(0.686)	-(0.384)	-(0.944)
Market Association	0.060	0.055**	0.054**	0.069**
	(2.719) **	(2.464)	(1.891)	(2.411)

Table 5 contd...

Explanatory Variable	Linear	Exponential	Double-Log	+Semi-Log
Credit Amount	0.0000000041	0.006	0.004	-0.000000012
	(0.041)	(0.438)	(0.217)	-(0.091)
Income	-0.0000000018	-0.008	-0.009	-0.00000000052
	-(0.025)	-(0.596)	-(0.530)	-(0.005)
R^2	0.556	0.525	0.534	0.568
Adj R^2	0.539	0.507	0.516	0.552
F-Statistic	9.487	6.866	7.387	10.374
Mean VIF	2.02	2.02	2.02	2.012
Breusch-Pagan Test	1.84(0.175)	1.81(0.165)	2.03(0.152)	2.12(0.148)
Observation	368			

Source: Field Survey Data, 2025. P< 0.05 = * and P < 0.01 = ** +Lead Equation Values in parentheses are t ratio

Table 6. Probit Regression on Socio-economic Factors Influencing Income Distribution of Women Cassava Marketers

Variable	Anambra State			Imo State			Pooled Data		
	β	SE	z-value	β	SE	z-value	β	SE	z-value
Household Size	-0.005	0.034	-0.147	0.060	0.082	0.732	0.036	0.048	0.75
Education	0.093**	0.025	3.72	-0.050	0.059	0.847	-0.036	0.034	-1.059
Marketing Experience	0.001	0.014	0.071	0.182	0.049**	3.712	0.099	0.028**	3.536
Amount of Credit	0.0000010	0.0000012	0.898	0.0000011	0.0000014	0.813	-0.00000081	0.000000082	-0.982
Age	-0.020	0.015	-1.333	-0.045	0.038	1.184	-0.030	0.022	-1.364
Distance to market	0.001	0.001	1.000	0.001	0.001	1.000	0.001	0.001	1.000
Marital Status	-0.277	0.311	-0.890	-2.089	0.802*	-2.605	-1.100	0.395*	-2.785
Level of Participation	-1.493**	0.223	-6.695	0.016	0.404	0.040	-0.019	0.238	-0.080
Marketing Association	-0.243	0.243	-1.000	-0.291	0.343	-0.848	-0.230	0.202	-1.139
Cox & Snell Pseudo R^2	0.470			0.192			0.194		
Chi Square	366.976**			338.182**			270.594		
-Log likelihood	250.104**			271.987**			271.594		
Mean VIF	1.011			1.100			1.021		
Tolerance	0.791			0.810			0.989		
Durbin-Watson	1.911			1.802			1.902		
Classification Accuracy	85%			85%			80%		
Normality	Satisfied			Satisfied			Satisfied		
Homoscendacity	Satisfied			Satisfied			Satisfied		

Source: Field Survey Data, 2025. Using SPSS * p < 0.05; ** p < 0.01 β = Coefficient SE = Standard Error

mean monthly income was ₦ 151,459.63. This observed differences may be attributed to differences in market participation intensity, business experience, volume of cassava handled, and access to productive resources. This findings agrees with Obianefo et al. (2021), who reported that differences in access to productive resources, credit infrastructure, and institutional support influences the economic performance of women engaged in agricultural activities. The observed variations in income distribution among women cassava marketers have important implication for extension education, agricultural policy, and rural development. The findings suggest that improving women's economic outcomes requires more than increasing market participation; it requires targeted interventions that address differences in access to productive resources, market information, financial services, and capacity-building opportunities. Agricultural extension programmes should therefore increase beyond production-focused advisory services to include training on enterprise management, value addition, financial literacy, record keeping, and market linkage strategies that can enhance the competitiveness of women marketers.

Moreover, the Gini coefficient analysis shows the existence of income inequality among women marketers in Anambra and Imo States. The estimated Gini coefficients were 0.36 for Anambra State, 0.42 for Imo State, and 0.39 for the pooled sample. Based on the adopted classification criteria, the value of 0.36 shows a moderate level of income inequality in Anambra State, while the value of 0.42 represents a high level of income inequality among marketers in Imo State. Similarly, the pooled Gini coefficient of 0.39 shows a moderate level of income inequality across the study area. The relatively higher inequality recorded in Imo State implies greater differences in income distribution among marketers, which may be associated with differences in marketing scale, access to financial resources, market opportunities, business experience, and operational capacity. Conversely, the moderate inequality recorded in Anambra State and the pooled sample indicates that although differences exist in marketers' income levels, income concentration is comparatively less pronounced.

These findings agrees with Obianefo et al. (2021), who reported that women involved in agricultural cooperatives in South-East

Nigeria experience differences in access to productive resources, including credit, infrastructure, improved technologies, and extension services, which may contribute to differences in economic performance. The result also agrees with Okafor et al. (2023), who noted that cooperative participation, access to information, training, and institutional support enhance women's involvement and livelihood outcomes in agricultural activities. These studies reinforce the current findings by showing that structural factors, including differences in scale of operation, access to transportation, financial services, and market information, continue to influence income distribution among women cassava marketers.

The observed deviation of the curve from the curve from the line of perfect inequality indicates the presence of income disparities, consistent with the pooled Gini coefficient of 0.39. Overall, the findings highlight the persistence of income disparities among women cassava marketers and emphasize the need for policies that promote equitable access to productive resources, strengthen market participation, and improve income-generating opportunities.

In Imo State, 91.21% of respondents recorded high participation, while 8.79% were at a moderate level. In Anambra State, 72.58% exhibited high participation and 25.27% moderate participation. The pooled result indicates that 82.64% of respondents had high participation, while 16.32% recorded moderate engagement. This suggests active involvement of women in cassava marketing, with stronger participation intensity in Imo State, possibly due to better cooperative structures, improved access to market opportunities, and stronger institutional support. In contrast, lower participation in Anambra may reflect infrastructural constraints and weaker information networks. This agrees with Obot et al. (2023), Udemezue (2023), Bamigboye et al. (2024) and Kademani et al. (2024) who linked participation levels to institutional support, infrastructure, and access to market information.

Further analysis of specific activities shows variation across roles. Participation was generally high in cassava product regulation and stakeholder decision-making in both states. However, cassava quality regulation and standardization were more active in Imo than Anambra. Membership in committees such as price monitoring and standard measurement was moderate in both states, while participation in marketing committees was high in Imo and moderate in Anambra. These findings align with Azeez et al. (2021), highlighting the importance of cooperative institutions in strengthening engagement and regulatory compliance within agricultural markets.

The linear, double-log, and semi-log functional forms were selected as lead models for Anambra, Imo, and the pooled sample, respectively. The R^2 values were 0.503 (Anambra), 0.760 (Imo), and 0.568 (pooled), indicating that the explanatory variables explained a substantial proportion of variation in participation. The F-statistics were significant at 1%, confirming model adequacy. Results show that education, marketing experience, age, household size, association membership, credit access, and income significantly influenced participation. Education had a positive effect in Anambra, implying that higher schooling improves market access and managerial ability, consistent with Obisesan (2018). Marketing experience was positive and significant across all models, indicating that accumulated knowledge and networks enhance participation, in line with Andaregie et al. (2021) and Zakari et al. (2023). Age was negatively significant in Anambra, suggesting lower participation among older women. Membership in market associations positively influenced participation, highlighting the role of collective action (Mango et al., 2017). Household size negatively affected participation in Imo, reflecting increased domestic pressure. Credit access also showed a negative effect, possibly due to diversion or repayment constraints. Income had mixed effects, positive in Anambra but negative in Imo, suggesting context-specific use of earnings in marketing activities.

The diagnostic tests confirmed that the estimated models satisfied the principal econometric assumptions for the Anambra, Imo, and pooled datasets. The mean Variance Inflation Factor (VIF) values of 1.011, 1.100, and 1.021, respectively, indicated the absence of serious multicollinearity among the explanatory variables. Similarly, the tolerance values of 0.791, 0.810, and 0.989 were above the acceptable threshold, further validating the independence of the explanatory variables. The homoscedasticity and normality tests confirmed that the models satisfied the assumptions of constant error variance and normally distributed residuals. In addition, the Durbin–Watson statistics of 1.911, 1.802, and 1.902 were close to the benchmark value of 2, suggesting that serial correlation was not a concern.

The Probit models demonstrated satisfactory goodness-of-fit across the three datasets, as indicated by the statistically significant Likelihood Ratio (LR) Chi-square values of 366.976, 338.182, and 270.594 ($p < 0.01$) for Anambra, Imo, and pooled samples, respectively. This implies that the explanatory variables jointly provided significant information in explaining variations in income distribution among women cassava marketers. The Cox and Snell Pseudo R^2 values of 0.470, 0.192, and 0.194 showed that the models explained approximately 47.0%, 19.2%, and 19.4% of the variations in income distribution, respectively. Although the explanatory power of the Imo and pooled models appears relatively modest, such values are considered acceptable in social science research where behavioural outcomes are influenced by several socioeconomic factors (Ozili, 2022). Furthermore, the classification accuracies of 85%, 85%, and 80% indicate good predictive performance, confirming the suitability and robustness of the estimated Probit models.

The results revealed that education and level of participation significantly influenced income distribution in Anambra State. Education exerted a positive and significant effect at the 1% level, indicating that women with higher educational attainment were more likely to achieve better income outcomes due to improved managerial skills, bargaining capacity, and access to market information. Conversely, the level of participation had a negative and significant influence, suggesting that inadequate involvement in marketing activities limits income-generating opportunities. In Imo State, marketing experience positively and significantly affected income distribution, implying that experienced marketers possess better knowledge of market dynamics, risk management strategies, and opportunities for improved returns. However, marital status had a negative and significant effect, suggesting that family responsibilities

may constrain resources available for business expansion and reinvestment. Overall, the findings highlight education, participation intensity, marketing experience, and marital status as important socioeconomic drivers of income distribution among women cassava marketers in the study area.

CONCLUSION

The findings revealed moderate income inequality 0.39 despite a high level of market participation, particularly in product regulation, value addition, cooperative marketing, and stakeholder decision-making. Education, marketing experience, association membership, household size, age, and credit access significantly influenced market participation, while education, marketing experience, marital status, and participation level significantly affected income distribution. Strengthening women's entrepreneurial capacity through extension education, improved access to market information, affordable credit, functional market associations, digital marketing platforms, and rural infrastructure will enhance market participation, reduce income inequality, and improve the livelihoods of women cassava marketers.

DECLARATION

Ethics approval and informed consent: This research was conducted in accordance with established ethical standards for social science research. The study was cleared from all ethical issues and approved by Department of Agricultural Economics, Federal University of Technology Owerri, Imo State, Nigeria. Verbal informed consent was obtained from all participating marketers before data collection. Respondents were assured of confidentiality, anonymity, and the voluntary nature of their participation throughout the study.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors further declare that they have thoroughly reviewed, revised, and edited the manuscript and take full responsibility for the final content of this publication. The authors declare that there is no conflict of interest regarding the publication of this paper.

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Research Article

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Prevalence of ITK Practices among Rice Farmers in Odisha: An Indian Knowledge System Perspective

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HIGHLIGHTS

- Family eldership remains the prominent informal channel of ITK dissemination.
- Extension contact and farming experience boosts up ITK adoption while economic motivation drives away from it.

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ABSTRACT

The study was conducted in 2025 to list out the Indigenous Technical Knowledge (ITK) practices with its extent of adoption among rice growers and the determinants influencing such adoption. Multi-stage random sampling was followed to culminate 320 respondents across four districts of the Odisha. Majority of the respondents exhibited moderate extent (51.25%) of ITK adoption. Botanical preservation of stored grains and sun-drying of paddy seeds recorded the highest adoption indices. Family eldership transpired as the primary source of ITK information. Multiple linear as well as stepwise regression models concurred that extension contact, farming experience and age have positively, whereas economic motivation has negatively, governed adoption extent of ITKs. Stepwise model kept four predictors delineating variance comparable to the linear model, underlining the efficiency of targeted extension-driven interventions for sustaining indigenous farming knowledge.

INTRODUCTION

India has achieved food self-sufficiency through modern intensive farming practice, though disproportionate to local resources (Ahmed et al., 2021), caused environmental pollution and reduced yield viability (Pandian et al., 2024), leaving one-third of arable land uncultivable (Krishna Chaitanya, 2024). Traditional knowledge of farming, are being looked at by agri-scientists as a sustainable alternative. Earning importance for sustainable development in 1980s globally, this particular knowledge now being rebranded as Indian Knowledge System (IKS) with its adoption being encouraged in diverse sectors including agriculture for sustainability (Das, 2025). The Indian Knowledge System (IKS), based on centuries of observation, experimentation and experience, is an invaluable repository of farming wisdom. In contrast to the existing intensive farming systems, IKS focuses on self-reliance, ecological balance, diversity and community participation. Many of the classical texts, as revered under IKS, such as *Vrksayurveda* (1000 CE), *Krishi Parasara* (400 BCE to 400 CE) and *Brihat Samhita* (1000-400 BCE) provisions standardized insights into soil

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classification, seed treatment, irrigation, plant protection and astronomical alignment congruence for farming, illustrating an integrated understanding of surroundings with its elements.

Such knowledge bank draw support from native oral customs and community practices such as local seed preservation, mixed cropping, luni-solar calendars and botanical pesticides which empowered the local farmers to counter the issues of pest invasion, disease attack, soil degradation and climate variability (Panda, 2026). The incorporation of such local traditional knowledge with scientific innovations along with sustainable practices is invaluable in current era (Mahajan, 2024). Since traditional agri-knowledge has been key areas within IKS; it manifests as Indigenous Technical Knowledge, which are practical, field-tested knowledge developed and passed down by farming communities (Singh et al., 2026) for practices from seed treatment till post-harvest storage. This eco-friendly, generationally refined knowledge can integrate with modern practices for production and sustainability (Praveenkumar et al., 2025). ITKs embodies accrued community wisdom sustained through oral transmission as cultural heritage (Borah et al., 2023) and disseminated via folklore, rituals and demonstration.

Several empirical studies on the adoption of ITK have been conducted in various agro-ecological settings. In Nepal, majority of the farmers studied had average level of adoption of Indigenous Technological Knowledge for agricultural practices (Khatri et al., 2021). Extension contact, education and market distance were identified as significant factors related to the adoption of indigenous knowledge-based livelihood practices in Ethiopia (Mengistu, 2024). However, within India, and Odisha specifically, empirical assessment of ITK adoption remains scarce with contemporary efforts mostly focused on documentation of ITKs rather than quantification of adoption extent or its determinants, especially towards rice farming-despite being state's predominant livelihood activity across agro-climatically diverse coastal, plateau and interior zones. Keeping in view of the above notion, an investigation was carried out on to assess the prevalence of ITK practices of rice growing farmers in Odisha.

METHODOLOGY

The study was conducted in the four prominent rice growing districts of Odisha- Bargarh, Ganjam, Kalahandi and Kendrapada whereby each of them belonged to different agroclimatic zones as classified for the state. The respondents were the rice growing farmers who had been following their ITK practices in their rice farming procedures since generations to pass over. Multi-stage sampling was followed over, whereby two blocks from each district and two villages from each block were selected randomly, thus constituting 16 villages from eight blocks under four districts. Twenty farmers were selected as respondents randomly, thus constituting total sample of 320 respondents.

Extent of Adoption of ITK practices has been operationalized as the degree to which farmers individually or collectively execute indigenous practices instead of or alongside, modern methodologies as relevant for paddy farming practices as suitable to their region. At first, a list of ITK practices followed in paddy cultivation in the sampled region was generated. A three-point continuum was followed namely as 'Fully adopted', 'Partially adopted' and 'Not adopted' for each item in the list with their respective corresponding scores of 3, 2 and 1 respectively. Respondents were asked to rate these items based on their perceived notion of adoption of concern ITK practice and later transformed to values by employing the scoring pattern. The index score for each respondent, as conducted Pateriya et al. (2026). in their study at Bundelkhand region of Uttar Pradesh, was formulated as follows:

$$\text{Adoption index} = \frac{\text{Total adoption score obtained for the respondent}}{\text{Maximum possible adoption score}} \times 100$$

Average and standard deviation of all the scores was calculated and employed in half-standard deviation method to generate the classification of respondents into low, medium and high extent of adoption based on their scores (Jayasingh & Mishra, 2024).

Factors relevant to the investigation were identified based on a comprehensive literature review, followed by the guidance of expert consultation. Then, a structured questionnaire was prepared with the help of scales taken up for the suitability to measure the concern factor as independent variable with a pre-testing exercise followed with modifications to make it adaptable for the concerned sample (Sahoo et al., 2025). Multiple linear regression was employed to assess the combined effect all and independent effect of each variable on extent of adoption followed by stepwise regression to determine the most parsimonious model. The research was carried on from March 2025 to December 2025 under the aegis of ex-post facto research design.

RESULTS

ITKs as practiced by the rural respondents

The Indigenous Technical Knowledge practices being employed by farm respondents are depicted in Table 1 along with its purpose, application and its degree of integration by them in terms of adoption index percentage. These practices cover the entire crop production system, from pre-sowing seed treatment to post harvest storage. Practices associated with seed include copper vessel sprouting, sun drying and summer ploughing for better seed germination and to remove soil-cum-seed borne pathogens. The low-cost, locally available solutions include weed and pest management practices like spiked harrowing, kerosene execution, straw mulching and use of botanical pest repellents such as neem and tobacco-garlic infusions. Stored grains were protected from insects and moisture by storage-related ITKs such as red pepper treatment, earthen pot smoking, cinnamon-ash treatment, and mud-plastered bamboo silos.

As per information depicted in Table 1, 'Botanical preservation of stored grains' had highest Adoption index (90.30), followed by 'sun-drying of paddy seeds' (89.43) and 'earthen pot smoking' (79.57), which showed that farmers were heavily dependent on plant protection and thermal methods of preservation. The other two were comparatively less adopted are 'Kerosene oil application' (51.13) and 'Tobacco-garlic infusion' (51.53), which may be attributed to change in the preference of input or perceived effectiveness. Overall, the table points to the ongoing value of traditional ecological knowledge for sustainable pest, storage and soil management.

Majority of the respondents (51.25%) were in medium extent of practice category. This was followed by 32.50 per cent of the

Table 1. List of Indigenous Technical Knowledge practices prevalent in the region, their working and its extent of practice as expressed by respondents

ITKs	Purpose	Remarks	Adoption Index
Accelerated seed sprouting in copper vessels (*Anda re Gajaa Maaribaa*)	Ensuring rapid, uniform seed germination before broadcasting	Anaerobic heat generated inside sealed vessel induces sprouting	87.97
Botanical preservation of Stored grains (*Nimba O Beguniaa Patra Sangraha*)	Protecting stored grains from pest attack by leaves of Neem and *Begunia*	Release of volatile compounds, act as powerful repellent and anti-feedant	90.30
Sun-drying of paddy seeds (*Bihana Khara Sekiba*)	Breaking seed-borne pathogens and deep embryo dormancy	Exposure to direct summer heat, killing hidden eggs and fungal spores	89.43
Mechanical spiked harrowing (*Bida Chaleiba*)	Thinning out overcrowded crops and uproot younger weeds	Dragging the wooden-spiked country *Bida* for weed shearing, improving soil aeration	65.43
Straw mulching (*Acchadana/Nauda Biccha)*	Suppressing weed-seed germination while preserving soil capillary moisture	Thick physical layer of straw creating light blockade and reduced evaporation	74.10
Kerosene oil (*Keropal Tela/Ghasatela Prayoga*)	Controlling destructive termite infestations at the root level	Broadcasting kerosene-soaked sand creating hydrocarbon film, suffocating the pests	51.13
Ash-dusted cover(*Paunsa Gunda Pakeiba*)	Anchoring delicate seedling radicles, before heavy monsoon	Spreading alkaline ash forms heavy matrix over bed, as protective barrier	73.87
Cement-groundnut-jaggery baits (*Gua Cementa Phaandaa*)	Eliminating field rats along narrow clay boundary walls	Dry bait acting lethal after ingested by rodents	55.80
Tobacco-garlic infusion (*Dhuaanpatra-Rasuna Gunda spray*)	Controlling heavy sucking pests like Brown Plant Hopper	Boiled mix of tobacco waste and crushed garlic inducing paralyzing effect on pests	51.53
Red pepper in storage (*Sukhilaa Lankaa Gunda Sanjoga*)	Keeping store-grain beetles and grain moths away from household food reserves	Dropping whole dried hot chillies in storage bins driving the pests away	85.53
Earthen pot smoking (*Haandi Dhuan Pratha)*	Sanitization of empty traditional grain storage structure	Burning dried dungs, red chillies and neem leaves inside bins, sealed for a day	79.57
Cinnamon with wood ash treatment (*Daalchini Paaunsa Gunda*)	Shielding saved seed bags from early weevil destruction	Powdered mixture creating an abrasive dust desiccant, harming pest attack	55.13
Mud-plastered bamboo grain silos (*Dhaana Kudhira*)	Storing grains safely for seasons	Bamboo bins plastered with cow dung and clay: forming insulated-resistant container	83.73
Underground or airtight curing of rice (*Khani Chaaula*)	Making fresh, non-sticky, easily digestible rice	Rice packed in earthen pots, sealed with wet cow dung, undergoing hermetic CO_2 curing	72.87
Summer ploughing (*Khara Chaasa*)	Eradicating soil-borne pathogens and pest pupae	Soil turning in May exposes pests and spores to lethal solar sterilization	83.60

respondents having low extent of ITK adoption and 16.25 per cent of the respondents had high extent of ITK adoption. This distribution indicates that although a large number of farmers still use indigenous practices to a moderate extent, there is no significant uptake of the full range of ITKs by the larger group, and almost one third of respondents had very little interaction with indigenous practices. The findings are in line with that Keerthana and Divakaran (2021) reporting moderate extent.

Informational source

Table 2 illustrates about the preferences for informational sources of ITK awareness by the respondents whereby 'Family eldership' received highest response (86.25%) reflecting the dominance of inherited, lineage of traditional knowledge bank within households. Then comes 'Community events' (71.25%) which comprises of organized gatherings such as festivals and village functions followed by 'peer-to-peer observation' referring to direct farmer-to-farmer learning through field-level interaction (68.75%), together showcasing the reinforcement of ITKs through structured social interaction and collective field experience. The cultural embedding of ITKs in oral tradition was further expressed in folklore and proverbs, cited as informational source by 62.50 percent of farm respondents. 'Informal village spaces' such as casual gathering points including tea stalls or village squares (56.25%) and 'local conduits', referring to intermediary individuals such as priests, school teachers, input dealers or panchayat members (48.75%) were comparatively less relied upon but remained meaningful, unstructured means of knowledge dissemination.

Table 2. Sources of ITK information as perceived by farm respondents

Source	Percentage
Family eldership	86.25
Folklores and proverbs	62.50
Community events	71.25
Informal village spaces	56.25
Peer-to-peer observation	68.75
Local conduits	48.75

Regressional analysis factors towards extent of adoption of ITKs

Since F-value acts as initial check point of regressional fitted models, findings of Table 3 with its F-value of 26.57, significant at

Table 3. Multiple linear regressional analysis of factors towards extent of adoption of ITKs
F(15, 304) = 26.57**; R^2 = 0.567; adjusted R^2 = 0.543; (n=320)

Variable	Coefficients (B)	Std. error	t-value	*p*-value
Age	2.345	1.188	1.974*	0.049
Gender	1.112	0.642	1.732	0.084
Education	12.349	27.750	0.445	0.657
Family type	-7.342	4.389	-1.673	0.095
Farming experience	4.318	1.933	2.234*	0.026
Occupational status	1.119	1.006	1.112	0.267
Annual Income	4.532	2.417	1.875	0.062
Landholding	0.112	0.147	0.764	0.445
Cosmopoliteness	0.894	15.960	0.056	0.955
Mass media exposure	1.113	0.458	2.432*	0.016
Economic motivation	-4.756	1.712	-2.779**	0.006
Decision making	1.184	0.772	1.533	0.126
Social norms	2.341	2.610	0.897	0.370
Extension contact	7.223	2.314	3.122**	0.002
Innovativeness	5.327	2.841	1.875	0.062

*=Significant at 5% level; **=Significant at 1 % level; NS=Non-significant.

one percent level, reaffirms the significance of explanation of ITK adoption by the variables and the same is conveyed again in the F-values to that of Table 4 also. In Table 4, the R^2 value of 0.567 meant that all the predictors explained about 56.7 percent of variation caused in extent of ITK adoption. Though the adjusted R^2 value was only slightly lower, indicating that there was not a significant amount of inflation due to a few minor, less meaningful variables.

At one percent level of significance, variables such as 'Extension contact' and 'Economic motivation' showcased positive and negative contribution respectively towards variation in extent of ITK adoption of farmer respondents whereas the likes age, farming experience and mass media exposure expressed significant contribution at five percent level of significance. The remaining set of predictors like education, cosmopoliteness, etc., conveyed contribution yet in non-significant manner.

Table 4 shows the stepwise regression results of the most parsimonious predictors of adoption of ITK. The four variables in the full model were also included in the reduced model: Age, Farming experience, Economic motivation, and Extension contact, and they produced an values of R^2 (0.531) and an Adjusted R^2 (0.524), as less different to the ones under full model, allowing the eleven variables to be excluded for the sake of parsimony without any significant contribution. The considerably greater F-value in the stepwise model opines greater statistical efficiency, as the same variance (R^2=0.531) was explained using far fewer predictors, consuming fewer degrees of freedom and yielding a more powerful test of overall significance. The findings of these table were somewhat analogous to the ones obtained by Patial (2025) and Pooja et al. (2025).

DISCUSSION

The ITK practices with the highest adoption indices such as botanical preservation and sun-drying can be explained by their intuitive, low-resource nature and their protective effects likely reinforced through farmers' recurrent observation across seasons. It is plausible that under resource constrained systems, neem-based chemical-free biochemicals are deemed as alluring option with no dependence on external inputs whereas low cost and simplicity feature of sun-drying well explains its continuation as a traditional seed-treatment method. Similarly, in comparision to the higher extent in case of earthen pot smoking and mud plastered bamboo silos, indigenous storage structures still remain prevalent particularly where modern options remain inaccessible. These indigenous structures reflect farmer's practical wisdom of microclimate controlling through cow dung and clay as natural insulating materials. Conversely, the decline in adoption of tobacco-garlic infusion and kerosene oil could be attributed to a shift towards synthetic pesticides, variable labour availability and lower perceived efficacy of such indigenous options, suggesting towards evolving priorities, market accessibility and exposure to readily available innovative technologies.

Most of the farmers are using ITK practices selectively, rather than completely, as indicated by majority of respondents, which

Table 4. Stepwise regressional analysis of factors towards extent of adoption of ITKs
F(4, 315)=73.45**; R^2= 0.531; adjusted R^2= 0.524; (n=320)

Variable	Coefficients (B)	Std. error	t-value	*p*-value
Age	4.723	2.016	2.343*	0.020
Farming experience	2.387	0.831	2.874**	0.004
Economic motivation	-3.342	0.974	-3.432**	0.001
Extension contact	1.784	0.842	2.118*	0.035

*=Significant at 5% level; **=Significant at 1 % level; NS=Non-significant

are possibly linked to practical considerations as some ITKs are comparatively more labour-intensive or time-consuming and maybe perceived as less beneficial relative to modern alternatives. While the present study did not directly assess the intergenerational knowledge transmission or resource access as variables, it is quite possible that high adopters are more likely to have thrived from stronger knowledge transmission within families, more shortage of modern inputs or a deliberate preference for sustainable practices as these notion do require further investigation to concur. The comparatively low-adoption segment may reasonably reflect a gradual decline in traditional knowledge, potentially linked to generational change, migration, diminishing elder dominance, or spiked penetration of conventional technologies, consistent with broader documented concerns regarding the erosion of ITK when transmission is not actively sustained. This is in keeping with a general issue in the ITK concerns that there lies potential loss of knowledge through discontinued use when it is not transmitted socially, extended, or documented in a farming community and eventually eroding the foundations of knowledge systems of Indian farming culture. Gogoi et al. (2026) concluded that wider adoption of ITKs demands for scientific validation, proper documentation and integration with modern practices.

The predominance of family eldership as the paramount information source justifies the household as the primary unit of transmission for ITK, which involves experiential knowledge transmission across generations, without formal instruction. This is a familiar pattern, since indigenous knowledge is, by nature, tacit, and is often best expressed through demonstration and lived experience rather than documented sources. Community events, such as festivals and organized village gatherings, along with peer-to-peer observation—direct farmer-to-farmer learning through field-level interaction—together emerged as strong collaborators in ITK dissemination, providing structured and experiential spaces for collective learning, reinforced through social validation. In contrast, informal village spaces (e.g., casual gathering points such as tea stalls or village squares) and local conduits (e.g., intermediary individuals such as input dealers or panchayat members) showed comparatively lower reliance, which may indicate a gradual erosion of these more spontaneous, unstructured interaction points—possibly linked to shifting social arrangements or reduced day-to-day community engagement. This distinction suggests that while organized and experiential community-based transmission channels remain robust, the more informal, incidental avenues of knowledge exchange may be weakening, underscoring the layered and uneven nature of ITK's social transmission pathways. These findings collectively point to the fragility of ITK systems should intergenerational and community-based transmission—particularly its informal, everyday channels—continue to deteriorate, reinforcing the need for purposeful documentation and extension-supported efforts to sustain the foundation of Indian Knowledge Systems in rural farming communities. Sindhu and Malik (2020) as well as Yimchunger et al. (2026) concurred that the absence of documentation and preservation efforts in ITKs has led towards the brink of dying out.

The level of agreement among the multiple linear and stepwise methods validates the interpretation that extension contact and economic motivation are the main factors that influence ITK adoption. Extension services seems to have a role in bridging traditional practices and formal agricultural science (Raji et al., 2024), as farmers with more contact with extension staff are more likely to validate, refine and maintain traditional practices rather than replacing them. Conversely, the significant negative contribution towards ITK adoption by economic motivation suggests about that in present era, the farming sector, driven by profit maximization, opt for modern methodologies with its benefits of faster and quantifiable returns as compared to traditional counterparts (De La Cruz et al., 2023). The age and farming experience that were controlled for in both models also help to corroborate the experiential and accumulative process of ITK acquisition, such that older farmers and those with more years of experience have more time to observe, experiment and internalize traditional methods, instead of modern methods, through the process of successive cropping seasons. Rizki and Andini (2025) also concluded from their review that older farmers possess extensive experience and knowledge depth in farming traditions which has been the basis of their livelihood sustenance. Importantly, the considerate spike in F-value under stepwise model, as compared to linear model, illustrates the statistical efficiency of the reduced model in explaining near about equivalent magnitude of variance by utilizing the four of the original 15 predictors. These findings tentatively recommends that interventions directed on empowering extension systems can be associated with enhanced and effective results in ITK adoption followed by retention, then that of broader, less-targeted socio-demographic interventions, though this inference would benefit from confirmation through intervention-based or longitudinal research. The confluence of the linear and stepwise regression models reinforces the robustness of the findings; that direct institutional involvement, economic rationality, and farming experience are the main factors shaping ITK adoption in the study area, while general socio-demographic and attitudinal characteristics are not. The outcomes of this research provide unambiguous, practical guidance to policy and extension practitioners to reinforce indigenous traditional knowledge as a subset of Indian Knowledge systems in today's agricultural extension systems.

CONCLUSION

Indigenous Technical Knowledge still persists as resource optimizing, ecologically sustainable and socio-culturally compatible aspect of paddy farming in Odisha, furnishing affordable solutions for seed treatment, pest management and food-grain storage. However, the prevalence of low-medium adopters along with downward trajectory on informal community channels signals towards possible erosion of such generational wisdom. The findings of regressional model advocates the dependency of ITK retention on institutional engagement rather than socio-demographic alone. Focused extension interventions instead of broad-based programmes should be emphasized for ITK conservation. An important function of agricultural extension is also ensuring documentation, scientific validation and linkage of ITK with modern practices to preserve such heritable lineage and fuel-up the efforts for revival forgotten paradigms of Indian Knowledge System in farming sector. This investigation provides indispensable region-specific insights, but

further testing in a variety of agroclimatic zones and crop systems is required to ascertain its broader generalizability.

DECLARATIONS

Ethical approval and consent to participate: The study was approved by the research Advisory Committee of Department of Extension Education, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. However, the informed consent was sought from all the respondents.

Data availability statement: Data are available with first author and may be provided on reasonable request.

Consent of publication: All the participants provided consent for publication

Conflict of interest: No conflict of interest among the author

Authors' Contribution: DKJ conceived and designed the study as the main researcher and drafted the discussion section of the manuscript. PB served as cooperating technician, conducted the data analysis, and contributed to the methodology. KB served as cooperating scientist, contributed to the methodology, and critically revised the manuscript. All authors read and approved the final manuscript

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Research Article

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Linking Livestock Farmer Group Performance to Household Food Security: Evidence from West Sumatra, Indonesia

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HIGHLIGHTS

- Food-secure and food-vulnerable households accounted for 46.7% and 44.4% of respondents, respectively.
- Group performance had a weak but significant positive correlation with household food security.
- Ordinal logistic regression showed no significant group-performance effect at the five percent level.
- Livestock groups require stronger economic functions to support members' food security.

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Keywords: PAKEM POKTAN, Institutional capacity, Food security status, Household welfare, Smallholder livestock farmers.

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ABSTRACT

Livestock groups are widely promoted for agricultural development, but empirical evidence linking their institutional performance to household food security remains scarce. This study described the food security status of livestock-farming households and examined the relationship between livestock group performance and household food security in West Sumatra, Indonesia. A descriptive quantitative design was used, involving 45 respondents from nine Madya-class livestock groups, surveyed from August to October 2025. Group performance was assessed using the Farmer/Livestock Group Capacity and Independence Assessment (PAKEM POKTAN) instrument, while household food security was classified by combining food expenditure share and energy adequacy level. Data were analyzed using descriptive statistics, Spearman's rank correlation, and ordinal logistic regression at a 5% significance level. Results showed that 46.7% of households were food secure, 44.4% food vulnerable, and 8.9% food insecure. Group performance was significantly but weakly correlated with food security status ($r_s = 0.312$; $p = 0.037$), yet had no significant effect in the ordinal logistic regression model ($p = 0.060$; Nagelkerke $R^2 = 0.094$). These findings indicate that current group capacity is associated with, but does not directly determine, household food security.

INTRODUCTION

Food security among farming households remains a development paradox because households that produce food can still be vulnerable to food insecurity. Food insecurity is shaped by interactions among production capacity, climate exposure, household income, market access, and local institutions (Raj et al., 2026). In Indonesia, food is legally recognized as a basic need and a citizen's right under Law No. 18 of 2012 on Food. The food security of farming households, therefore, has implications not only for welfare but also for rural development policy.

Institutional strengthening through farmer and livestock groups is one strategy used to improve smallholder access to information, technology, production inputs, credit, and markets (Niranjan et al., 2023). Collective action can reduce coordination costs and improve bargaining capacity in smallholder agriculture (Markelova et al., 2009; Fischer & Qaim, 2012) and empirical studies show that farmer organizations improve member welfare when they perform as

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effective economic and learning institutions (Wossen et al., 2017; Bachke, 2019). A similar pattern has been reported for farming institutions in developing regions (Rout et al., 2026) and institutional strengthening has likewise been linked to sustainable agriculture and food security support in local Indonesian settings (Listiana et al., 2021). In Indonesia, the Farmer/Livestock Group Capacity and Independence Assessment (PAKEM POKTAN) is used to assess formal group performance across organizational dimensions, including planning, organizing, implementation, control, reporting, and leadership development (BPPSDM of Agriculture, 2018). However, this contribution is not automatic: it depends on group capacity, household assets, access to credit, land tenure, gender relations, and market conditions (Wossen et al., 2017; Vijayan et al., 2023; Jabbar et al., 2025), since groups may have adequate administrative performance but limited capacity to influence household food access unless they strengthen income, capital formation, market linkages, or production resilience. This makes it necessary to test whether formal group performance is reflected in the food security status of member households.

In West Sumatra, livestock groups have been supported through government programs, yet previous studies have reported that many assisted groups did not progress to higher-capacity classes and often experienced declining livestock populations (Madarisa et al., 2024; Putra et al., 2023). A recent assessment of the same nine Madya-class livestock groups found an average performance score of only 52.9% of the maximum PAKEM POKTAN score, with leadership development as the weakest dimension (Madarisa et al., 2026). That assessment described organizational capacity but did not examine whether that capacity was associated with the food security of member households. This study addressed that gap by analyzing group performance and household food security in the same livestock-group setting. The objectives were to describe the food security status of livestock-farmer households in Madya-class groups and to analyze the relationship and effect of group performance on household food security status. The evidence is expected to inform extension policy for livestock-group development by clarifying how formal institutional performance relates to household-level welfare outcomes in similar smallholder settings.

METHODOLOGY

This descriptive quantitative study was conducted in West Sumatra Province, Indonesia, from August to October 2025. Study sites were selected from livestock groups recommended by the West Sumatra Provincial Livestock and Animal Health Service. Nine groups classified as Madya under PAKEM POKTAN, with scores ranging from 456 to 607, were selected as the units of analysis. These were the same groups previously assessed for organizational capability (Madarisa et al., 2026).

The study involved 45 respondents, purposively selected from the nine groups, with five respondents per group: two group administrators and three active members. This composition was intended to represent both the leadership and membership perspectives relevant to group performance, consistent with group dynamics theory emphasizing the complementary roles of administrators and members in group learning, cooperation, and production functions (Hariadi, 2011). The independent variable was group performance score (GP), measured using the PAKEM POKTAN instrument with a maximum score of 1,000. The dependent variable was household food security status, classified by combining two indicators: the proportion of food expenditure to total household expenditure using a 60% threshold, and the energy adequacy level using a 2,100 kcal/capita/day reference from the national recommended dietary allowance and an 80% adequacy threshold (Ministry of Health of the Republic of Indonesia, 2019) The combination produced four categories: food secure, food vulnerable, food insecure, and food at risk (Maxwell et al., 2000; Widada et al., 2017).

Household food consumption was recorded using a 7-day food-consumption recall covering food type, quantity, and price. Energy and protein contents were converted using Indonesian food composition tables (Ministry of Health of the Republic of Indonesia, 2018) and compared with per capita adequacy levels to calculate energy and protein adequacy percentages. Household income was estimated using an expenditure-based proxy, summing monthly food and non-food expenditures. Analysis combined descriptive statistics with Spearman's rank correlation (to examine the association between group performance and food security status) and ordinal logistic regression (to test the effect of group performance on food security category), with group performance entered as the model's single predictor. No intervention or treatment was administered to respondents or their livestock; all tests used a five percent significance threshold and were conducted in SPSS.

RESULTS

The results are presented according to the research objectives. The section first describes respondent characteristics, group performance, and household food security, then reports the relationship and effect of group performance on household food security status.

Respondent profile and group performance

Respondents were, on average, 50.4 years old (range: 28–70 years), and the average household size was 4.7 persons. Educational attainment was dominated by elementary school (40.0%) and senior high school (37.8%), followed by junior high school (11.1%), no formal schooling (8.9%), and a bachelor's degree (2.2%). Most respondents (62.2%) did not work outside their household's livestock or farming activities, while 37.8% had additional income-generating activities.

The nine Madya-class livestock groups had performance scores ranging from 456 to 607 out of 1,000 (Table 1). The highest score was recorded by Sumber Rezeki (607), while the lowest was recorded by Durian Sabatang (456). The 151-point difference indicates that the groups were not homogeneous, even though all belonged to the same formal capacity class. None reached the Utama threshold of 701, confirming that the observed groups remained within a medium institutional-capacity range.

Food security status of livestock households

Household food security was classified using the proportion of food expenditure and the energy adequacy level. The largest share

Table 1. Group performance scores

Code	Groups	Score
A	Mama Ceria KWT	457
B	Pemuda Setia	562
C	Mulia	460
D	Pincuran Gadang	594
E	Milenial	552
F	Sumber Rezeki	607
G	Sawah Bangsa	584
H	Kawasan Sigajai	487
I	Durian Sabatang	456
	Average	528.78

Source: Madarisa et al. (2026)

Table 2. Food security status of livestock households

Category	Food expenditure (%)	Energy adequacy (%)	Share (%)
Food secure	48.0	108.4	46.7
Food vulnerable	62.6	103.2	44.4
Food insecure	43.0	62.9	8.9
Food at risk	-	-	0.0
Total			100.0

Source: Primary data, processed (2026)

of respondents was categorized as food secure (46.7%), followed by food vulnerable (44.4%) and food insecure (8.9%), while no household was categorized as food at risk (Table 2). Food-vulnerable households had the highest proportion of food expenditure (62.6%), although their energy adequacy level remained high (103.2%). In contrast, food-insecure households had a lower food expenditure proportion (43.0%) but a low energy adequacy level (62.9%).

As a supplementary descriptive measure not used in the food security classification in Table 2, the average protein adequacy level across all respondents was 104.5%, alongside an average energy adequacy level of 105.7%. The average share of food expenditure in total household expenditure was 57.6%, close to the 60% threshold. This indicates that many households had adequate average energy and protein intake, yet limited economic flexibility.

Animal protein was the largest component of monthly food expenditure, accounting for 43.9% of total food expenditure, followed by other foods (21.3%) and grains (15.9%) (Table 3). Legumes and root crops contributed only 1.1% and 1.4%, respectively, indicating limited diversification of plant-based food sources.

Table 3. Average food expenditure composition

Component	Average (Rp/month)	Share (%)
Animal protein	1,549,943	43.9
Other foods	751,581	21.3
Grains	560,095	15.9
Vegetables	345,205	9.8
Oils and fats	122,048	3.5
Fruits	109,600	3.1
Root crops	50,943	1.4
Legumes	39,619	1.1
Total food expenditure	3,529,033	100.0

Source: Primary data, processed (2026)

Food expenditure accounted for 57.6% of the average total household expenditure of Rp 6,122,645 per month, while non-food expenditure accounted for 42.4%. The average per capita income was Rp1,355,372 per month, with a range from Rp553,357 to Rp3,568,429. Most respondents were in the lower-middle class (75.6%), followed by vulnerable and stable-middle classes at 11.1% each, while 2.2% were in the poor class and none were in the upper class (Table 4). Overall, 97.8% of respondents were in lower-middle- to lower-income classes.

Table 4. Per capita income class distribution

Income class	Range/capita/month	Share (%)
Poor class	< Rp582,932	2.2
Vulnerable class	Rp582,932 to Rp874,398	11.1
Lower-middle class	Rp874,398 to Rp2,040,262	75.6
Stable middle class	> Rp2,040,262 to Rp9,909,844	11.1
Upper class	> Rp9,909,844	0.0
Total		100.0

Source: Primary data, processed (2026)

Correlation between group performance and food security

Spearman's rank correlation showed a positive and significant relationship between livestock group performance and household food security status (rs = 0.312; p = 0.037; Table 5). The relationship was weak, meaning that better group performance was associated with better household food security, but it was not strong enough to explain food security differences on its own.

Table 5. Spearman correlation test results

Variable	rs	p	N
Group performance on food security	0.312	0.037	45

Source: Primary data, processed (2026)

Effect of group performance on food security

Ordinal logistic regression produced a positive coefficient for group performance (0.010), but the effect was not significant at the five percent level (p = 0.060; Table 6). The model met goodness-of-fit requirements, with Pearson p = 0.252 and Deviance p = 0.178, and the parallel-lines assumption was satisfied (p = 0.170). The Nagelkerke R^2 value of 0.094 is a pseudo-R^2 statistic that reflects relatively low overall explanatory strength for the model; unlike R^2 in ordinary linear regression, it should not be interpreted as the literal proportion of variance explained. Taken together with the non-significant coefficient, this indicates that group performance

Table 6. Ordinal logistic regression results

Parameter	Estimate	Wald	df	p
Group performance	0.010	3.551	1	0.060

Source: Primary data, processed (2026)

alone has limited explanatory power for household food security status within this model.

DISCUSSION

The nine Madya-class groups scored an average of 528.78 out of 1,000 (52.9% of the maximum), a level consistent with a companion assessment of organizational capabilities in the same groups, which found leadership development to be the weakest dimension (27.8%) and organizational ability the strongest (63.5%) (Madarisa et al., 2026). This pattern suggests that the groups have established basic administrative and organizational routines but have not yet developed strong leadership capacity to convert group activities into consistent economic benefits for members, which may help explain why formal group performance shows only a weak association with household food security, as discussed below.

The findings show that calorie adequacy alone does not fully represent household food security. Although the average energy adequacy level exceeds the standard, 44.4% of households are food-vulnerable, and 8.9% are food-insecure. Food-vulnerable households have sufficient energy intake but allocate more than 60% of their total expenditure to food, consistent with reduced economic flexibility rather than a direct measure of purchasing power. Food-insecure households have lower expenditure pressure but fail to meet energy adequacy. This confirms that economic vulnerability and nutritional vulnerability may appear through different pathways. Similar studies on farming households in Indonesia identify income constraints, household expenditure structure, and livelihood capacity as important determinants of food security (Rahmi et al., 2013; Widada et al., 2017; Rahmadanih et al., 2018), with recent evidence from Indonesia's borderland farming communities further highlighting the role of extension access and farmer motivation in supporting household food security (Banunaek et al., 2026). In the present study, the dominance of animal protein expenditure and the low share of legumes and root crops also suggest limited diversification in dietary costs.

The weak but significant Spearman correlation ($r_s = 0.312$) indicates that livestock groups still matter for household food security, but their contribution is limited by the same organizational gap noted above: groups perform adequately in planning and administration but have not yet built the leadership and economic linkage functions needed to translate group performance into measurable household outcomes. This pattern is consistent with broader evidence that farmer organizations support welfare, productivity, and food security only when collective action is translated into economic services, market access, credit facilitation, and effective learning (Markelova et al., 2009; Fischer & Qaim, 2012; Wossen et al., 2017; Bachke, 2019). Therefore, formal group performance provides an institutional signal, but not yet a strong food-security mechanism.

The ordinal logistic regression result reinforces this interpretation: group performance was not a statistically significant predictor of food security status ($p = 0.060$), and its explanatory power was low. Unmeasured household-level factors — such as income, household size, education, and livelihood diversity — likely account for a larger share of the variation, consistent with findings from other Indonesian food security studies (Hakim et al., 2021; Akbar et al., 2023) and studies of livestock-rearing household adaptive capacity in other regional contexts (Mishra et al., 2026). The practical implication is that livestock-group development should move beyond administrative compliance. Groups need stronger roles in member income generation, access to capital, collective marketing, production planning, and livestock business continuity. Strengthening these economic functions may convert institutional capacity into measurable gains in household welfare.

This study has three main limitations. First, all nine groups belonged to the Madya class; of the 17 groups recommended by the West Sumatra Provincial Livestock and Animal Health Service, none reached the Utama class, so Madya represented the highest performance tier available in this population rather than a selection choice by the researchers (Madarisa et al., 2026). Second, the cross-sectional design, single independent variable, and small sample ($n = 45$) limit causal inference and the precision of the correlation and regression estimates. Third, group membership size and respondent gender were not recorded, limiting the characterization of respondent representativeness.

CONCLUSION

The nine Madya-class livestock groups studied were the most consistently active groups recommended by the West Sumatra Provincial Livestock and Animal Health Service, representing the highest formal performance tier reached within this population. During the study period, member households were predominantly food-secure and food-vulnerable, with average energy and protein adequacy exceeding minimum standards. Group performance showed a weak but statistically significant correlation with household food security and did not significantly predict food security status in the regression model, indicating that formal group capacity alone is not yet a strong determinant of household outcomes. This pattern is consistent with the groups' organizational profile: solid administrative capacity but weak leadership development, which limits their ability to translate formal performance into economic benefits for members. Strengthening group performance for food security purposes should therefore prioritize economic functions — capital access, market linkages, and income-generating activities — alongside leadership development.

DECLARATIONS

Ethical approval and consent to participate: This study was conducted in accordance with the ethical standards for social research in vogue in Indonesia. Respondent participation was voluntary, provided after participants received information regarding the study's purpose, benefits, and assurance of data confidentiality. Participant identity data were kept confidential and were not disclosed for any purpose other than scientific use. Respondents' identities are reported in aggregate form.

Conflict of interest: The author declares that this research was carried out without any commercial or financial relationships that could be interpreted as a potential conflict of interest. The authors confirm that they carefully reviewed, revised, and edited the content of this work as necessary during its preparation, and they take full responsibility for the final published content.

Authors' contribution: RAP conceptualized the study, designed the methodology, analyzed the data, and drafted and finalized the manuscript. FM contributed to the conceptualization, provided critical review and revision of the manuscript, and supervised the overall research process. NN supported data collection, data organization, and manuscript revision. All authors read and approved the final manuscript.

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Research Article

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Strengthening ICT-Based Agricultural Extension through Human Capacity and Institutional Support in West Java

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HIGHLIGHTS

- Extension-worker competence and cosmopolitanism strengthened ICT-enabled advisory services.
- Institutional, infrastructure, and regulatory support reinforced Agricultural Extension Centre performance.
- Conventional methods alone did not improve digital extension implementation.
- Hybrid advisory strategies can combine digital reach with trusted face-to-face facilitation.

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ABSTRACT

Agricultural Extension Centers connect farmers with information, innovation, consultation, and institutional networks. This study analysed the human and institutional factors associated with centre performance and information and communication technology-based agricultural extension in West Java. The study was conducted from May to November 2022 in Subang and Cianjur Regencies. Survey data from 156 extension workers and farmers were complemented by interviews, observations, and document review. Descriptive statistics and partial least squares structural equation modelling were applied. The centres performed strongly as information, development-movement, learning, agribusiness-consultation, and partnership-networking hubs. Digital-extension adoption capacity and sustainability were also rated highly. Positive path coefficients were observed from respondent characteristics to centre performance (0.257) and digital extension (0.293), and from extension support to the same outcomes (0.326 and 0.319, respectively). Extension methods had a negligible coefficient for digital extension (-0.008). Cosmopolitanism, extension-worker competence, infrastructure, institutional support, and regulations were prominent indicators. The findings show that digital advisory services are supported by capable personnel, enabling institutions, reliable infrastructure, and hybrid strategies that combine digital communication with face-to-face facilitation.

INTRODUCTION

Agricultural extension increasingly operates through digital and face-to-face channels that connect farmers with production knowledge, markets, climate information, and institutional services. Information and communication technology (ICT) can accelerate the delivery of timely advice, widen geographical coverage, and support more responsive decision-making. However, technology alone does not create effective advisory services. Extension-worker competence, information-seeking behaviour, organisational support, infrastructure, and regulations determine whether digital tools become embedded in routine practice. Recent evidence shows that farmers' acceptance of ICT-based advisory services depends on usefulness, trust, accessibility, responsiveness, and personalisation (Paliwal et al., 2026), while extension personnel need differentiated skills in digital communication, document management, troubleshooting, cybersecurity, and emerging applications (Sahoo et al., 2025).

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Indonesia institutionalised this transformation through the Strategic Command for Agricultural Development, which positioned Agricultural Extension Centers at sub-district level as operational hubs for data, learning, consultation, development programmes, and partnerships. The centers were expected to use ICT to coordinate local agricultural development and link farmers with innovation systems. Their effectiveness is especially important in West Java, where farmers continue to rely strongly on extension workers as trusted information intermediaries. Evidence from the province also indicates that advisory services and livelihood resources strengthen farmers' resilience through capacity-building pathways rather than information delivery alone (Azhari et al., 2025), while global research mapping confirms the growing integration of agricultural extension within climate-resilience scholarship (Azhari et al., 2026).

Conventional visits, lectures, and demonstrations continue to build trust and enable contextual problem solving, whereas digital channels increase speed and reach. Treating these modes as substitutes may therefore weaken extension quality. Digital transformation is more plausibly understood as a hybrid institutional process in which human capability and organisational conditions enable technology to complement interpersonal advisory work. Research has commonly examined digital access, extension competence, or institutional support separately, leaving limited evidence on their combined relationships with centre performance and digital extension implementation.

Subang and Cianjur Regencies offered relevant settings because their extension centres had implemented the national programme across contrasting rice and horticultural systems. The study tested whether respondent characteristics, extension methods, and extension support influenced the role of Agricultural Extension Centres and ICT-based agricultural extension. It was hypothesised that human capability and institutional support would have positive effects, while reliance on conventional methods without digital integration would not strengthen ICT-based services. The objective was to identify the most influential human and institutional factors and derive practical directions for hybrid agricultural extension in West Java.

Earlier Indonesian studies documented the importance of centre readiness and extension-worker performance in implementing the national programme (Anto & Andriansyah, 2020; Kinasih et al., 2021; Pakpahan et al., 2021). Internet use has also been associated with extension-worker performance in Cianjur (Purwatiningsih et al., 2018), while field evidence continues to show the contribution and limits of ICT within local extension practice (Prayoga, 2018; Utomo et al., 2022). More recent work places digital learning and social capital at the centre of capacity development for sustainable food systems (Sumardjo et al., 2026). Together, these studies justify examining technology use within the institutional and human system that supports it.

METHODOLOGY

An explanatory survey was conducted from May to November 2022 in Subang and Cianjur Regencies, West Java. The locations were selected purposively because all Agricultural Extension Centres had implemented the Strategic Command for Agricultural Development and represented contrasting rice and horticultural production systems. Respondents were drawn from seven centres in each regency. The final sample comprised 156 agricultural extension workers and farmers involved in centre activities. Data were collected using a structured questionnaire and were complemented by field observations, document review, and in-depth interviews with programme innovators, managers, extension workers, farmers, and other community representatives. The model included respondent characteristics, extension methods, and extension support as explanatory constructs.

Respondent characteristics captured extension-worker competence and cosmopolitanism. Extension methods represented conventional and digital approaches, while extension support covered institutional, infrastructure, and regulatory support. The two endogenous constructs were the role of Agricultural Extension Centres and ICT-based agricultural extension. Centre roles comprised data and information, agricultural development movements, learning, agribusiness consultation, and partnership networking. ICT-based extension comprised adoption capacity and sustainability. Items were rated using ordinal response scales and converted to interval data before modelling. The construct specification followed the view of extension as a facilitated learning and capacity-development process rather than one-way information transfer (Amanah, 2007).

Instrument testing was conducted with 42 respondents from six Agricultural Extension Centres in Bogor Regency. Item validity coefficients ranged from 0.343 to 0.926 and reliability coefficients from 0.661 to 0.943, supporting use of the instrument. Descriptive analysis summarised respondent access, support, institutional roles, and digital-extension performance. Partial least squares structural equation modelling was performed using SmartPLS 4 to estimate measurement loadings, path coefficients, and explained variance. The structural analysis examined the relationships of respondent characteristics, extension methods, and extension support with both endogenous constructs. Qualitative evidence was used to interpret the institutional context and the continued role of interpersonal extension. Participation was voluntary, respondents were informed about the study purpose, and responses were analysed confidentially.

RESULTS

Human readiness and extension practices

Based on Table 1, respondents averaged 46 years of age, and 37.82% had completed undergraduate education. Average work experience was 11 years. Digital access was already substantial: 92.31% had personal or family access to an internet-enabled smartphone and 77.56% had personal or family access to a computer or laptop. Extension-worker competence reached a moderate index of 69.39%. Respondents were able to manage information, understand digital-era responsibilities, anticipate barriers, and recognise the advantages of innovation, but the moderate score indicated room for more advanced facilitation and data-management skills. Information seeking was most frequent in other villages and agricultural or extension service offices, averaging four visits per month. This cosmopolitan orientation exposed extension actors to innovations and professional networks beyond their immediate work environment.

Table 1. Respondent readiness for digital extension

Indicator	Result
Mean age	46 years
Undergraduate education	37.82%
Mean work experience	11 years
Smartphone access[1]	92.31%
Computer/laptop access[1]	77.56%
Competence index	69.39% (moderate)
Information visits to villages	4 per month
Visits to extension service offices	4 per month

[1]Includes personal or family ownership

Both conventional and digital practices remained active. Farm visits were used often or always by 80.77% of respondents for technological innovation and 77.56% for facilities and infrastructure information. Social media were used often or always by 70.51% for technological innovation, 73.08% for facilities and infrastructure, and 73.71% for marketing information (Table 2). Internet sources other than social media were less consistently used. The pattern indicates an emerging hybrid system: farm visits remained central for observation, demonstration, and trust, while social media accelerated follow-up communication and information distribution. Digital channels should complement rather than displace interpersonal methods because farmer decisions frequently require local diagnosis and confidence in the adviser (Yadav et al., 2026).

Table 2. Frequent use of selected extension methods

Method	Technological innovation (%)	Marketing (%)	Facilities (%)	Inputs (%)
Farm visits	80.77	77.56	77.56	81.41
Lectures	59.62	55.13	58.98	63.46
Social media	70.51	73.71	73.08	69.23
Other internet sources	58.33	60.26	57.70	53.85

Institutional performance and enabling support

Based on Table 3, institutional, infrastructure, and regulatory support were all rated highly. The data and information centre recorded the highest mean index (98.18), followed by the agricultural development movement (96.69). Respondents associated institutional support with innovation assistance, technical and methodological training, internships, and seminars. Infrastructure included internet connectivity, operational facilities, and learning resources, while regulations provided legitimacy and direction for centre activities. The similarly high values show that digital extension was enabled by a bundle of organisational conditions rather than a single intervention.

Table 3. Extension support and centre performance indices

Dimension	High category (%)	Mean index
Institutional support	89.74	91.03
Facilities and infrastructure	78.21	88.35
Regulatory support	77.56	88.03
Data and information centre	93.59	98.18
Agricultural development movement	94.87	96.69
Learning centre	94.24	96.51
Agribusiness consultation	86.53	91.77
Partnership networking	92.31	96.58

Determinants of centre roles and ICT-based extension

The structural model explained 28.3% of the variance in the role of Agricultural Extension Centres and 30.4% in ICT-based agricultural extension. Positive coefficients were observed from respondent characteristics to centre roles (0.257) and ICT-based extension (0.293), and from extension support to centre roles (0.326) and ICT-based extension (0.319). In contrast, extension methods had a negligible negative coefficient for ICT-based extension (-0.008). The measurement model identified cosmopolitanism (0.923) and extension-worker competence (0.887) as strong indicators of respondent characteristics. Infrastructure (0.927), institutional support (0.904), and regulations (0.821) strongly represented extension support. ICT adoption capacity (0.945) and sustainability (0.934) also loaded strongly on the digital-extension construct.

DISCUSSION

The findings indicate that ICT-based agricultural extension depends not only on access to technology but also on the capacity of extension workers to convert digital resources into relevant advisory services. The positive coefficients linking respondent characteristics with both Agricultural Extension Centre roles and ICT-based extension underline the importance of competence and cosmopolitanism. Access creates opportunities for communication, whereas competence determines whether information can be verified, contextualised, and communicated effectively. This interpretation is consistent with Panda et al. (2019) and Kumar (2025), who reports that productive ICT use is associated with

Table 4. Structural model results

Relationship or indicator	Coefficient/loading	Interpretation
Characteristics → centre roles	0.257	Positive
Characteristics → ICT extension	0.293	Positive
Extension support → centre roles	0.326	Positive
Extension support → ICT extension	0.319	Positive
Extension methods → ICT extension	-0.008	Negligible negative
R^2 centre roles	0.283	Moderate explanatory value
R^2 ICT extension	0.304	Moderate explanatory value

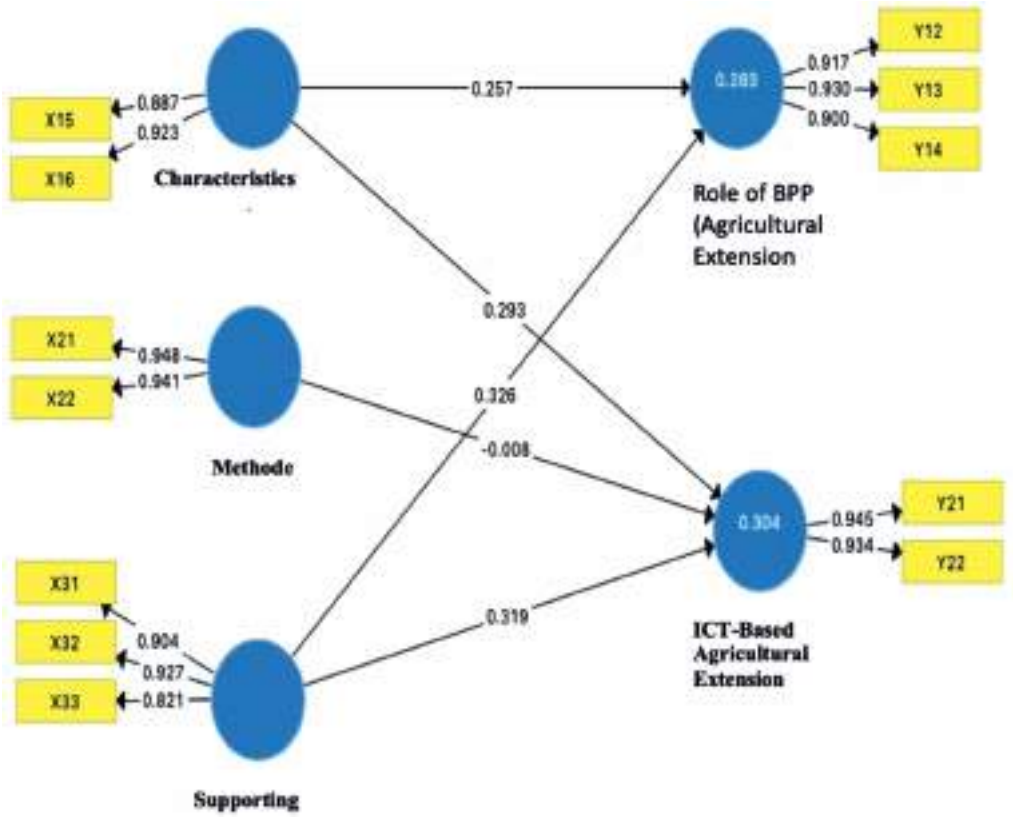


Figure 1. Structural model of ICT-based agricultural extension

education, media exposure, social participation, and extension contact. Digital competence therefore extends beyond platform operation to information verification, content development, online facilitation, data protection, and interpretation of farmer feedback (Sahoo et al., 2025). This broader capability orientation is consistent with integrative approaches to strengthening extensionists' roles in farmer empowerment (Amanah et al., 2026).

Cosmopolitanism connects local agricultural problems with knowledge and resources beyond the immediate community. Contacts with research institutions, universities, government agencies, private organisations, and professional networks expose extension workers to alternative practices and innovations. Digital platforms expand these opportunities through webinars, virtual demonstrations, and communities of practice. However, external information becomes useful only when it is assessed against farmers' resources, production systems, and risks. Extension centres can strengthen organisational learning by encouraging staff to evaluate and share knowledge obtained through external networks.

The continuing use of farm visits alongside social media supports a hybrid extension approach. Digital channels are appropriate for timely alerts, reminders, market information, and verified materials, whereas field interaction remains important for diagnosis, demonstration, negotiation, and complex problem-solving. The negligible coefficient linking extension methods with ICT-based extension does not show that conventional methods are ineffective. Rather, it suggests that adding digital media to existing activities does not automatically produce digital transformation. Effective hybrid extension deliberately connects field diagnosis, digital follow-up, farmer feedback, and institutional information while considering farmers' literacy, connectivity, device access, and the complexity of the agricultural problem.

The centres also show potential as local information and innovation intermediaries. Their strong information, learning, and partnership functions indicate that they perform more than administrative roles. This interpretation agrees with Azhari et al. (2025) and Syamsiah et al. (2025), who emphasise the contribution of extension, learning, and social resources to resilient farming systems. It also aligns with evidence that social transformation and institutional collaboration are central to food-system sustainability (Sumardjo et al., 2023; Godara et al., 2024; Godara et al., 2025). The comparatively lower agribusiness-consultation score, although still high, points to a gap between technical information provision and enterprise-oriented support. Agribusiness consultation requires individualised analysis of production costs, markets, financing, partnerships, and risks, together with coordination beyond the conventional extension system.

The positive coefficients for extension support confirm that digitalisation requires a supportive institutional environment comprising functioning infrastructure, organisational commitment, operational funding, technical assistance, and clear regulations. Digital farmer field schools improve knowledge when technology is integrated into facilitated learning (Kadam et al., 2026), while interactive platforms can strengthen farmer agency when they move beyond one-way information delivery (Godara et al., 2024; Yadav et al., 2026). Infrastructure may remain underused when connectivity is unreliable, training is discontinuous, or operational guidance is unclear. ICT-based extension should therefore be developed as part of the broader functions of Agricultural Extension

Centres rather than as a separate technology project (Sondarava et al., 2023). The moderate explained variance also indicates that trust, digital literacy, leadership, workload, organisational culture, farmer demand, and locally relevant content warrant examination in future longitudinal or multigroup studies.

CONCLUSION

Agricultural Extension Centres in West Java function as strong local hubs for information, learning, programme coordination, consultation, and partnerships. Their performance and the implementation of digital advisory services depend more clearly on extension-worker capability, outward information seeking, institutional support, infrastructure, and enabling regulations than on method choice alone. Conventional methods remain valuable for trust, diagnosis, and practical learning, but they need to be deliberately connected with digital communication and follow-up. Extension policy should therefore prioritise continuous digital competence development, peer learning across locations, reliable connectivity, operational support, and governance arrangements that integrate field and online services. A hybrid extension system built around capable personnel and supportive institutions offers a practical pathway for widening access without losing the interpersonal qualities that make agricultural advice credible and locally relevant.

DECLARATIONS

Ethics approval: Formal ethical clearance or institutional review board approval was not specifically required under the institutional procedures applicable to minimal-risk, non-invasive social research at the time of data collection. This institutional determination was confirmed by Bogor Agricultural Development Polytechnic in the Letter of Ethical Consideration No. 346.1/SM.220/I.8/02/2026, dated 4 February 2026. The study involved competent adult participants, did not include medical or clinical interventions, biological sampling, vulnerable populations, or highly sensitive personal data, and followed the ethical principles of the Declaration of Helsinki (1964) and its subsequent amendments insofar as they apply to non-clinical social research.

Consent to participate: Before data collection, all respondents received information about the study purpose, the voluntary nature of participation, the right to decline or withdraw without consequence, and the confidential handling of their responses. Informed consent was obtained from every participant before the questionnaire or interview, and anonymity was maintained during analysis and reporting.

Data availability statement: The de-identified data supporting the findings of this study are available from the corresponding author upon reasonable request. Public release is restricted to protect participant confidentiality.

Conflict of interest: The authors declare no commercial, financial, or non-financial conflicts of interest related to this study.

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Research Article

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Decoding the Barriers to Adoption of Dairy Interventions among Farmers: A Principal Component Analysis from Uttar Pradesh, India

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HIGHLIGHTS

- Dairy farmers faced severe constraints in adopting dairy interventions.
- Feed cost, fodder scarcity and veterinary treatment cost were the major constraints.
- Principal component analysis retained five components explaining 63.83 per cent of total variance.

ARTICLE INFO

Keywords: Constraint severity index, Farmer's perception, Principal component analysis, Livestock services, Fodder scarcity.

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ABSTRACT

The study was conducted during 2025-26 in Banda and Bulandshahr districts of Uttar Pradesh to identify and classify perceived constraints to dairy intervention adoption among farmers. Data were collected from 240 dairy farmers through a structured interview schedule covering 20 constraints. Constraints were analysed using frequency, percentage, weighted mean score, constraint severity index and principal component analysis. The overall constraint severity index was 73.70, indicating a severe constraint situation. High cost of cattle feed ranked first with a WMS of 4.41 and CSI of 88.25, followed by year-round non-availability of green and dry fodder (WMS 4.30; CSI 86.00) and high cost of veterinary medicines and treatment (WMS 4.27; CSI 85.33). The KMO value was 0.808 and Bartlett's test was significant. Five components were retained and together explained 63.83 per cent of total variance. The components represented production-resource and input, animal-health and breeding-service, extension and participation, credit and insurance, and milk-market access and price-realisation constraints. The findings indicated that farmers perceived constraints across production, service, financial and marketing areas of dairy farming.

INTRODUCTION

Dairying is a major livelihood activity for rural households in India, particularly for small and marginal farmers who depend on livestock for regular income, nutrition and risk reduction. India produced 247.87 million tonnes of milk during 2024-25, while per capita milk availability reached 485 g/day. Uttar Pradesh remained the leading milk-producing state, contributing 15.66 per cent of national milk production (Department of Animal Husbandry and Dairying, 2025)." Uttar Pradesh is the leading milk-producing state of the country, yet dairy development benefits are not uniform across regions or farm households. Productivity and profitability depend on farmers' access to quality feed and fodder, timely veterinary care, improved breeding services, credit, training, insurance and remunerative milk markets. Improved dairy interventions in breeding, feeding, health care, housing and management are promoted to improve animal productivity and farm income. Adoption of such practices varies across production contexts and is closely associated with the productivity status of milch animals (Pouchepparadjou et al., 2024). Dairy technology

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adoption is shaped by enabling services, farm resources and the cost of using improved practices (Korir et al., 2023). Kaushik et al. (2024) identify lack of support, high cost and investment-related barriers as major challenges in dairy technology adoption, while Erdem and Agir (2024) relate adoption to income, investment, breed ownership and advisory interaction. Kirimi et al. (2024) report that income, education, credit, extension contact and farmer group participation influence adoption of modern dairy technologies. Reddy et al. (2024) identified knowledge, education and extension access as important factors in adoption of climate-resilient dairy farming practices. High feed cost, fodder scarcity, veterinary expenses, poor access to artificial insemination, credit difficulty, weak insurance coverage and unstable milk prices can restrict farmers' use of recommended interventions. Earlier dairy constraint studies report feed cost, veterinary expenditure, fodder scarcity, weak extension support, credit limitations, high input cost and lack of technical knowledge as important barriers to improved dairy farming (Gupta et al., 2013; Singh et al., 2016; Dhaka et al., 2017; Panchbhai et al., 2017; Smitha et al., 2019). Similar constraints related to green fodder, concentrate availability, veterinary service charges, emergency treatment and milk marketing are reported by Barman et al. (2024). Acharya et al. (2022) identify gaps in adoption of sustainable dairy management practices where management conditions and service access are limiting. In eastern Uttar Pradesh, Maurya et al. (2025) report that marginal and small dairy farmers face important institutional and financial constraints, with insurance-related problems emerging strongly. Recent evidence from Uttar Pradesh also shows that dairy farmers prefer low-cost and easily available feeding options (Shruti et al., 2025). The present study is located in two contrasting dairy situations of Uttar Pradesh. Bulandshahr represents a comparatively developed dairy production environment of Western Uttar Pradesh, whereas Banda represents Bundelkhand, where livestock production operates under comparatively greater limitations in water, feed resources and institutional support (Mishra et al., 2026). This contrast provides a useful setting to examine constraints affecting adoption of dairy interventions. Constraint severity analysis is used to assess the seriousness of individual constraints, while principal component analysis is applied to examine broader patterns among the constraint variables for extension planning and dairy-development support.

METHODOLOGY

The study was conducted during 2025-26 in Banda and Bulandshahr districts of Uttar Pradesh. The districts were purposively selected to represent contrasting dairy-production situations, with Bulandshahr representing Western Uttar Pradesh and Banda representing Bundelkhand. Two development blocks were selected randomly from each district, followed by four villages selected randomly from each block. Dairy farmers possessing at least two dairy animals were considered eligible, and 15 eligible farmers were selected randomly from each village, giving a total sample of 240 farmers. Inference was restricted to the two contrasting study settings. Primary data were collected through personal interviews using a structured and pre-tested interview schedule. Constraint items were identified through literature review, field observations, stakeholder consultation, expert scrutiny and pre-testing. The final schedule contained 20 constraints covering production resources, animal-health and breeding services, institutional support, credit and insurance, extension contact, milk marketing, labour and social participation. Internal consistency of the 20-item scale was satisfactory (Cronbach's $\alpha = 0.812$). Each constraint was rated on a five-point continuum from very severe to not a constraint, with scores of 5 to 1. Item scores ranged from 1 to 5 and the total possible score from 20 to 100.

Constraints were analysed using frequency, percentage, Weighted Mean Score (WMS) and Constraint Severity Index (CSI). WMS was computed as $WMS_j = \Sigma f_{ij}\ s_i/N$, where f_{ij} was the frequency in the ith response category, s_i was the corresponding score and N was the number of respondents. CSI was calculated as $CSI_j = (WMS_j/5) \times 100$, following the weighted constraint-severity approach used in agricultural constraint analysis (Innazent et al., 2022). Equal class intervals of 0.80 classified WMS values of 4.21 to 5.00, 3.41 to 4.20, 2.61 to 3.40, 1.81 to 2.60 and 1.00 to 1.80 as very severe, severe, moderately severe, less severe and not a constraint, respectively. Principal Component Analysis (PCA) was applied to all 20 constraint variables. Suitability was assessed using the Kaiser-Meyer-Olkin measure, Bartlett's test of sphericity, individual Measures of Sampling Adequacy and extraction communalities. Components were initially examined using eigenvalues greater than one and the scree plot. The retention decision was further assessed through parallel analysis using 1,000 random datasets and the 95th-percentile criterion (O'Connor, 2000). Varimax rotation with Kaiser normalization was applied. Absolute component loadings of 0.50 or above were used for interpretation, and component names were assigned from the substantive meaning of the variables with the strongest loadings. Data were analysed using IBM SPSS Statistics 26.

RESULTS

Table 1 presents the constraints perceived by dairy farmers in the adoption of dairy interventions. The overall mean WMS was 3.69 and the overall CSI was 73.70, indicating a severe level of constraints. Three constraints were rated very severe. High cost of cattle feed ranked first with a WMS of 4.4125 and CSI of 88.25, followed by non-availability of green and dry fodder round the year (WMS 4.3000; CSI 86.00) and high cost of veterinary medicines and treatment (WMS 4.2667; CSI 85.33). Twelve constraints were classified as severe and four as moderately severe. Social or family restrictions limiting participation in training or dairy activities received the lowest WMS of 2.5708 and CSI of 51.42 and were classified as less severe.

Table 2 presents the sampling adequacy and extraction communalities of the 20 constraint variables used in principal component analysis. The Kaiser-Meyer-Olkin value was 0.808 and Bartlett's test of sphericity was significant ($÷^2 = 1662.152$, df = 190, $p < 0.001$), supporting the use of PCA. Individual MSA values ranged from 0.669 to 0.897, while extraction communalities ranged from 0.525 to 0.713. All variables recorded MSA and communality values above 0.50 and were retained for component extraction.

Table 3 presents the eigenvalues and variance explained by the retained principal components. Five components had eigenvalues greater than one. Component I had an eigenvalue of 4.552 and

Table 1. Constraints perceived by dairy farmers in adoption of dairy interventions

S.No.	Constraint	WMS	CSI	Severity	Rank
1.	High cost of cattle feed	4.4125	88.25	Very severe	I
2.	Non-availability of green and dry fodder round the year	4.3000	86.00	Very severe	II
3.	High cost of veterinary medicines and treatment	4.2667	85.33	Very severe	III
4.	Non-availability/high cost of improved/crossbred dairy animals	4.0583	81.17	Severe	IV
5.	Inadequate land or irrigation for fodder cultivation	3.9750	79.50	Severe	V
6.	Delay in emergency veterinary care	3.9167	78.33	Severe	VI
7.	Lack of need-based training and technical guidance	3.8583	77.17	Severe	VII
8.	Frequent animal-health issues/disease outbreaks	3.8000	76.00	Severe	VIII
9.	Low milk yield from local/non-descript animals	3.7833	75.67	Severe	IX
10.	Lack of regular interaction with extension/veterinary staff	3.7042	74.08	Severe	X
11.	Low and fluctuating prices received for milk	3.6875	73.75	Severe	XI
12.	Poor access to livestock insurance/claim procedures	3.6333	72.67	Severe	XII
13.	Difficulty obtaining cattle loans from banks	3.6083	72.17	Severe	XIII
14.	High labour cost for dairy management	3.5500	71.00	Severe	XIV
15.	Dependence on middlemen for milk marketing	3.5042	70.08	Severe	XV
16.	High interest/inflexible terms on cattle loans	3.4000	68.00	Moderately severe	XVI
17.	Low conception rate after artificial insemination	3.3833	67.67	Moderately severe	XVII
18.	Difficulty accessing quality artificial insemination services nearby	3.2833	65.67	Moderately severe	XVIII
19.	Absence of milk collection/chilling centres in village	3.0042	60.08	Moderately severe	XIX
20.	Social/family restrictions limiting participation in training/dairy activities	2.5708	51.42	Less severe	XX

Overall mean WMS = 3.69; Overall CSI = 73.70; Overall severity category = Severe.
Note: WMS = Weighted Mean Score; CSI = Constraint Severity Index.

Table 2. Sampling adequacy and communalities of constraint variables used in PCA

Particulars	Value
A. KMO and Bartlett's test	
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.808
Bartlett's Test of Sphericity: Approx. Chi-square	1662.152
Degrees of freedom	190
Significance under Bartlett's test	<0.001

Particulars	Extraction communality	Individual MSA
B. Extraction communalities of constraint variables		
High cost of cattle feed	0.662	0.857
High cost of veterinary medicines and treatment	0.642	0.818
Non-availability of green and dry fodder round the year	0.583	0.882
Inadequate land or irrigation for fodder cultivation	0.638	0.827
High labour cost for dairy management	0.525	0.897
Lack of need-based training and technical guidance	0.700	0.669
Difficulty accessing quality artificial insemination services nearby	0.556	0.867
Low conception rate after artificial insemination	0.563	0.848
Frequent animal-health issues/disease outbreaks	0.650	0.818
Delay in emergency veterinary care	0.685	0.833
Difficulty obtaining cattle loans from banks	0.660	0.776
High interest/inflexible terms on cattle loans	0.656	0.789
Poor access to livestock insurance/claim procedures	0.713	0.734
Low milk yield from local/non-descript animals	0.584	0.816
Non-availability/high cost of improved/crossbred dairy animals	0.581	0.889
Lack of regular interaction with extension/veterinary staff	0.691	0.700
Absence of milk collection/chilling centres in village	0.670	0.728
Dependence on middlemen for milk marketing	0.707	0.693
Low and fluctuating prices received for milk	0.690	0.730
Social/family restrictions limiting participation in training/dairy activities	0.609	0.783

Individual MSA values were obtained from the diagonal of the anti-image correlation matrix. MSA = Measure of Sampling Adequacy.

Table 3. Total variance explained by retained principal components

Component	Initial eigenvalue	Variance explained (%)	Cumulative variance (%)	Rotated sum of squared loadings	Rotated variance (%)	Rotated cumulative variance (%)
I	4.552	22.761	22.761	3.510	17.550	17.550
II	2.876	14.382	37.143	3.014	15.068	32.617
III	1.920	9.601	46.744	1.932	9.662	42.279
IV	1.842	9.210	55.954	2.208	11.042	53.321
V	1.575	7.877	63.831	2.102	10.511	63.831

Parallel analysis based on 1,000 random datasets and the 95th-percentile criterion supported retention of five components. The observed eigenvalues for Components I-V exceeded the corresponding random eigenvalues, while Component VI did not.

explained 22.761 per cent of the total variance, followed by Components II, III, IV and V with eigenvalues of 2.876, 1.920, 1.842 and 1.575, respectively. Together, the five components explained 63.831 per cent of the total variance. After Varimax rotation, Components I-V accounted for 17.550, 15.068, 9.662, 11.042 and 10.511 per cent of the variance, respectively. Parallel analysis supported the same five-component solution. The observed eigenvalues for Components I-V exceeded their corresponding 95th-percentile random eigenvalues of 1.649, 1.517, 1.431, 1.354 and 1.293, whereas the sixth observed eigenvalue (0.705) was lower than the corresponding random eigenvalue (1.235).

The scree plot in Figure 1 showed a decline across the first five components followed by a marked drop between Components V and VI and a gradual flattening thereafter. Five components had eigenvalues greater than one. The scree pattern and parallel analysis both supported retention of the five-component solution.

Table 4 presents the Varimax-rotated component matrix of the 20 constraint variables. Absolute loadings of 0.50 or above were considered for interpretation. All variables recorded a loading above 0.50 on one component, with no salient cross-loadings at the adopted cut-off. Component I comprised six constraints related

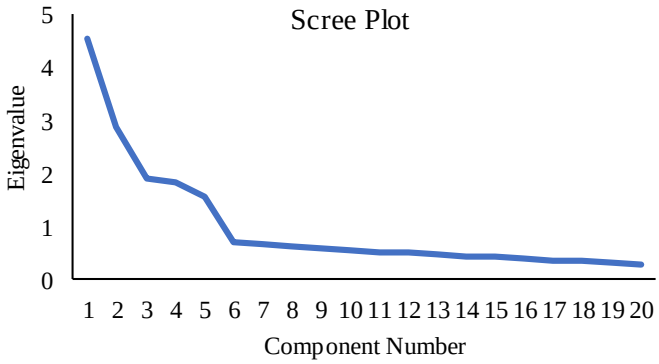


Figure 1. Scree plot showing eigenvalues of principal components

mainly to feed and fodder resources, labour, milk yield and access to improved dairy animals, and was termed production-resource and input constraints. Component II contained five constraints concerning veterinary care, animal health and artificial insemination and was termed animal-health and breeding-service constraints. Component III grouped need-based technical guidance, interaction with extension or veterinary personnel and restrictions on

Table 4. Rotated component matrix of perceived constraints to dairy intervention adoption

Constraint variable	Component I	Component II	Component III	Component IV	Component V
High cost of cattle feed	0.806				
Inadequate land or irrigation for fodder cultivation	0.789				
Low milk yield from local/non-descript animals	0.751				
Non-availability/high cost of improved/crossbred dairy animals	0.742				
Non-availability of green and dry fodder round the year	0.736				
High labour cost for dairy management	0.676				
Frequent animal-health issues/disease outbreaks		0.800			
Delay in emergency veterinary care		0.790			
High cost of veterinary medicines and treatment		0.772			
Difficulty accessing quality artificial insemination services nearby		0.739			
Low conception rate after artificial insemination		0.714			
Lack of need-based training and technical guidance			0.833		
Lack of regular interaction with extension/veterinary staff			0.801		
Social/family restrictions limiting participation in training/dairy activities			0.703		
Poor access to livestock insurance/claim procedures				0.838	
High interest/inflexible terms on cattle loans				0.793	
Difficulty obtaining cattle loans from banks				0.785	
Dependence on middlemen for milk marketing					0.831
Low and fluctuating prices received for milk					0.818
Absence of milk collection/chilling centres in village					0.803

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser normalization.

participation and was termed extension and participation constraints. Component IV comprised three constraints related to cattle loans and livestock insurance and was termed credit and insurance constraints. Component V grouped milk collection, dependence on middlemen and milk-price problems and was termed milk-market access and price-realisation constraints.

DISCUSSION

The overall Constraint Severity Index of 73.70 places the perceived constraints of dairy farmers in the severe category. High cost of cattle feed, year-round non-availability of green and dry fodder, and high cost of veterinary medicines and treatment occupy the first three ranks. These are regular requirements in dairy farming and add to the cost of maintaining recommended feeding and health-care practices. Smitha et al. (2019) similarly identify cattle-feed cost and expenditure on veterinary services and medicines among the major constraints of dairy farmers in Kerala. Barman et al. (2024) also report limited concentrate availability, high veterinary charges and difficulty in obtaining emergency treatment among important dairy-farming constraints. Comparable findings from Jabalpur identify year-round green fodder shortage, veterinary treatment cost, low conception after artificial insemination and low milk price among important dairy-farming constraints (Somtiya et al., 2024). The next group of highly ranked constraints includes the cost or non-availability of improved dairy animals, inadequate land or irrigation for fodder cultivation, delay in emergency veterinary care, lack of need-based technical guidance, frequent animal-health problems and limited interaction with extension or veterinary personnel. The ranking shows that farmers' difficulties are not confined to input prices; access to production resources and timely technical and veterinary services also remains important. Dhaka et al. (2017) report constraints related to knowledge, extension support and credit in the adoption of improved dairy practices. Maurya et al. (2025) also identify financial and institutional difficulties among dairy farmers in eastern Uttar Pradesh, with livestock insurance emerging as an important concern. Social or family restrictions receive the lowest rank in the present study, indicating that production, financial and service-related problems are rated more seriously within the set of constraints examined.

PCA provides a complementary view by showing which constraint ratings vary together across farmers. The five retained components explain 63.83 per cent of the total variance. Component I groups feed cost, fodder and land resources, labour cost, milk yield and access to improved dairy animals, forming a production-resource and input component. The inclusion of feed and fodder constraints in this component is consistent with their high position in the severity ranking. Component II brings together veterinary treatment cost, disease problems, emergency veterinary care and the two artificial-insemination constraints, giving a distinct animal-health and breeding-service component. The remaining components represent more specific institutional areas. Component III combines need-based training, regular interaction with extension or veterinary personnel and restrictions on participation. Component IV groups cattle-loan access, loan terms and livestock insurance, while Component V contains absence of milk collection or chilling facilities, dependence on middlemen and low or fluctuating milk prices. A similar combination of veterinary access, artificial insemination, credit, feed, technical knowledge and milk-marketing constraints has been reported among dairy farmers in northern Bihar (Saurav et al., 2024). Similarly group dairy constraints into service delivery, local market, artificial insemination, affordability and awareness-related categories using PCA. Gupta et al. (2021) also report separate patterns related to breeding, feeding, health care, management, marketing and finance. The present structure follows this broader pattern, although the composition of the components reflects the production and institutional conditions of the study area. The severity ranking and PCA serve different but complementary purposes. WMS and CSI identify the constraints rated most seriously by farmers, whereas PCA groups constraints according to similarity in their response patterns. Feed and fodder costs require particular attention because of their high severity, while the component structure also identifies veterinary and breeding services, extension contact, credit and insurance, and milk marketing as separate areas of concern. Dairy-development efforts in the study districts should combine technical guidance with reliable service access and stronger financial and marketing support.

CONCLUSION

Dairy farmers in the study area face considerable production, service, financial and marketing constraints in using recommended dairy interventions. High feed cost, year-round fodder scarcity and veterinary treatment cost emerge as the most serious concerns. The component analysis further separates the constraints into five groups associated with production resources and inputs, animal-health and breeding services, extension and participation, credit and insurance, and milk marketing. The findings indicate that addressing individual constraints alone may leave other important difficulties unresolved. Greater availability of fodder resources, timely veterinary and breeding services, regular need-based technical guidance, easier access to institutional credit and livestock insurance, and stronger local milk-marketing arrangements are required to improve the conditions under which dairy farmers adopt and continue recommended practices.

DECLARATION

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection. The study involved no invasive procedure on human participants as such the committee of Department of Extension Education, BUAT Banda, India waived the ethical approval.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that during the preparation of this work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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APV, BPM, GS); preparation of the original manuscript (AS); review and revision of the manuscript (BKG, GM, APV, BPM, GS); supervision of the research (BKG). All authors read and approved the final manuscript.

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Research Article

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A Comparative Assessment of Agricultural Students on Career Aspiration among Public and Private Universities

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HIGHLIGHTS

- Achievement motivation, ICT skills, entrepreneurship training and mass media exposure were significant predictors of overall career aspiration.
- Public university students reported significantly higher educational aspirations compared to private university students in the sampled institutions.
- Private university students reported significantly higher self-employment and social aspirations compared to public university students in the sampled institutions.
- Public and private university students differed significantly in selected dimensions of career aspiration.

ARTICLE INFO

Keywords: Achievement motivation, Agricultural undergraduates, Career aspiration, ICT skills, Entrepreneurship training, Institutional differences.

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ABSTRACT

Career aspiration played a crucial role in developing human capital for the rapidly evolving economy. Despite the rapid expansion of agricultural education in India, limited empirical evidence exists on differences in career aspiration across institutional setting in agricultural higher education. The present study explored the institutional differences and other attributes on career aspiration of agricultural students in West Bengal. The present cross-sectional study compared five dimensions of career aspiration among 120 agricultural students from six purposively selected universities, with 20 students randomly selected from each institution. Data was collected through a structured personal interview method and analyzed using descriptive statistics, Z-test, correlation and multiple regression analysis. The findings highlighted significant differences between public and private university students in educational, self-employment and social aspiration dimensions, whereas job and economic aspirations did not differ significantly. Achievement motivation, ICT skills, information seeking behaviour, mass media exposure, and entrepreneurship training exposure were significantly associated with career aspiration across dimensions. Multiple regression analysis revealed that achievement motivation, ICT skills, mass media exposure and entrepreneurship training exposure significantly predicted career aspiration, explaining 54.2% of the variance. The findings suggested the need for institutional collaborations, entrepreneurship-oriented learning, and digital competencies to strengthen career aspiration.

INTRODUCTION

The Indian Agricultural Education system has experienced a significant growth in the number of universities, with a total of 74 ICAR-accredited universities, and has been attracting about 28,000 undergraduate and 17,500 postgraduate students every year (Indian Council of Agricultural Research, 2024). There are four hundred

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private colleges across the country of which ICAR accredited private agricultural universities have grown from five in 2020–21 to 22 in 2024–25 (Press Information Bureau, 2025). The state of West Bengal is in the highest cluster of agricultural education enrollment, having 65 to 72 per cent of all students enrolled in agriculture disciplines at the state level (Kumar and Jain, 2022). The enrolment in Higher Education in India has grown from 3.42 crore in 2014-15 to 4.33 crore in 2021-22 (Ministry of Education, 2024). The academic (43.90%) and public-sector (35.04%) careers are preferred by the agricultural students, with only 1.18% preferring farming, which means the students are oriented towards white-collar jobs (Raju & Devarani, 2023). The present investigation is inspired by this contradiction that agriculture is a professional degree with hands-on training and practical experience, and yet, the graduates do not appear to be drawn towards traditional agrarian livelihoods. Educational qualification is a key determinant of occupational preferences, where higher education is associated with less farming interest (Chinchmalatpure & Tekale, 2019). West Bengal has seen an improvement in career-oriented competences among rural youth, with the support from the institutions (Ghosh et al., 2026). The institutional dimension has been gaining importance, with training exposure being linked to the development of entrepreneurship competency (Arunkumar et al., 2021; Ray et al., 2022) and psychological factors and institutional support being correlated to entrepreneurial intentions (Panigrahi et al., 2025: Kademani et al., 2026). Career preference formation is mediated by institutional environment and peer networks (Meinam et al., 2023). But most of the studies available are single institution studies (Ashokkumar et al., 2026). The relationship between public and private university affiliation with students' career aspirations is under-researched in West Bengal. The study aims to fill this gap and to compare the career aspirations of public and private agricultural university students of West Bengal in terms of five dimensions (educational, job, self-employment, social and economic) of career aspiration. Career aspiration is a multidimensional concept that encompasses future goals and expectations for education, employment, self-employment, social status and economic attainment (Gottfredson, 1981; Lent et al., 1994). It is different from career choice (a decisional outcome), career readiness (preparedness for transition) and perceived employability (self-assessed job acquisition capability). The study is based on Social Cognitive Career Theory (Lent et al., 1994) that states that career aspirations are influenced by three factors: self-efficacy beliefs, outcome expectations, and contextual supports. The study attempted to analyze association between selected socio-personal, psycho-communication and socio-economic variables and five dimensions of career aspiration; find out the significant predictors of overall career aspiration by using multiple regression; and compare five dimensions between public university students and private university students.

METHODOLOGY

The present study was conducted in six universities located across different districts of West Bengal during 2024-2025. Three public universities, namely Bidhan Chandra Krishi Viswavidyalaya (Nadia), Uttar Banga Krishi Viswavidyalaya (Cooch Behar), and Palli Shiksha Bhawan, Visva-Bharati (Birbhum) as well as three private universities, namely Brainware University (Kolkata), The Neotia University (South 24 Parganas), and Seacom Skills University (Birbhum district) were selected using purposive sampling. Public university selection was confined to only three universities present in the state. The private universities selection was based on ICAR accreditation or affiliation and a minimum of five years of operation of their agricultural departments. The target population comprised all the agricultural students of the 4th year B.Sc. (Agriculture Honors) programme at the selected universities for the academic year 2024-2025. The fourth-year students were selected as respondents as they were on the verge of completing their degree programme and had developed relatively stable career aspirations. Simple random sampling using Fisher and Yates (1963) random number table was employed to select 20 students from each university. A total sample of 120 respondents was obtained from the procedure. Career aspiration was measured through the pre-structured scale of Gaikwad (2011) with slight modifications. The modified scale was assessed for content validity by a panel of subject experts from agricultural extension, educational psychology, and career counselling, who evaluated each item for relevance and clarity. Items were retained based on expert consensus. The scale was subsequently pilot tested on 20 respondents outside the study region and demonstrated acceptable internal consistency (Cronbach's $\alpha = 0.72$). The overall dependent variable in regression was the composite score of the career aspiration scale, which was the mean of all scale items. Established indicators were used to measure 17 predictor variables. A pre-tested structured interview schedule was used to gather the data and analyzed through frequency and percentage distributions. Bivariate correlation analysis was used to identify the relationship between the independent and dependent variable with the help of Pearson product-moment correlation coefficient (r). A two-sample Z-test compared mean differences between groups, justified by equal sample sizes (n = 60 each) exceeding 30. To find the key determinant influencing career aspiration as well as R^2 coefficient of determination, multiple linear regression analysis was performed. Statistical significance was assessed at the 5% and 1% levels, as appropriate. Standardized beta coefficients (β) were used to compare the relative contribution of predictors.

RESULTS

Correlates of career aspiration

Pearson's correlation showing the relationship between selected independent variables and different dimensions of career aspirations is presented in Figure 1. None of the socio-personal attributes of the respondents, namely age, caste, residential area, family type and participation in co-curricular activities, established a significant relationship with any dimension of career aspiration. Only the academic variable, Academic performance ($r = 0.22$, $p<0.05$) measured through CGPA, reported significant positive association with educational aspiration.

The psycho-communication variables, such as achievement motivation, information seeking behaviour, ICT skills, mass media exposure and entrepreneurship training were found to be the

Figure 1. Heatmap of correlations between predictors and career aspiration dimensions

Independent Variables	Dimensions of Career Aspirations (r)				
	Educational Aspiration	Job Aspiration	Self-Employment Aspiration	Social Aspiration	Economic Aspiration
Age	0.08	-0.05	-0.12	0.03	0.06
Caste	0.02	-0.13	-0.15	0.00	0.04
Residential Area	0.10	0.05	0.04	-0.14	-0.01
Family Type	-0.02	-0.09	-0.05	0.01	0.09
CGPA	0.22*	0.18	0.02	0.08	0.11
Co- curricular Activities	-0.04	-0.04	0.13	-0.09	0.10
Father's Education	0.16	0.12	0.06	0.08	0.07
Mother's Education	0.14	0.09	0.04	0.11	0.09
Family Income	0.08	0.06	0.19*	0.12	0.21*
Material Possession	0.19*	0.14	0.26**	0.15	0.22*
Land Holding	0.12	0.05	0.31**	0.08	0.18*
Information Seeking Behaviour	0.31**	0.28*	0.35**	0.22*	0.26*
Mass Media Exposure	0.24*	0.19	0.22*	0.33**	0.29*
Achievement Motivation	0.42**	0.36**	0.51**	0.43**	0.39**
Entrepreneurship Training provided by university	0.15	-0.22*	0.48**	0.18	0.24*
ICT Skills developed by university	0.35**	0.31**	0.28*	0.26*	0.33**
Library Exposure provided by university	0.23*	0.11	0.08	0.14	0.05

Correlation Coefficient (r)

−0.60	−0.40	−0.20	0.00	0.20	0.40	0.60

*** p < 0.01* (Significant at 1% level), ** p < 0.05* (Significant at 5% level)

significant correlates across several dimensions. Achievement motivation recorded a highly significant positive relationship across all five dimensions, showing the strongest relationship with self-employment aspiration (r = 0.51, p<0.01). Information seeking behaviour reported significant and positive association with all five dimensions, with the strongest relationship being with the self-employment aspiration (r = 0.35, p<0.01) followed by educational aspiration (r = 0.31, p<0.01). ICT skills developed by the university also showed a significant positive correlation with all five dimensions. Mass media exposure was found to have significant relationship with educational, self-employment, social and economic aspiration. Entrepreneurship training provided by the university portrayed a unique pattern where it was positively related to self-employment aspiration (r = 0.48, p<0.01) and economic aspiration (r = 0.24, p<0.05) but negatively related to job aspiration (r = -0.22, p<0.05).

Socio-economic indicators, namely family income, material possession and land holding, reported positive association with self-employment and economic aspiration but largely failed to influence educational, job and social aspiration. Library exposure showed a modest significant relationship with educational aspiration (r = 0.23, p<0.05).

Predictors of career aspiration

The results of multiple regression model highlighting the factors influencing career aspirations among agricultural students is outlined in Table 1, explained 54.2 per cent of the total variance in career aspiration (R^2 = 0.542; Adjusted R^2 = 0.466; p<0.001. Among the seventeen predictors included in the model, mass media exposure (β = 0.281), achievement motivation (β = 0.405), entrepreneurship training provided by the university (β = 0.298) and ICT skills developed by the university (β = 0.392), were found to be significant independent predictors influencing career aspiration at the 1% level of significance. Achievement motivation being the strongest predictor, followed by ICT skills, entrepreneurship training and mass media exposure in the order.

Information seeking behaviour showed positive and significant relationship with all five dimensions, however, it failed to emerge as a significant predictor in multiple regression model. Socio-personal variables, such as CGPA, parental education and family

Table 1. Factors Influencing Career Aspirations among Agricultural Students

Independent Variables	Unstandardized *B*	Standard Error	Standardized *β*	*t* value	*p*-value	Significance
Age	–0.245	0.234	–0.062	“1.047	0.297	NS
Caste	–0.178	0.187	–0.054	“0.952	0.343	NS
Residential Area	0.198	0.176	0.061	1.125	0.263	NS
Family Type	–0.112	0.148	–0.034	“0.757	0.451	NS
CGPA	0.089	0.287	0.019	0.310	0.757	NS
Co-curricular Activities	–0.058	0.128	–0.029	“0.453	0.651	NS
Father’s Education	0.134	0.156	0.057	0.859	0.392	NS
Mother’s Education	0.098	0.134	0.043	0.731	0.466	NS
Family Income	0.004	0.015	0.010	0.267	0.790	NS
Material Possession	0.178	0.148	0.086	1.203	0.231	NS
Land Holding	0.089	0.128	0.043	0.695	0.489	NS
Information Seeking Behaviour	0.112	0.078	0.085	1.436	0.154	NS
Mass Media Exposure	0.268	0.067	0.281	4.000	<0.001	**
Achievement Motivation	0.398	0.065	0.405	6.123	<0.001	**
Entrepreneurship Training provided by university	0.245	0.054	0.298	4.537	<0.001	**
ICT Skills developed by university	0.328	0.051	0.392	6.431	<0.001	**
Library Exposure provided by university	0.124	0.167	0.051	0.743	0.459	NS

Model Summary: R^2 = 0.542 | Adjusted R^2 = 0.466 | *Note:* * $p < 0.05$; ** $p < 0.01$; NS = non-significant

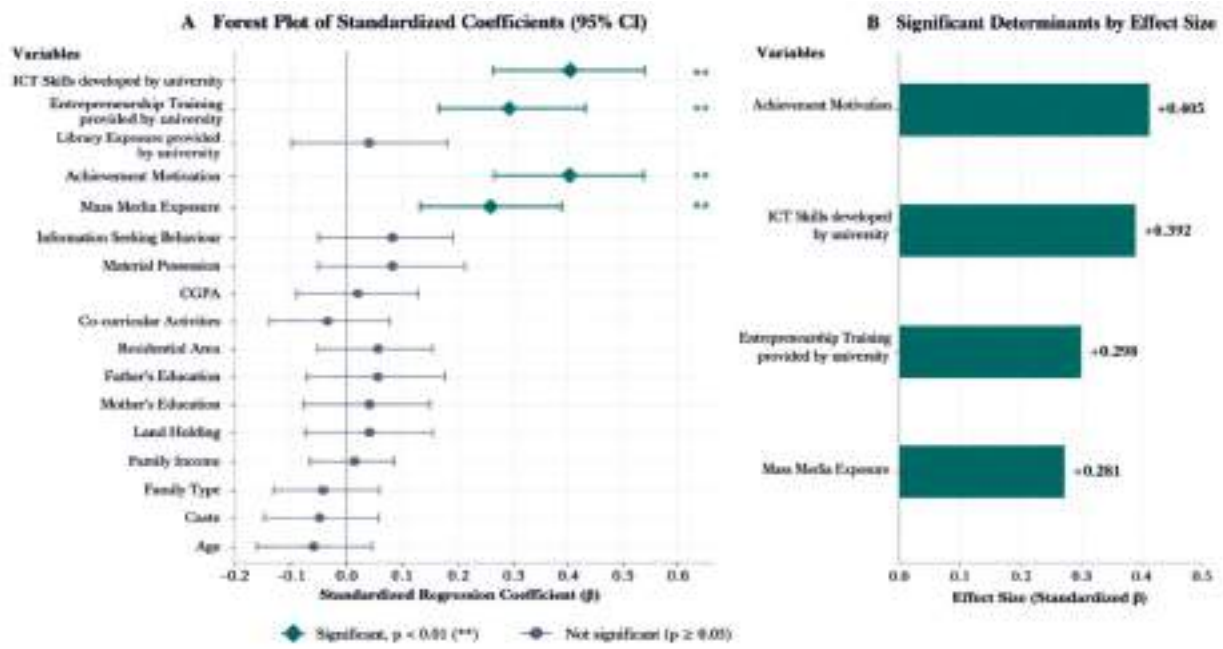


Figure 2. Forest plot of standardized coefficients for career aspiration

income, similarly did not emerge as significant predictors of career aspiration.

Comparison between private and public university students

The comparative analysis between public and private university students shown in Table 2 revealed statistically significant differences in three of the five aspiration dimensions. Public university students reported significantly higher educational aspiration than private university students with a medium effect size (d = 0.56). Private university students reported significantly higher self-employment aspiration with a medium-size effect (d= -0.74), as well as higher social aspiration with small-size effect (d = -0.44). No significant differences were observed between the two groups in terms of Job aspiration and Economic aspiration.

DISCUSSION

Information seeking behaviour was consistently associated with all five dimensions indicating that students who actively seek out career-related information through various sources tend to develop clearer and broader occupational goals. The study conducted by Chayal et al. (2023) found that the stream of study is significantly related to systematic information seeking behavior among undergraduates, but the study did not directly investigate career aspiration. In the present study, the link between information

Table 2: Comparison of Career Aspiration Dimensions among Agricultural Students of Public and Private Universities in West Bengal

Category	Public Mean ± SD	Private Mean ± SD	Z-Statistic	p-value	Significance	Cohen's d	Effect Size
Educational Aspirations	3.83 ± 1.06	3.17 ± 1.32	3.05	0.002	**	0.56	Medium
Job Aspirations	4.88 ± 1.74	4.33 ± 1.82	1.69	0.090	NS	0.31	Small
Self-Employment Aspirations	2.37 ± 1.73	3.98 ± 2.55	-4.06		**	-0.74	Medium
Social Aspirations	5.20 ± 1.45	5.80 ± 1.30	-2.38	0.017	*	-0.44	Small
Economic Aspirations	3.63 ± 0.97	3.73 ± 0.99	-0.55	0.577	NS	-0.10	Negligible

Note: * $p < 0.05$; ** $p < 0.01$; NS = non-significant

seeking behavior and career aspiration was investigated in relation to several dimensions of career aspiration among agricultural students.

The strong association of achievement motivation with self-employment aspiration provides empirical support for the classical proposition of McClelland (1961) that individuals with a high need for achievement consistently set challenging goals and seek out opportunities like entrepreneurship that offer autonomy and measurable success.

The exposure to mass media was related to most of the aspiration dimensions, except for job aspiration. Mass media exposure was operationalized as a composite variable in the present study, which included print, electronic and digital media, and the relative individual contribution of each of these were not examined. This trend indicates that media exposure could reach a wider audience of career paths related to entrepreneurship and social mobility than traditional career paths. All five dimensions were found to be uniformly related to ICT skills, which shows that ICT skills play an important role in facilitating the career orientation among agricultural students. Bairagi and Shahi (2026), also found a positive correlation between digital competence and career readiness in Indian university students, noting that digital employability readiness was positively associated with vocational attitude maturity.

The negative relationship between entrepreneurship training and job aspiration implies that there is a possibility that students who are trained in entrepreneurship may express lower intentions to seek employment. The same pattern was noticed in the case of students in the agricultural field who had received entrepreneurship education by Modak et al. (2018) and Patel and Chauhan (2023). They found that agricultural students exposed to entrepreneurship education shift from employment-seeking towards entrepreneurial pursuits. The finding is also consistent with recent extension study on the behavioral determinants of entrepreneurial orientation among rural enterprise operators (Sonu & Jha, 2025). However, due to the cross-sectional design, this association cannot be interpreted as a causal link from entrepreneurship training to a decrease in job aspiration; students who were less likely to aspire to jobs might have chosen to participate in entrepreneurship training or the relationship could be a two-way street.

The selective impact of socio-economic indicators, such as family income, material possession and land holding, on self-employment and economic aspiration but not on educational, job or social aspiration suggests that resource endowment primarily helps to build the risk-bearing capacity which is a component of the motivation to pursue an entrepreneurial career, rather than shaping academic or job-related goals.

Although information seeking behaviour shows bivariate correlations with other variables, the loss of significance in the regression model may be due to shared variance with the other variables. This independent contribution may have been modified by its association with ICT skills and mass media exposure, which are sources of information most used. The present study did not test formally whether information seeking behaviour mediated the effect of the use of ICT and mass media on career aspiration, which requires a longitudinal study or structural equation modelling. In a regression model of career choice behaviour, Reddy and Rani (2020) found a similar pattern in which some of the behavioral variables were dominated by the more general psycho-communicative variables. The significant role of achievement motivation and ICT skills, as well as entrepreneurship training and mass media exposure as significant predictors in the regression model indicate that these psychological factors and digital competence jointly drive the career aspiration of agricultural students more decisively than any single socio-personal or socio-economic attribute.

Similarly, the non-significance of CGPA further corroborates Sebastian (2021) who found that the perceived employability of agricultural students was mostly influenced by their acquired skills and training experiences than by their socio-economic background and Agarwal and Saini (2021) who reported that socio-economic factors alone had less impact than skills-oriented and communicative factors on the career aspiration and employability perception of agricultural graduates of India. The negligible influence of socio-personal attributes such as age, caste, residential area and family type on the career aspiration suggests that the personal background of the respondents had a marginal influence on their career outlook (lekang et al., 2016; Lekang et al., 2017; Sharma et al., 2022). These findings suggest that demographic characteristics alone are insufficient to explain students' career aspiration.

The differential pattern of aspiration between public and private university students could be attributed to the distinct institutional orientation of the universities. Public universities having predominantly research and academic-driven culture traditionally focus on higher studies, research and competitive examinations. Public university provide stronger research infrastructure with government funded support system, greater access to scholarships and closer linkages with national agricultural research organisations which plausibly explains the stronger educational aspiration reported among their students, as mentioned by Mishra et al. (2021) in a comparative study of the employment and career preferences of public- and private-sector-oriented agricultural students. On the other hand, many private universities have established entrepreneurship cells, experiential learning, industry collaborations, integrated incubation facilities and skill-based learning exposure into

their agricultural programmes, which appears to cultivate a higher self-employment and social aspiration among their students, as reported by Ashokkumar et al. (2026) and Sharma et al. (2022), who found comparatively higher entrepreneurial and social orientation among students exposed to skill-oriented agricultural curricula.

The absence of a significant difference between the two categories regarding job and economic aspiration indicates that agricultural students almost share equal expectations regarding stable employment and economic security irrespective of their institution affiliation. This is in line with the findings of Agarwal and Saini (2021) that employability aspiration among agricultural graduates in India is shaped more by macro-level labour market conditions in both sectors than by affiliation to the institution.

CONCLUSION

The study established that career aspiration of the agricultural students in West Bengal is more strongly associated with the psycho-communication factors like Achievement Motivation and ICT skills rather than the socio-economic or demographic factors. Clear Institutional Differences were exhibited between the universities where public university students reported stronger educational aspirations whereas private university students exhibited stronger self-employment and social aspiration. Strengthening students' mass media exposure and structured information-seeking skills through career guidance cells, introducing career visioning credit courses in university curriculum and internship exposure linked to Krishi Vigyan Kendras could further reinforce the psycho-communicative competencies. Cross institutional semester exchanges and integrated mentorship can also help drive the career aspirations by outlining the strengths of different institutes. Socio-digital campaigns and dedicated portals collaborating with regional media for better dissemination of information should be considered.

DECLARATIONS

Ethical consideration and consent to participate: All procedures performed in studies involving human participants were in accordance with the ethical standards of social research. The Divisional review board, Agricultural Extension Division, of UBKV, Cooch Behar waived the ethical approval vide reference no. 195/26 and date 14 August 2026. All respondents participated voluntarily after receiving an explanation of the research objectives, the benefits of the research, and assurances of data confidentiality. The verbal consent of respondents was obtained, and their identity is kept confidential and is used only for academic purposes.

Conflict of interest: The authors have declared that no conflict of interest, financial or non-financial, exists that could affect the implementation, analysis, or reporting of the results of this research.

Data Availability statement: The data generated and analysed during the present study are not publicly available because they contain participant-level information and are subject to confidentiality and ethical considerations. The dataset is available from the corresponding author on reasonable request, subject to applicable institutional and ethical restrictions.

Authors' contribution: Atreyee Sarkar conducted the field investigation, data collection, statistical analysis. Litan Das supervised the study and contributed to research design and interpretation of results. Prabhat Kumar Pal, Sabita Mondal, Saumyadip Chakraborty, Swapnamay Ghosh, SK Mahabub Alam, Marimuthu Praveenkumar, Avirup Das, Dipankar Barai assisted in literature review, data interpretation, manuscript preparation and editing. All authors read and approved of the final manuscript.

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Research Article

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Disconnect between Academic Research and Farmer Needs in Indian Agricultural Systems: A Comparative Study

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HIGHLIGHTS

- There is a gap between agricultural research and farmer's needs showing inequality.
- Extension exposure and awareness of research are the most important factors for adoption.
- Agricultural research needs to be more participatory and farmer-centric.

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ABSTRACT

The study was conducted in 2024-25 to assess the gap between agricultural research and farmers' needs and to compare the factors influencing technology adoption in Punjab and Uttar Pradesh. A convergent parallel mixed-methods design was adopted, and 384 farmers were selected from Ludhiana and Bathinda in Punjab and Varanasi and Azamgarh in Uttar Pradesh using multistage stratified random sampling. Primary data were collected through structured interviews, focus group discussions, and personal interviews and were analyzed using descriptive statistics, t-test, chi-square, correlation, and regression analysis. The study found that the farmers in Punjab showed higher awareness of recent agricultural research, greater extension contact, and higher adoption of improved technologies than farmers in eastern Uttar Pradesh. Regression analysis indicated that research awareness, extension contacts, irrigation access, farm size, and education significantly influenced technology adoption, with research awareness showing the strongest effect. The findings indicated that the research–farmer gap was associated with unequal access to knowledge, extension services, infrastructure, and resources. The study highlighted the need for participatory, region-specific, and farmer-centric agricultural research and stronger extension linkages.

INTRODUCTION

Agricultural development has been a major pillar of the overall development of the country. In terms of agricultural development, the pace of development of the individual farmer producer in the country has not yet kept pace with it (Lowder et al., 2025). Agricultural research promotes production, rural development and thus sustainable development by providing knowledge, methodology and technology. However, even where there is diversity in the types of agriculture, inequality persists (Khan et al., 2025). Developed areas and farmers have abundant resources such as irrigation, markets and educational opportunities. All these challenges are extremely difficult for underdeveloped farmers (Vyas et al., 2025). They have smaller farms, less access to farmer advisory services, more vulnerable to markets (Singh et al., 2024) and climate change. In this context, inequality is also found in the benefits of agricultural research. This means that only a few groups are benefiting from the same technological progress resulting from research (Shitaye et al., 2025).

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Farmers in India face many challenges, such as land fragmentation, climate risks, income instability and lack of institutional support (Mishra et al., 2024; Kademani et al., 2026). Due to these constraints, the relationship between research institutions and farmers is weak. Therefore, it is extremely important to establish harmony between research and the needs of farmers, so that it can be effective and helpful in solving the problems of farmers at every level (Singh et al., 2014; Kademani et al., 2020). This includes identifying the problems of the farmers, experiencing the field conditions and testing the technology, getting evaluation and feedback from the farmers and finding solutions to their problems (Nain et al., 2012; Srivastava et al., 2025). Although this research is scientifically advanced, it still has some limitations, such as the distance from land to laboratory and from laboratory to land, studies and technologies are often confined to laboratories and journals, and farmers may have difficulty implementing these studies in their daily lives, causing innovations and studies to remain on paper and not reach farmers (Karunathilake et al., 2023). Farmers are interested in adopting new technologies, they hesitate due to lack of knowledge and assurance, resulting in slow transfer from the laboratory to the field. Therefore, it is very important to make it practical, low-cost and risk-free which suits the local climatic conditions, soil conditions and market demand (Pochtrager et al., 2026).

In comparative study between Punjab and Uttar Pradesh, nature of agriculture and agri-parameter differs; Punjab usually practices commercialized, intensive and market-oriented practices (Vatta, 2014) whereas Uttar Pradesh practices are different, such as subsistence, based low input survival oriented. This is because Punjab has greater research integration such as strong research extension and farmers linkage whereas Uttar Pradesh lacks and has weak linkage to research exposure, so to enhance condition in Uttar Pradesh it is important to improve farmer awareness, campaigns and trainings or introducing more farmers fairs or to improve better coordination between scientists, extension workers and farmers (Yadav et al., 2026). For this study, two states with different scenarios in each parameter required for agricultural development.

METHODOLOGY

A convergent parallel mixed methods design was adopted to assess the gap between agricultural research and farmers needs in Punjab and Uttar Pradesh. Progressive and marginalized small farmers were selected from Ludhiana and Bathinda in Punjab and Varanasi and Azamgarh in Uttar Pradesh respectively, using multi stage stratified random sampling method. The basis of area selection was 95 percent irrigated land and land holding of more than 5 hectares in Punjab and rain-fed, flood affected areas and land holding of less than 2 hectares in Uttar Pradesh.

Adoption rates among the respondents were measured as differences using quantitative surveys. Production disparities were clarified through qualitative interviews conducted with farmers. Validity of the study was ensured by integration through joint demonstrations among farmers. The sample size was 384, equally divided in both state, using Yamane's formula:

$$n = \frac{N}{1 + N(e)^2}$$

Where, n is the sample size, N is the total population, and e is the acceptable sampling error.

Primary data were collected through a structured interview schedule. In addition, focus group discussions and personal interviews were used to gather deeper views from farmers, extension officers, and researchers. Secondary data were collected from reports, published papers, census documents, and institutional records to support the analysis. The data were analyzed using a range of statistical tools. Descriptive statistics was used to describe the socio-economic profile of respondents and summarize the basic characteristics of the sample. t-test was used for continuous variables such as awareness scores, extension visits, and income for comparison between the two regions and determine the significance. Chi-square test was used for categorical variables such as adoption of a technology or participation in training. Correlation analysis was used for relationships among important selected variables. Regression analysis was used to identify the factors affecting adoption among the farmers. The statistical tools Cronbach alpha, Bartlett test and KMO measure were incorporated for testing the reliability of the variables and suitability of the data towards multivariate analysis. Therefore, the study used descriptive, inferential, and qualitative combination tools to produce a complete overview of the research-farmer disconnect.

RESULTS

The farmers connected with current developments in the agricultural practices and resources are thought to be in better profile. In the same path, the results showed that the socio-economic profile shows a clear structural difference between the two regions studied. A farmer with education, more land and higher income is more likely to experiment with new technologies, while a farmer with less land and less education tends to be risk averse. Thus, it is confirmed that both study areas are not only socially different, but also differ in their ability to adopt innovations.

The awareness index in Punjab is 0.78, while in Uttar Pradesh it is 0.42. This shows that research messages are reaching the farmers of Punjab more effectively. This large gap in awareness of improved varieties and climate-friendly agricultural practices indicates that farmers in Punjab receive formal agricultural information more frequently. Access to research publications is low in both regions, but the difference is clearly visible, reflecting unequal access to sources of knowledge. The average information score also reflects a more widespread dissemination of information in Punjab. These findings show that the issue is not just the production of research, but also its dissemination and accessibility. If farmers are not aware of the existence of a technology, they cannot adopt it, no matter how scientifically useful it is. The lack of awareness in Uttar Pradesh shows that academic research is far from the real-life conditions of farmers. The better awareness in Punjab is probably due to stronger extension networks, demonstrations and better institutional connectivity.

Agricultural extension linkages are much stronger in Punjab than in Uttar Pradesh, reflecting significant institutional differences between the two regions. Farmers in Punjab receive more than three times as many agricultural extensions visits annually, and their

Table 1. Disparity in awareness of Punjab and Uttar Pradesh farmers

Categories	Variables	Punjab	Uttar Pradesh
Awareness towards latest research in Agriculture	Awareness index	0.78	0.42
	Improved varieties knowledge (%)	88.0	54.0
	Climate-smart practices (%)	71.5	33.2
	Accessed research publications (%)	43.8	12.6
	Mean information score	4.1	2.6
Contacts with the extension personnels	Extension visits per year	6.4	2.1
	Training participation (%)	68.0	29.5
	Contact with KVK (%)	57.2	18.4
	Contact with Agri-input dealers (%)	74.5	61.3
	Advisory satisfaction score (out of 5)	3.9	2.3
Adoption of the latest technological advancements	Improved seed varieties	82.6	49.8
	Balanced fertilization	76.3	41.5
	Water-saving irrigation	69.4	24.7
	Mechanization practices	84.1	35.6
	Crop protection recommendations	73.8	38.9

participation in training programs is more than twice that of farmers in Uttar Pradesh. Contact with agricultural centers (KVKs) is also more common in Punjab, indicating that farmers in the developed region are better connected to formal advisory systems. Although agricultural input dealers remain an important source of advice in both sectors, the quality and reliability of such guidance may vary. Advice satisfaction scores are quite low in Uttar Pradesh, meaning that even when advice is available, it may not be timely, useful or relevant. This table is important because extension is the medium for putting research into practice at the agricultural level. Where research is not carried out in depth, the research remains abstract and is not properly converted into practical suggestions. The findings therefore suggest that the gap between research and practice is partly due to widespread access. This emphasizes the need for a more decentralized, participatory and locally sensitive extension system in less developed areas.

Inter-regional variations are clearly visible in the adoption of improved seed varieties, balanced fertilizer use, irrigation-saving practices, mechanization and crop protection recommendations. This pattern shows that farmers in Punjab are not only more aware of innovations but also more capable of implementing them due to better capital availability, irrigation infrastructure and institutional support. Low adoption rates in Uttar Pradesh probably reflect a combination of lack of resources, small farms, greater uncertainty, and weak counseling systems. This Table 1 is important because it shows the final practical outcome of the research-practice series. Research has value only when it leads to useful change at the farm level, and these figures show that the process of converting knowledge into practice is much stronger in Punjab. Low adoption in Uttar Pradesh should not be attributed to resistance alone; This may be a result of lack of coordination between technology and local constraints. Therefore, the table 1 reinforces the argument that innovation should be context-specific. Applying the same approach to all is unlikely to solve the problem of low adoption in backward agricultural systems.

The results of regression analysis confirm that factors such as extension connectivity, availability of irrigation, education, farm size and research awareness significantly influence the technology adoption process. Of these, the coefficient of research awareness is the strongest. This means that having access to information is a big reason why people adopt new technologies. Extension connectivity and the availability of irrigation also have positive effects. This shows that adopting new technology depends not only on determination but also on having access to support and useful resources. The size of a farm is important because it shows that bigger farms can be more flexible and less risky when trying out new things. Education also helps with this by making it easier to understand technical information and making better decisions. This Table 2 is important for analysis because it shows why Punjab does better than Uttar Pradesh when it comes to adopting new technologies. Farmers from Punjab are likely to do better on all the important factors, while farmers from Uttar Pradesh are behind. Farmers from Punjab are likely to do better on all the important factors, while farmers from Uttar Pradesh are behind on almost all of them.

Table 2. Significance level of the factors responsible for adoption among the respondents

Variable	Coefficient	Std. Error	z value
Education	0.182**	0.061	2.98
Farm size	0.241**	0.074	3.26
Extension contacts	0.317*	0.089	3.56
Irrigation access	0.286*	0.083	3.45
Research awareness	0.354*	0.091	3.89

(* = $P \leq 0.05$, significant; ** = $P \leq 0.01$, highly significant)

Therefore, regression analysis provides econometric support for the descriptive results. This shows that the gap between research and practice is not accidental; It arises systematically due to unequal access to knowledge, services and resources. The model also indicates that adoption requires more than distribution of technologies.

Both regions were found having disparities in constraints. Punjab was found with unstable prices and markets, which was due to the commercial expansion in the area. Rest all the constraints

with the structural issues were found with the farmers in the Uttar Pradesh. Major issues highlighted were vulnerability to climate, small holdings and poor extension services. Limited services of extension prove that they are insufficient in Uttar Pradesh. The improved methods are difficult to be adopted with such small holding. Climatic vulnerabilities such as droughts and floods guarantee uncertainty and therefore frightens the farmers from making investments. The results in the Table 3 supports that the same study differed in the two locations. Farm efficiency and profit is priority of the Punjab farmers with research results whereas institutional access and fundamental support for flexibility is desired by Uttar Pradesh farmers. It displays and reveals that research institutes should not make similar recommendations. Rather, they should experiment with interventions based on regional limitations. So, farm research is meaningful only to the extent that it meets farmers' needs, regional specificity and resource constraints.

Table 3. Comparation of constraints associated with Punjab and Uttar Pradesh farmers

Constraint	Punjab (%)	Uttar Pradesh (%)
High input cost	62.4	54.1
Poor extension access	28.7	79.5
Market instability	51.9	48.6
Small landholding	19.3	83.2
Flood/drought risk	24.6	71.8

Correlation values indicate whether awareness, extension contacts, adoption, income and irrigation move in the same direction, and this is very important in the study of research-behavior gap. The positive correlation between awareness and extension contact shows that farmers who have more frequent contact with advisory systems are also more likely to learn about improved technologies. The highest relationship is between exposure to extension services and usage, implying that not only is information transmitted to farmers through extension services, but they also actively suggest agricultural practice. This key result confirms the claim that research does not result in a change in agricultural practices without the delivery of the research through effective extension services. This is also true of the relationship between irrigation and use, suggesting that it is easier to use the technology in areas with better infrastructure. So, even if a farmer knows about a technology, farmer more likely to use it, if has access to water and the environment is suitable for growing crops. The income-usage relationship makes sense, too, because as income rises, the farmer is less likely to experience a financial loss from using the technology.

Diagnostic values add to the scientific rigor of the analysis. The value of Cronbach's alpha (0.84) shows that the items used to measure the variables are reliable. The KMO value of 0.71 suggests that the data are suitable for multivariate analysis while the significance of Bartlett's test suggests that there is enough correlation between the variables for this type of analysis. The variance inflation factor (VIF) values are low (1.22-2.84), which indicates that there is no multicollinearity. This is great news as the regression coefficients can be interpreted in an unbiased way. Lastly, the pseudo-R^2 value of 0.41 shows that the model explains a fairly good part of the adoption process, which is very good for agricultural studies.

DISCUSSION

The research indicates that the gap between the academic agricultural research and farmers demand is not only a communication problem, but it is a structural and institutional problem. In contrast to Punjab, the small structure of agriculture in Uttar Pradesh limits farmers ability to adopt innovations, even if these innovations are scientifically sound (Rajeev et al., 2025). This confirms that the process of research adoption is equally influenced by both the agricultural environment and the quality of the research.

There is a discrepancy found between the study and practice. Protection methods are becoming more and more advanced in Punjab. A high innovative environment is stimulated to above all with the help of technological advancements, advisory services, and financing facilities. In contrast all the above advancement are found at low adoption among the farmers. This was due to lack in the institutional support, innovations etc. with the farmers in Uttar Pradesh (Yadav et al., 2025). The adoption is not just a behavioral choice but the result of structural readiness. This is an important point because many agricultural research systems hold the misconception that farmers will adopt technologies only if recommended.

Table 4. Correlation matrix and diagnostic profile of the variables

Variables	Awareness	Extension contacts	Adoption	Income	Irrigation
Awareness	1.00	0.62***	0.58***	0.41**	0.49**
Extension contacts	0.62***	1.00	0.67***	0.46**	0.44**
Adoption	0.58***	0.67***	1.00	0.53***	0.59***
Income	0.41**	0.46**	0.53***	1.00	0.39**
Irrigation	0.49**	0.44**	0.59***	0.39**	1.00

Diagnostic measure	Value
Cronbach's alpha	0.84
KMO measure	0.71
Bartlett's test	Significant, $p < 0.001$
Variance Inflation Factor (VIF) range	1.22 to 2.84
Pseudo-R^2	0.41

(** & *** = $P \leq 0.01$ & $P \leq 0.001$, highly significant)

The information on the determinants of adoption, provides econometric support confirms that farmers who are better informed, better equipped and who frequently receive advisory support are more likely to implement the recommendations (Goodluck et al., 2024). The importance of extension contact also reinforces the argument that information distribution cannot be left to publications alone. The model therefore shows that the adoption process is influenced by both human capital and institutional linkages. In practice, this means that simply releasing technologies is not enough to improve adoption. For this, it is necessary to create such social and infrastructural conditions that will enable farmers to use them. The regression results thus validate the central argument that the research-practice gap is not random but systematic.

The constraints and priorities revealed that there are different types of agricultural stress in Punjab and Uttar Pradesh. Farmers in Punjab were more concerned about input costs, market instability and pressures of commercialization, while farmers in Uttar Pradesh were more affected by inadequate access to agricultural extension services, small landholdings and risk of flood or drought (Gireesh et al., 2019; Yadav et al., 2025). Hence, this section argues that research must be managed to suit demands of farming. The approach adopted in Punjab may not be adopted in Uttar Pradesh unless it has adaptation to the local needs and priorities.

The correlations and clinical profiles show that, adding a more statistical dimension to the study. Positive correlations between awareness, extension contacts, adoption, income and irrigation suggest that these variables complement each other. Similar findings were observed by Kumar et al. (2023) in case of ZBNF. It can be concluded that farmers do not always benefit from agricultural research. This disparity is mainly due to differences in socio-economic conditions, such as lack of knowledge and experience (Begho et al., 2022). Developed farmers in Punjab are found to be progressive thinking and endowed with innovative facilities. Farmers have access to good markets, infrastructure and extension services. At the same time, it is very difficult for the farmers of Uttar Pradesh to get these facilities. This makes farmers more vulnerable to risks and vulnerabilities. Therefore, it can be concluded that research should always be at the grassroots level, based on solid foundation, accessible to all and tailored to the needs of the farmers. During policy formulation, extension and educational institutions should be directly linked to the farmers (Kumar et al., 2026).

CONCLUSION

The study shows that the gap between agricultural research and farmer's needs is weak due to extension linkages, structural inequality, and unequal access to resources. The success of agricultural research depends not only on its scientific quality but also on the suitability of the technology to the farmer's adoption and conditions. Correlation and regression patterns show that income and irrigation promote adoption, while low access to extension services and small land holdings reduce it. Therefore, the gap between research and practice is not accidental. This arises due to unequal institutional and economic conditions. The policy implication is that agricultural research needs to be made more participatory, local and farmer-centric. Researchers should involve farmers right from the planning stage, especially in underdeveloped areas like Uttar Pradesh, so that technologies reflect real ground challenges. Extension systems should also be strengthened to provide timely, simple and local specific suggestions.

DECLARATIONS

Ethical considerations and consent to participate: The study was conducted in accordance with the principles laid out in the Declaration of Helsinki, 1964, and its modifications. The study was approved by the Departmental Review Board of the Department of Agricultural Economics and Extension, Lovely Professional University, Phagwara-144411 (Punjab), and ethical approval was waived off. Also, the Participation of respondents were voluntary, and informed verbal consent was obtained from all respondents. The confidentiality and anonymity of participants were strictly maintained throughout the research process.

Conflict of interest: The authors declare that the research possesses NIL conflict of interest in any manner whether financial or non-financial. The preparation of the article is thoroughly reviewed and revised as needed. The authors take full responsibility for the content of this manuscript.

Data availability statement: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. The data are not publicly available because they contain information that could compromise participant confidentiality.

Authors' contribution: ASM and BY designed the study, developed the research design, carried out the fieldwork, data analysis, and drafted the first report. AK, RKK and KKS monitored the formulation of the study plan, and critically analyzed the work for intellectual content and finally contributed towards the finalization and proof reading of the article.

Declaration of using AI tool: The authors have used Grammarly, as an AI tool for improving the text of grammar.

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Research Article

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Information Processing Behaviour of Sugarcane Growers in Lucknow Division of Uttar Pradesh

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HIGHLIGHTS

- Judgment based on economic feasibility was the most preferred information evaluation method (MPS = 88.02).
- Economic motivation (r = 0.661) and extension contact (r = 0.580) were the strongest correlates of information processing behaviour.

ARTICLE INFO

Keywords: Agricultural communication, Correlation analysis, Economic motivation, Extension contact, Z-test.

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ABSTRACT

Effective processing of agricultural information by farmers is a critical determinant of technology adoption and improved farm decision-making, yet this behaviour remains inadequately documented among sugarcane growers. The present study was conducted during 2025 to assess the information processing behaviour (IPB) of sugarcane growers and its relationship with selected socio-economic and psychological characteristics in the Lucknow division of Uttar Pradesh. Primary data were collected from 320 respondents selected from Lakhimpur Kheri and Lucknow districts through a structured interview schedule, and IPB was measured using a three-point continuum scale across three dimensions: information evaluation, storage, and transfer. The economic feasibility ranked first overall (MPS = 88.02), while memorizing the information emerged as the top storage method (MPS = 100.00). Sharing information with those who actively seek ranked first among transfer methods. The Z-test revealed a statistically significant difference in IPB between the two districts (Z = 15.39, p < 0.01), with Lakhimpur Kheri farmers recording higher scores than those in Lucknow. Correlation analysis showed that economic motivation (r = 0.661) and extension contact (r = 0.580) had the highest positive and significant association with IPB. The study underscores the need to strengthen extension contact and participatory communication approaches.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the most important commercial crops in the world and plays a significant role in the agricultural economy of many developing countries. The crop is cultivated in more than 90 countries across approximately 26.5 million hectares, producing nearly two billion tonnes annually (FAOSTAT, 2024). Sugarcane is primarily grown for sugar production and also serves as a major raw material for several by-products such as jaggery, ethanol, molasses, and bioenergy, thereby contributing to agro-industrial development and rural livelihoods. India is the world's second-largest sugarcane producer, and the crop holds a prominent position in the country's agricultural sector. Sugarcane is cultivated in both tropical and subtropical regions of India, covering about 5.74 million hectares with a production exceeding 453 million tons during the 2023–24 season (Government of India, 2024). Among major sugarcane-producing states, Uttar Pradesh ranks first in both area and production, cultivating sugarcane

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on nearly 23.17 lakh hectares with an estimated production of around 188 million tonnes (Government of India, 2024). The sugar industry plays a crucial role in the rural economy of the state and is supported by more than 120 operational sugar mills during the 2024–25 crushing season (Government of India, 2024).

Despite its economic importance, sugarcane cultivation in many regions continues to face several challenges such as low productivity, limited adoption of improved technologies, and inadequate access to timely and reliable agricultural information. In modern agriculture, information has emerged as an essential input, comparable in importance to land, water, seeds, and fertilizers. The success of agricultural innovations largely depends on the extent to which farmers are able to access, interpret, and utilize relevant information effectively (Babu et al., 2012; Niranjan et al., 2023). At present, farmers increasingly draw on a mix of interpersonal, mass media, and digital sources for agricultural information, yet institutional extension services continue to reach only a limited proportion of the farming population, underscoring the continuing importance of understanding how farmers themselves process the information they receive (Mondal et al., 2024; Godara et al., 2024). Information processing behaviour involves several stages including information evaluation, information storage, and information transfer. Through these processes, farmers assess the credibility and usefulness of agricultural information, retain it for future use, and disseminate it within their social networks (Panda et al., 2019; Prasad et al., 2022). Understanding these behavioural patterns is essential for developing effective extension strategies and improving the dissemination of scientific agricultural knowledge at the grassroots level (Ravikumar et al., 2015; Acharya et al., 2023).

Although several studies have examined farmers' information-seeking behaviour and technology adoption, relatively limited research has focused on the information processing behaviour of farmers, particularly in the context of sugarcane cultivation. Reddy and Reddy (2008) and Kadam and Gaikwad (2014) examined communication and information-seeking behaviour among sugarcane farmers. Mondal et al. (2024) on the communication behaviour of fish farmers in West Bengal has extended this line of enquiry to other farming systems; however, comprehensive studies encompassing all three dimensions of information processing evaluation, storage, and transfer remain scarce, particularly for sugarcane.

METHODOLOGY

The present study was conducted during 2025 in the Lucknow division of Uttar Pradesh, one of the 18 administrative divisions of the state. The division was purposively selected due to its distinction as the highest sugarcane-producing division in Uttar Pradesh (Government of India, 2024). It comprises six districts, of which Lakhimpur Kheri and Lucknow were purposively chosen to represent districts with the maximum and minimum sugarcane production, respectively (Lakhimpur Kheri recording the largest area under sugarcane in the division and Lucknow the smallest, as per Cane Commissioner, Uttar Pradesh records; Government of India, 2024), to capture variation in information environment and extension exposure. From each selected district, four blocks were chosen through simple random sampling. Subsequently, four villages were randomly selected from each block, resulting in a total of 32 villages. From each village, 10 respondents were randomly selected, yielding a total sample of 320 respondents (160 from each district). Primary data were collected through a pre-structured and pre-tested interview schedule administered via personal interviews. The interview schedule incorporated questions related to sugarcane production technology and information behaviour. Information processing behaviour was assessed across three key dimensions: information evaluation, information storage, and information transfer. Each item was measured using a three-point continuum scale (Always = 3, Sometimes = 2, Never = 1). The total score obtained by each respondent was calculated by summing responses across all items. Based on cumulative scores, respondents were categorised into low (below Mean – SD), medium (Mean ± SD), and high (above Mean + SD) levels of information processing behaviour using the mean ± standard deviation method. To quantify the overall extent of each method, the Mean Percent Score (MPS) was calculated as: MPS = (Obtained score / Maximum possible score) × 100.

To detect significant differences between the mean information processing behaviour scores of the two districts, the Z-test (standard normal deviate test) was applied, which is appropriate for large independent samples ($n > 30$). The formula used was: $Z = (\bar{X}_1 - \bar{X}_2) / \sqrt{(\sigma_1^2/n_1 + \sqrt{}_2^2/n_2)}$, where $\bar{X}_1$ and $\bar{X}_2$ are the means, σ_1 and σ_2 are the standard deviations, and n_1 and n_2 are the sample sizes of the two groups respectively. Pearson product-moment correlation coefficient (r) was used to examine the direction and magnitude of association between selected socio-economic and psychological characteristics and information processing behaviour. All statistical inferences were tested at least at the five per cent level of significance, and results significant at the more stringent one per cent level are additionally reported where applicable. Data were processed and analysed using SPSS version 25.0.

RESULTS

Extent of methods used for information evaluation, storage, and transfer

Table 1 presents the Mean Percent Scores (MPS) and ranks of the methods adopted by sugarcane growers across the three dimensions of information processing behaviour. Among evaluation methods, judgment based on economic feasibility ranked first overall (MPS = 88.02) and in Lucknow (MPS = 90.21), while it ranked third in Lakhimpur Kheri (MPS = 85.83). Discussion with family members, friends, fellow farmers, and neighbours ranked second overall (MPS = 85.52), and weighing the merits of an innovation in light of past experience ranked third (MPS = 77.81). Discussion with cane supervisors ranked first in Lakhimpur Kheri (MPS = 90.21) but fell to seventh in Lucknow (MPS = 47.50), reflecting district-level variation in access to and trust of extension personnel. Formal channels such as agricultural department officials and university experts ranked last (MPS = 36.98), indicating low reliance on institutional sources. Among storage methods, memorizing the information ranked first with a perfect MPS of 100.00 in both districts – indicating that every respondent reported "always" relying on memory to retain information, a plausible outcome given

Table 1. Extent of methods used in information processing behaviour

S. No.	Method	Lakhimpur Kheri MPS	Rank	Lucknow MPS	Rank	Total MPS	Rank
A. Information evaluation methods							
1.	Discussion with officials of State Agriculture Department or Agricultural University	37.29	IX	36.67	IX	36.98	IX
2.	Discussion with cane supervisors or officers of the sugar mill	90.21	I	47.50	VII	68.85	IV
3.	Acceptance of received information with modifications	65.00	V	60.21	V	62.60	VI
4.	Judgment based on economic feasibility	85.83	III	90.21	I	88.02	I
5.	Acceptance of received information as such	55.63	VIII	40.21	VIII	47.92	VIII
6.	Discussion with family members, friends, fellow farmers, and neighbours	87.71	II	83.33	II	85.52	II
7.	Judgment in light of climatic conditions	60.21	VII	55.00	VI	57.60	VII
8.	Judgment based on technical feasibility	64.58	VI	63.33	IV	63.96	V
9.	Weighing merits of an innovation in light of past experience	75.63	IV	80.00	III	77.81	III
B. Information storage methods							
1.	Conveying to family members and asking them to remember	98.13	II	91.67	II	94.90	II
2.	By maintaining classified notebooks or diary	41.67	IV	45.42	IV	43.54	IV
3.	Preservation in the form of printed literature	36.04	V	35.00	VI	35.52	V
4.	By maintaining subject matter file	33.75	VI	36.46	V	35.10	VI
5.	Memorizing the information	100.00	I	100.00	I	100.00	I
6.	Gathering information from social system	95.21	III	61.67	III	78.44	III
C. Information transfer methods							
1.	Sharing information with those who actively seek	100.00	I	100.00	I	100.00	I
2.	To friends, fellow farmers, progressive farmers, and neighbours	93.75	II	80.00	III	86.88	III
3.	To relatives	66.04	IV	51.67	IV	58.85	IV
4.	Providing information to those to whom land has been leased out	91.25	III	83.33	II	87.29	II
5.	Speaking in local meetings	48.54	V	40.00	V	44.27	V
6.	By conducting demonstrations to show practical aspects	33.33	VII	33.33	VII	33.33	VII
7.	Telling others what was learnt during training or meetings	34.17	VI	34.58	VI	34.38	VI

MPS = Mean Percent Score

that recall is a low-cost, universally practised behaviour requiring no literacy or material resources, unlike documentation-based methods – followed by conveying information to family members and asking them to remember (MPS = 94.90) and gathering information from the social system (MPS = 78.44). Formal documentation practices, such as maintaining notebooks, preserving printed literature, and maintaining subject matter files were least preferred, suggesting limited adoption of systematic record-keeping. Among transfer methods, sharing information with those who actively seek ranked first in both districts (MPS = 100.00), reflecting a predominantly reactive approach to information dissemination. Providing information to those to whom land has been leased out ranked second overall (MPS = 87.29), while sharing with friends, fellow farmers, and neighbours ranked third (MPS = 86.88). Less preferred transfer methods included speaking in local meetings (MPS = 44.27), sharing knowledge gained from training (MPS = 34.38), and conducting demonstrations (MPS = 33.33).

Comparison of information processing behaviour between the two districts

To examine the difference in information processing behaviour between sugarcane growers of Lakhimpur Kheri and Lucknow districts, the Z-test was applied. The null hypothesis (H•) stated that there is no significant difference in information processing behaviour between the two districts; the alternative hypothesis (H_1) stated that a significant difference exists. The results are presented in Table 2. The calculated Z-value (15.39) was considerably higher than the tabulated value of 1.96 at the five per cent level of significance. The null hypothesis was therefore rejected, confirming that a statistically significant difference in information processing behaviour exists between sugarcane growers of Lakhimpur Kheri and Lucknow districts, with Lakhimpur Kheri farmers recording a higher mean score (44.82) than those in Lucknow (40.49).

Table 2. Comparison of information processing behaviour between Lakhimpur Kheri and Lucknow

District	Mean	SD	Z-value
Lakhimpur Kheri	44.82	2.44	15.39**
Lucknow	40.49	2.59	

** Significant at the 1 per cent level ($p < 0.01$)

Relationship between selected characteristics and information processing behaviour

Table 3 presents the correlation coefficients between selected independent variables and information processing behaviour of sugarcane growers. All eight variables exhibited a positive relationship with information processing behaviour, though the magnitude and level of significance varied. Economic motivation ($r = 0.661$, $p < 0.01$) showed the highest positive and highly significant correlation, followed by extension contact ($r = 0.580$, $p < 0.01$), risk orientation ($r = 0.469$, $p < 0.01$), education ($r = 0.410$, $p <$

Table 3. Correlation between selected characteristics and information processing behaviour (n = 320)

Variables	Correlation coefficient (r)
Age	0.115*
Education	0.410**
Landholding	0.366**
Extension contact	0.580**
Scientific orientation	0.405**
Economic motivation	0.661**
Cosmopolitan outlook	0.121*
Risk orientation	0.469**

* $p < 0.05$; ** $p < 0.01$

0.01), scientific orientation ($r = 0.405$, $p < 0.01$), and landholding ($r = 0.366$, $p < 0.01$). Age ($r = 0.115$, $p < 0.05$) and cosmopolitan outlook ($r = 0.121$, $p < 0.05$) were positively but weakly and significantly associated at the five per cent level, indicating comparatively lesser influence on information processing behaviour.

DISCUSSION

The predominance of medium-level information-processing behaviour among sugarcane growers in the Lucknow division is consistent with findings from related studies. Similarly, the majority of dairy farmers reported to exhibit a medium level of information processing behaviour, attributed to moderate educational attainment, limited landholding size, and partial exposure to extension services (Prasad et al., 2022). The present findings corroborate this pattern and extend it to the specific context of commercial sugarcane cultivation in Uttar Pradesh. It has further been noted that the structural and functional characteristics of farmers' information environments including access to credible sources and interpersonal networks shape their overall information processing capacity, which aligns with the moderate levels observed in both districts of the present study (Acharya et al., 2023).

The dominance of economic feasibility as the primary evaluation criterion reflects rational decision-making behaviour among farmers in a commercial crop context. This finding is consistent with the observation that farmers' evaluation of agricultural information is predominantly guided by economic returns, particularly in regions where input costs are high and market uncertainty is significant (Singh & Meena, 2013). The strong preference for peer-based and experiential evaluation methods discussion with family members and fellow farmers and weighing innovations against past experience over formal institutional channels aligns with the finding that mass media and local extension functionaries are more trusted than formal institutional sources (Nain et al., 2015; Duhan & Singh, 2017). This preference reflects the influence of social capital and cognitive anchoring in agricultural information evaluation, where accessible and familiar channels are inherently more persuasive.

The universal preference for memorization as the primary storage method and the reactive sharing approach are consistent with the finding that memorization remains the dominant information retention strategy among smallholder farmers, despite the risk of information loss (Friedman et al., 2024). Interpersonal face-to-face communication has similarly been reported to dominate agricultural information transfer in regions with limited access to formal extension services and digital technologies (Assefa et al., 2021; Singh et al., 2023). The low scores for demonstration-based transfer and training-related sharing indicate that knowledge generated through formal training events does not effectively re-enter informal information networks a critical gap for extension planners.

The significant difference in information processing behaviour between Lakhimpur Kheri and Lucknow ($Z = 15.39$) can be attributed to the considerably greater density of sugarcane cultivation, more active cane supervisory networks, and deeper penetration of sugar mill extension services in Lakhimpur Kheri. Among the correlation results, the strongest associations between economic motivation and extension contact reflect that both intrinsic drive and structured external support are indispensable for effective information processing. The role of risk orientation and scientific orientation is consistent with the observation that psychologically progressive farmers with higher risk tolerance and empirical thinking tend to seek, evaluate, and internalize agricultural information more actively (Verma et al., 2019). The low correlations between age and cosmopolitan outlook suggest that these traits have marginal influence and that more proximate motivational and structural factors determine information-processing capacity.

Taken together, these patterns suggest that sugarcane growers process information through a predominantly experience-based and socially embedded pathway rather than a formally documented one. Farmers appear to prioritise economic feasibility because sugarcane is a high-investment, market-linked crop in which the immediate financial consequence of an information-based decision (for example, adopting a new variety or input) is more tangible and easier to verify through peer experience than technical explanations offered by extension personnel. Reliance on memorisation over written records is consistent with the largely oral tradition of information exchange in rural social networks and with the practical constraints of literacy, time, and record-keeping habits among smallholders; it also means that valuable information is vulnerable to loss or distortion once the immediate holder forgets it or is unavailable, which extension programmes need to address by encouraging simple, low-literacy recording aids. The reactive pattern of transfer, whereby farmers mainly share information when actively approached rather than proactively disseminating it, indicates an information system that functions well for maintaining existing social ties but is unlikely, on its own, to accelerate the spread of new practices to less-connected farmers; this points to a specific role for extension agencies in stimulating more proactive peer sharing, for instance through farmer facilitators or lead-farmer models. For extension planning, these findings imply that economic-benefit framing, backed by verifiable field-level demonstrations and cost-return data, is likely to be more persuasive to sugarcane growers than purely technical messaging. Low-literacy, easily recalled formats such as short audio or video advisories, illustrated leaflets, and repeated field-level reinforcement can help offset the limitations of memorisation-based storage. Structured farmer group interactions, participatory demonstrations, and the deliberate involvement of trusted peers and cane supervisors as intermediaries can convert the presently reactive sharing pattern

into a more proactive and wider-reaching information flow. The markedly higher information processing scores recorded in Lakhimpur Kheri, the division's leading sugarcane-producing district, relative to Lucknow, where sugarcane occupies a comparatively smaller share of the cropping pattern, further suggest that the specific advantage enjoyed by high-production districts lies in the density of crop-linked institutional touchpoints, cane supervisors, sugar mill field staff, and larger farmer-to-farmer networks, that provide more frequent and reinforcing exposure to sugarcane-specific information; replicating equivalent institutional touchpoints in lower-production districts could help narrow this gap.

CONCLUSION

Sugarcane growers in the Lucknow division of Uttar Pradesh predominantly exhibit a medium level of information processing behaviour, with economic reasoning, peer interaction, and unaided recall-based retention serving as the dominant modes of evaluation, storage, and transfer, respectively. Lakhimpur Kheri farmers process agricultural information significantly more effectively than their Lucknow counterparts, reflecting superior access to crop-specific extension support. Economic motivation and extension contact are the most influential determinants of information processing behaviour, underscoring the need for income-linked advisory services and more intensive extension engagement. Extension agencies must prioritise participatory demonstration methods, structured farmer group interactions, and digital advisory tools to convert the existing moderate processing capacity into high-quality, action-oriented information behaviour among sugarcane growers.

DECLARATIONS

Ethical approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Department of Extension Education, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India waived the ethical approval. Informed consent was obtained from all respondents before data collection. The respondents were informed about the purpose of the study, and their participation was voluntary.

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Author contributions: Conceptualization of research (AD, NRM, RKD); Designing of the experiments (AD, NRM, RKD); Contribution of experimental materials (AD, NRM, RKD, AK); Execution of field survey and data collection (AD, AK, YP, YK); Analysis of data and interpretation (AD); Preparation of manuscript (AD, KS).

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Knowledge, Technology Adoption and Production Constraints of Black Pepper Growers in Kolli Hills

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HIGHLIGHTS

- Nutrient and soil management and marketing practices recorded higher knowledge and adoption.
- Moderate technology adoption highlights the need for stronger extension interventions.
- Labour scarcity, increasing production cost and inadequate institutional support remain the major production constraints.

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ABSTRACT

Black pepper (*Piper nigrum* L.) is an important spice crop supporting the livelihoods of farmers in Kolli Hills, Tamil Nadu. The study assessed the knowledge and technology adoption levels of black pepper growers and identified the major constraints affecting the adoption of recommended cultivation practices. Primary data were collected from 280 growers using a structured interview schedule during 2025 in Kolli Hills. Twenty-eight knowledge statements and twenty-eight technology adoption statements were constructed to measure on a five-point continuum and grouped into nine indicators. Principal Component Analysis was employed to derive indicator weights and construct composite Knowledge and Technology Adoption Indices. The Kaiser–Meyer–Olkin measure indicated satisfactory sampling adequacy, with values of 0.741 for knowledge and 0.791 for technology adoption. The overall Composite Knowledge Index (0.599) indicated a moderate level of knowledge, whereas the Composite Technology Adoption Index (0.495) indicated comparatively lower adoption of the recommended cultivation practices. Garrett's Ranking Technique revealed that high labour cost, scarcity of skilled labour and high input cost were the major production constraints. The findings highlight the importance of need-based extension services, capacity-building programmes and institutional support in addressing the identified knowledge, technology adoption and production constraints among black pepper growers in Kolli Hills.

INTRODUCTION

Black pepper (*Piper nigrum* L.), widely recognized as the "King of Spices," is a commercially important spice crop cultivated across the tropical regions of the world. India is among the world's leading producers of black pepper, and the crop contributes significantly to rural livelihoods and employment generation. Cultivated predominantly as an intercrop with perennial vegetation, black pepper forms an integral component of agroforestry-based hill farming systems, with live support trees such as Silver Oak (*Grevillea robusta*) and bamboo providing structural support for the climbing vines. Globally, black pepper production during 2023 was 539 thousand tonnes, while India produced 126,038 metric tonnes during 2023-2024, ranking among the leading pepper-

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producing countries (International Pepper Community, 2024; Spices Board India, 2024). Black pepper productivity is influenced by both biophysical factors and growers' knowledge and timely adoption of recommended production technologies. Studies have shown that technology adoption remains uneven because of production constraints and limited input use.

Kolli Hills of Namakkal district is a predominantly tribal hill region where black pepper cultivation is an important livelihood and income-generating activity for farming households. Although the region possesses favourable agro-climatic conditions for pepper cultivation, productivity remains below its potential because of several production constraints. Agricultural extension services in the region provide technical guidance, demonstrations and farmer-oriented training to support growers in understanding and adopting recommended black pepper cultivation practices. Recent studies have reported that effective extension interventions significantly improve technology adoption and farmers' decision-making capacity (Devi et al., 2024).

In black pepper production, agricultural extension plays an important role in disseminating recommended cultivation technologies, including improved varieties, crop establishment, nutrient and soil management, water and canopy management, pest and disease management, and post-harvest practices through farmer training, field demonstrations and technical advisory services. Improved access to technical information enables growers to make better production decisions, while adoption of recommended technologies contributes to higher productivity, efficient resource use and improved farm income. Besides knowledge, technology adoption is influenced by socio-economic conditions, institutional support, market access and farmers' perceptions of technological benefits. Therefore, evaluating growers' knowledge, technology adoption and production constraints provides useful evidence for planning location-specific extension interventions (Patra et al., 2023; Devi et al., 2024).

Previous studies on black pepper have addressed specific aspects of knowledge, technology adoption and production constraints. Jolly and Mazhar (2023) assessed the knowledge level of black pepper growers in Idukki district of Kerala, while Eliyas and Sumathi (2018) examined factors associated with the adoption of recommended production practices among pepper growers in Wayanad district. Rejula et al. (2018) studied the production system, technology adoption profile and major constraints of black pepper cultivation in Kerala. There is limited evidence on the use of PCA-based weighted composite indices to simultaneously assess knowledge and technology adoption across multiple recommended cultivation domains and to examine the perceived production constraints of growers. The novelty of the present study lies in integrating these dimensions through PCA-based Composite Knowledge and Technology Adoption Indices, together with Garrett's Ranking Technique for production constraints, among black pepper growers in Kolli Hills.

METHODOLOGY

The study was conducted during 2025 in Kolli Hills of Namakkal district, Tamil Nadu, a prominent tribal region known for black pepper cultivation. Since the variables had already occurred and could not be manipulated by the investigator, an ex-post facto research design was adopted (Devi et al., 2024). Kolli Hills was selected purposively based on its importance in black pepper cultivation, and four major pepper-growing villages, namely Ariyur Nadu, Devanur Nadu, Thinnanur Nadu and Vaalavanthi Nadu, were selected for the study. The respondents comprised 280 black pepper growers. The sample size was determined using Slovin's formula at a 5 per cent precision level, and the sampling procedure followed Kothari (2004). The total sample of 280 growers was distributed among the selected villages in proportion to the number of black pepper-growing households in each village. From each village, the required number of growers was selected using random sampling from the available list of black pepper growers.

$$n = \frac{N}{1 + Ne^2}$$

Where, n = required sample size, N = total population and e = allowable error (0.05). The respondents were selected through proportionate random sampling. Primary data were collected through personal interviews using a pre-tested structured interview schedule.

Knowledge and technology adoption were measured using 28 statements each, grouped under nine indicators covering recommended black pepper cultivation practices. The schedule was developed based on the package of practices of the Spices Board of India and Tamil Nadu Agricultural University and was validated by subject matter experts. Responses were recorded using a five-point continuum, with the response categories defined according to the respective knowledge and technology adoption statements. The same structured schedule was administered to all respondents to ensure consistency in data collection.

The indicator values were normalized using the Min–Max normalization technique (OECD & JRC, 2008):

$$Z_{ij} = \frac{X_{ij} - X_{min}}{X_{max} - X_{min}}$$

Where, Z_{ij} = normalized value, X_{ij} = observed value, X_{min} = minimum value and X_{max} = maximum value. The normalized indicator values therefore ranged from 0 to 1 and were subsequently used in the construction of the Composite Knowledge and Technology Adoption Indices.

Principal Component Analysis was employed to derive empirical weights for each indicator and to construct weighted Composite Knowledge and Technology Adoption Indices. The suitability of the data was assessed using the Kaiser–Meyer–Olkin measure and Bartlett's Test of Sphericity. Components with eigenvalues greater than one were retained, and Varimax rotation was applied to obtain an interpretable factor structure. The eigenvalue of each retained component was used to determine its relative contribution, and the component weights were normalized by dividing each eigenvalue by the sum of the eigenvalues of all retained components. The normalized weights were then combined with the corresponding normalized indicator scores to construct the composite indices. The composite index was computed as:

$$CI = \Sigma (W_i Z_i)$$

Where, CI = composite index, Wi = normalized weight assigned to the ith indicator, Z_i = normalized indicator score and n = number of indicators. Higher composite index values indicate relatively higher

levels of knowledge or technology adoption among the respondents. Production constraints were prioritised using Garrett's Ranking Technique (Garrett & Woodworth, 1969). The percent position for each rank was calculated as:

$$\text{Percent Position} = \frac{100(R_{ij} - 0.5)}{N_j}$$

Where, R_{ij} is the rank assigned by the jth respondent to the ith constraint and N_j is the total number of constraints ranked. The corresponding Garrett scores were obtained from the standard Garrett conversion table. The scores were then summed across respondents and divided by the number of respondents to obtain the mean Garrett score for each constraint. The constraints were ranked according to their mean Garrett scores, with higher scores indicating greater relative importance assigned by the respondents.

RESULTS

The suitability of the dataset for Principal Component Analysis was assessed to determine whether the data were adequate for PCA using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity (Table 1). The Kaiser-Meyer-Olkin values of 0.741 for knowledge and 0.791 for technology adoption indicated satisfactory sampling adequacy for Principal Component Analysis (Kaiser, 1974). Bartlett's Test of Sphericity was highly significant ($p < 0.001$) for both datasets, confirming adequate intercorrelation among the variables. These results indicated that the selected indicators were appropriate for Principal Component Analysis. Similar findings have been reported by Sathyan et al. (2026) and Thakur et al. (2024).

Table 1. Suitability of data for Principal Component Analysis

Particulars	Knowledge	Technology adoption
Number of respondents	280	280
Number of variables	28	28
Kaiser–Meyer–Olkin Measure	0.741	0.791
Bartlett's Test of Sphericity (χ^2)	3898.504	11054.004
Significance	<0.001	<0.001

Principal Component Analysis of the 28 knowledge variables related to recommended black pepper cultivation practices resulted in the extraction of nine principal components (Table 2). The

Table 2. Principal component loadings and weights of knowledge variables

Component	Indicator	Knowledge variables	Factor Loading	Eigenvalue	Normalized Weight
PC1	High-yielding and disease-free varieties	i. Panniyur-1	0.898	3.418	0.030
		ii. Panniyur-2	0.874		0.029
		iii. Karimunda	0.873		0.029
PC2	Crop establishment practices	i. Propagation through Serpentine layering method (Rooted Cuttings)	0.835	4.667	0.038
		ii. Recommended pit size (50 ×50 × 50 cm)	0.880		0.040
		iii. Recommended spacing (3 × 3 m)	0.837		0.039
		iv. Recommended planting season (May-June)	0.856		0.039
PC3	Live support trees	i. Silver Oak tree	0.905	2.080	0.019
		ii. Bamboo tree	0.901		0.018
PC4	Nutrient and Soil Management	i. Farm Yard Manure (10 kg/vine/year)	0.821	5.889	0.048
		ii. Azospirillum	0.844		0.049
		iii. Phosphobacteria	0.859		0.050
		iv. Azotobacter	0.825		0.048
		v. Mulching	0.867		0.050
PC5	Water Management	i. Flower Initiation	0.913	2.287	0.021
		ii. Berry development	0.902		0.020
PC6	Canopy Management	i. Pruning	0.911	3.209	0.029
		ii. Shade regulation	0.893		0.028
PC7	Integrated Management	i. Spraying of Neem Oil for the management of Pollu Beetle	0.922	3.864	0.035
		ii. Phytosanitary measures for the management of Foot rot	0.874		0.033
		iii. Weeding	0.893		0.034
PC8	Harvest and Post-Harvest Management	i. Harvesting berries at the recommended maturity stage	0.929	2.671	0.024
		ii. Drying of pepper to the recommended moisture content (10-12%)	0.893		0.024
PC9	Marketing and Value Addition	i. Quality grading	0.840	5.391	0.045
		ii. Value addition	0.852		0.045
		iii. Packaging	0.837		0.044
		iv. Market information	0.839		0.045
		v. Institutional support	0.842		0.045

PC = Principal Component

retained components had eigenvalues greater than one and collectively explained 93.862 per cent of the total variance. The first component explained 14.095 per cent of the variance, followed by the second component (12.350%), third component (12.036%), fourth component (10.493%), fifth component (10.230%), sixth component (9.833%), seventh component (8.811%), eighth component (8.533%) and ninth component (7.481%). The cumulative variance explained by the nine retained components was 93.862 per cent. Varimax rotation with Kaiser normalization was applied to obtain an interpretable factor structure, and the rotated factor loadings showed strong associations between the variables and their respective components. The extracted components represented key knowledge domains, namely high-yielding and disease-free varieties, crop establishment, live support standards, nutrient and soil management, water management, canopy management, integrated management, harvest and post-harvest management, and marketing and value addition. The normalized indicator weights were subsequently used for constructing the Composite Knowledge Index.

The indicator-wise Composite Knowledge Index of black pepper growers is presented in Table 3. Among the nine knowledge indicators, Nutrient and Soil Management recorded the highest Composite Knowledge Index (0.141) and was ranked first, followed by Marketing and Value Addition (0.139) and Crop Establishment Practices (0.095). Integrated Management ranked fourth with an index value of 0.063, while High-yielding and Disease-free Varieties ranked fifth (0.050). Comparatively lower index values were observed for Canopy Management (0.036), Harvest and Post-Harvest Management (0.028), Water Management (0.024) and Live support trees (0.023). The overall Composite Knowledge Index was estimated at 0.599. Based on the study's normalized 0–1 interpretation scale, this value falls within the moderate category, indicating that the respondents demonstrated an intermediate level of knowledge across the assessed black pepper cultivation practices, with scope for improvement in the comparatively weaker knowledge domains. The indicator-wise assessment highlights the knowledge domains requiring greater extension attention.

Principal Component Analysis of the 28 technology adoption variables related to recommended black pepper cultivation practices resulted in the extraction of nine principal components (Table 4). The retained components had eigenvalues greater than one and collectively explained 94.945 per cent of the total variance. The first component explained 17.700 per cent of the variance, followed by the second component (16.366%), third component (12.820%), fourth component (11.169%), fifth component (10.370%), sixth component (7.769%), seventh component (6.978%), eighth component (6.223%) and ninth component (5.549%). The cumulative variance explained by the nine retained components was 94.945 per cent. Varimax rotation with Kaiser normalization was applied to obtain an interpretable factor structure, and the rotated factor loadings showed strong associations between the variables and their respective components. The extracted components represented the major technology adoption domains, namely high-yielding and disease-free varieties, crop establishment practices, Live support trees, nutrient and soil management, water management, canopy management, integrated management, harvest and post-harvest management, and marketing and value addition. The normalized indicator weights were subsequently used for constructing the Composite Technology Adoption Index.

Table 3. Indicator-wise composite knowledge index of black pepper growers

Component	Indicator	Composite Knowledge Index	Rank
PC4	Nutrient and Soil Management	0.141	I
PC9	Marketing and Value Addition	0.139	II
PC2	Crop establishment practices	0.095	III
PC7	Integrated Management	0.063	IV
PC1	High-yielding and disease-free varieties	0.050	V
PC6	Canopy Management	0.036	VI
PC8	Harvest and Post-Harvest Management	0.028	VII
PC5	Water Management	0.024	VIII
PC3	Live support trees	0.023	IX
Overall Composite Knowledge Index		0.599	

PC = Principal Component

The indicator-wise Composite Technology Adoption Index of black pepper growers is presented in Table 5. Among the nine technology adoption indicators, Marketing and Value Addition recorded the highest Composite Technology Adoption Index (0.129) and secured the first rank, followed by Nutrient and Soil Management (0.119) and Crop Establishment Practices (0.074). Integrated Management ranked fourth with an index value of 0.047, while High-yielding and Disease-free Varieties ranked fifth (0.045). Comparatively lower index values were observed for Harvest and Post-Harvest Management (0.024), Water Management (0.023), Live support trees (0.019) and Canopy Management (0.016). The overall Composite Technology Adoption Index was estimated at 0.495. Based on the study's normalized 0–1 interpretation scale, this value falls within the moderate category, indicating an intermediate level of adoption across the assessed technologies, with comparatively greater scope for improvement in the lower-ranked technology domains. The indicator-wise assessment suggests that growers adopted production and marketing practices to varying extents, highlighting the need for strengthening extension efforts and technical support for comparatively less-adopted technologies.

The major constraints perceived by black pepper growers are presented in Table 6. High labour cost for field operations and harvesting emerged as the highest-ranked perceived constraint with a mean Garrett score of 72.49, followed by scarcity of skilled labour during peak season (69.51) and high cost of fertilizers and other agricultural inputs (66.39). Limited availability of quality planting materials ranked fourth with a mean Garrett score of 63.54. Among the production-related constraints, foot rot disease incidence (60.95) and unpredictable weather affecting crop productivity (60.63) ranked fifth and sixth, respectively. Inadequate extension and technical advisory services (57.64) and low farm-gate price received during the harvest season (54.75) were also ranked among the major perceived constraints affecting black pepper cultivation. Limited access to institutional credit (51.95) and lack of market information and value addition facilities (49.04) were ranked ninth and tenth, respectively. The Garrett ranking results indicate that labour scarcity,

Table 4. Principal component loadings and weights of technology adoption variables

Component	Indicator	Technology adoption variables	Factor Loading	Eigenvalue	Normalized Weight
PC1	High-yielding and disease-free varieties	i. Panniyur-1	0.972	5.793	0.031
		ii. Panniyur-2	0.970		0.031
		iii. Karimunda	0.971		0.031
PC2	Crop establishment practices	i. Propagation through Serpentine layering method (Rooted Cuttings)	0.973	7.162	0.038
		ii. Recommended pit size (50 ×50 × 50 cm)	0.966		0.038
		iii. Recommended spacing (3 × 3 m)	0.967		0.038
		iv. Recommended planting season (May-June)	0.972		0.038
PC3	Live support trees	i. Silver Oak tree	0.975	3.477	0.018
		ii. Bamboo tree	0.977		0.018
PC4	Nutrient and Soil Management	i. Farm Yard Manure (10 kg/vine/year)	0.967	9.143	0.048
		ii. Azospirillum	0.966		0.048
		iii. Phosphobacteria	0.969		0.048
		iv. Azotobacter	0.964		0.048
		v. Mulching	0.969		0.048
PC5	Water Management	i. Flower Initiation	0.981	4.340	0.023
		ii. Berry development	0.983		0.023
PC6	Canopy Management	i. Pruning	0.970	3.100	0.016
		ii. Shade regulation	0.970		0.016
PC7	Integrated Management	i. Spraying of Neem Oil for the management of Pollu Beetle	0.972	6.240	0.033
		ii. Phytosanitary measures for the management of Foot rot	0.973		0.033
		iii. Weeding	0.974		0.033
PC8	Harvest and Post-Harvest Management	i. Harvesting berries at the recommended maturity stage	0.977	3.898	0.021
		ii. Drying of pepper to the recommended moisture content (10-12%)	0.977		0.021
PC9	Marketing and Value Addition	i. Quality grading	0.968	9.888	0.052
		ii. Value addition	0.966		0.052
		iii. Packaging	0.966		0.052
		iv. Market information	0.969		0.052
		v. Institutional support	0.964		0.052

PC = Principal Component

Table 5. Indicator-wise composite technology adoption index of black pepper growers

Component	Indicator	Composite Technology Adoption Index	Rank
PC9	Marketing and Value Addition	0.129	I
PC4	Nutrient and Soil Management	0.119	II
PC2	Crop Establishment Practices	0.074	III
PC7	Integrated Management	0.047	IV
PC1	High-yielding and Disease-free Varieties	0.045	V
PC8	Harvest and Post-Harvest Management	0.024	VI
PC5	Water Management	0.023	VII
PC3	Live support trees	0.019	VIII
PC6	Canopy Management	0.016	IX
Overall Composite Technology Adoption Index		0.495	

PC = Principal Component

increasing production costs, pest and disease incidence, and inadequate institutional and market support were among the major constraints perceived by black pepper growers in Kolli Hills.

DISCUSSION

The relatively higher knowledge observed in nutrient and soil management, marketing and value addition, and crop establishment may be associated with the greater familiarity of growers with these practices in their routine pepper cultivation and marketing activities. In contrast, the comparatively lower knowledge of canopy management, water management, live support trees, and harvest and post-harvest management suggests areas where growers may require more specialised technical guidance. The overall Composite Knowledge Index of 0.599 indicates a moderate level of knowledge, while the variation across indicators shows that knowledge is not uniform across all recommended practices. Similar patterns have been reported by Chahal et al. (2014); Ravikumar et al. (2015); Jolly and Mazhar (2023); Mishra et al. (2024) and Patra et al. (2023), who observed differences in farmers' knowledge across commonly practised and specialised agricultural technologies. Therefore, extension programmes may give greater attention to the comparatively weaker knowledge domains through practical demonstrations and location-specific advisory services.

The technology adoption pattern follows the knowledge pattern, but the lower overall Composite Technology Adoption

Table 6. Major constraints faced by black pepper farmers

S.No.	Constraints	Total Garrett Score	Mean Garrett Score	Rank
1	High labour cost for field operations and harvesting	20,297	72.49	I
2	Scarcity of skilled labour during peak season	19,463	69.51	II
3	High cost of fertilizers and other agricultural inputs	18,589	66.39	III
4	Limited availability of quality planting materials	17,791	63.54	IV
5	Foot rot disease incidence	17,065	60.95	V
6	Unpredictable weather affecting crop productivity	16,976	60.63	VI
7	Inadequate extension and technical advisory services	16,139	57.64	VII
8	Low farm-gate price received during harvest season	15,330	54.75	VIII
9	Limited access to institutional credit	14,546	51.95	IX
10	Lack of market information and value addition facilities	13,730	49.04	X

Note: Mean Garrett Score = Total Garrett Score ÷ Number of respondents (280).

Index suggests that knowledge of recommended practices was not reflected uniformly in field-level adoption. Marketing and value addition, nutrient and soil management and crop establishment practices recorded relatively higher adoption, whereas canopy management, live support trees and water management showed comparatively lower adoption. The difference between the knowledge and adoption indices may reflect the practical challenges associated with implementing certain technologies under hill-farming conditions. Labour availability, production costs, access to inputs, institutional support and technical guidance may be relevant considerations; however, the present study did not statistically establish causal relationships between these factors and technology adoption. Similar observations have been reported by Rejula et al. (2018); Eliyas and Sumathi (2018); Parvathi and Waibel (2015), who highlighted the importance of economic and institutional factors in the adoption of improved black pepper production practices.

The PCA results provide useful evidence on the multidimensional nature of knowledge and technology adoption among black pepper growers. The KMO values of 0.741 for knowledge and 0.791 for technology adoption, together with the significant Bartlett's Test of Sphericity, indicated that the variables were suitable for data reduction and construction of composite indices. The extraction of nine components for both knowledge and technology adoption shows that growers' responses were distributed across distinct domains of recommended black pepper cultivation practices rather than being represented by a single dimension. The relatively high cumulative variance explained by the retained components, 93.862 per cent for knowledge and 94.945 per cent for technology adoption, further indicates that the retained components represented a substantial proportion of the variation in the respective datasets. The use of PCA-based weights therefore provided an empirical basis for combining the indicators into composite measures rather than assigning equal weights to all indicators. Similar applications of PCA-based composite index construction have been reported by Thakur et al. (2024); Kademani et al. (2025); Sathyan et al. (2026), supporting the usefulness of weighted indices for assessing multidimensional behavioural attributes.

Growers identified high labour cost for field operations and harvesting, scarcity of skilled labour during the peak season and high cost of fertilizers and other agricultural inputs as the major perceived constraints affecting black pepper cultivation. Foot rot disease, unpredictable weather conditions, inadequate extension and technical advisory services, low farm-gate prices, limited institutional credit and inadequate market information were also reported as important constraints. The Garrett ranking results describe the relative importance assigned to these constraints by the respondents and do not establish their causal effects on technology adoption or farm profitability. Similar observations have been reported by Maya et al. (2025), who identified labour scarcity and rising cultivation costs as major constraints reported by farmers, while Gireesh et al. (2019); Kumar et al. (2023); Niranjan et al. (2023) and Smija et al. (2025) also emphasised the importance of extension support and market linkage in agricultural development. These findings indicate the need for appropriate extension, input, institutional and market support measures to address the constraints perceived by black pepper growers.

The findings have practical implications for agricultural extension programmes in Kolli Hills. Since knowledge and technology adoption were comparatively lower in areas such as canopy management, live support trees and water management, extension programmes may focus on need-based training, field demonstrations and practical skill development in these areas. The major perceived constraints, particularly high labour cost, scarcity of skilled labour, high input costs and inadequate technical advisory services, also indicate the importance of timely extension support and improved access to production-related information. Regular farmer–scientist interactions, locally relevant training programmes and dissemination of information on recommended cultivation practices can help address the gaps identified in the study. Institutional support for quality planting materials, credit access and market information may further complement extension interventions for black pepper growers.

CONCLUSION

The study indicates that black pepper growers in Kolli Hills possess a moderate level of knowledge and technology adoption regarding the recommended cultivation practices, with technology adoption remaining comparatively lower than the corresponding knowledge level. Growers recorded higher knowledge and adoption in nutrient and soil management, crop establishment practices and marketing-related activities, whereas comparatively lower values were observed for canopy management, live support trees and water management. High labour cost, scarcity of skilled labour, increasing

input prices, disease incidence and inadequate technical support were perceived by respondents as major constraints affecting black pepper cultivation. The PCA-based composite indices provided a systematic approach for assessing the multidimensional knowledge and technology adoption levels of the growers, while Garrett ranking identified the relative importance of perceived production constraints. The findings highlight the need for regular need-based training, field demonstrations, timely technical advisory services and farmer–scientist interactions, together with improved access to quality planting materials, institutional credit and market information.

DECLARATIONS

Ethical approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Agricultural Economics SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District-603201, Tamil Nadu, India waived the ethical approval. Informed consent was obtained from all respondents before data collection. The respondents were informed about the purpose of the study, and their participation was voluntary.

Availability of supporting data: Supporting data are available upon request.

Competing interests: No competing interests were declared.

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Research Article

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Drivers of Farmers' Intention to Adopt Digital Platforms for Natural Farming Inputs in Andhra Pradesh

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HIGHLIGHTS

- Personal Innovativeness was the strongest driver of farmers' intention (β = 0.483; 100% normalized importance).
- Performance Expectancy, Facilitating Conditions, Effort Expectancy positively influenced farmers' behavioural intention.
- Perceived Cost, Perceived Risk and Social Influence showed no significant effect on behavioural intention (p>0.05).
- SEM-ANN model explained 51.8% of the variance in behavioural intention, with all three analytical methods ranking Personal Innovativeness first.

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ABSTRACT

The study examined the drivers of farmers' intention to adopt a Natural Farming digital input platform. The Unified Theory of Acceptance and Use of Technology was extended by incorporating Personal Innovativeness, Perceived Cost and Perceived Risk alongside Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions. Primary data were collected between July and November 2024 from 795 Natural Farming farmers across Andhra Pradesh, employing a structured questionnaire through direct interviews and supported by *Rythu Sadhikara Samstha*, the state nodal agency for Natural Farming. An integrated methodology combining a two-stage Partial Least Squares Structural Equation Modelling with an Artificial Neural Network approach, complemented by Importance Performance Map Analysis, was employed. Results showed a positive and significant influence of Personal Innovativeness, Performance Expectancy, Effort Expectancy and Facilitating Conditions on behavioural intention, explaining 51.8% of its variance, while Social Influence, Perceived Cost and Perceived Risk were statistically non-significant. The Artificial Neural Network sensitivity analysis confirmed Personal Innovativeness as the most important predictor. Strengthening rural digital infrastructure and designing intuitive regional-language interfaces could accelerate inclusive adoption intention among small and marginal farmers.

INTRODUCTION

Indian agriculture's growing dependence on chemical inputs since Green Revolution is widely linked to declining soil health and environmental harm (Balla & Goswami, 2022; Timilsina et al., 2025; Zhou et al., 2025). Natural Farming has emerged as a sustainable, chemical-free solution that relies on farm-level bio-inputs prepared from cattle derivatives and locally available materials (Bharucha et al., 2020; Saride & Sharad, 2024). Natural Farming enhances soil fertility and microbial activity and lowers per-acre costs (Centre for Economic and Social Studies, 2019; Koner & Laha, 2021; Mastiholi et al., 2023).

In India, the practice extends over roughly 1.005 million hectares (NITI Aayog, 2025b). Within Andhra Pradesh,

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approximately 630,000 farmers practise Natural Farming on 290,000 hectares under Andhra Pradesh Community Managed Natural Farming initiative, administered by *Rythu Sadhikara Samstha* (NITI Aayog, 2025a). Despite these efforts, its wider adoption remains limited, mainly because of substantial on-farm labour needed to prepare bio-inputs and the scarce supply of ready-made bio-inputs (Balla & Goswami, 2022; Kumar et al., 2025). A digital input-procurement platform can ease these constraints by aggregating seasonal demand, letting producers supply farmers who cannot self-prepare inputs and ensuring timely, quality supply. Comparable platforms have improved input access and service delivery for smallholders (Cimino et al., 2024; Morepje et al., 2024; Sharma et al., 2024). The conditions for such platforms are increasingly favourable, as 95.15% of villages are now covered by third- or fourth-generation mobile networks, together with widespread use of mobile phones among farmers (Press Information Bureau, 2024; Kumar, 2025).

Various methods and theoretical frameworks explain the intentions of farmers towards agricultural technologies, Theory of Planned Behaviour (Ajzen, 1991), Technology Acceptance Model (Davis, 1989) and Unified Theory of Acceptance and Use of Technology, commonly referred to as UTAUT (Venkatesh et al., 2003) are among them. The UTAUT combines Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions to shape behavioural intention, and has been widely applied in agriculture to study digital advisory services (Cimino et al., 2024), precision agriculture (Larasati et al., 2024), digital literacy among tea growers (Lin et al., 2023) and fintech uptake (Sharma et al., 2024). The original UTAUT omits context-specific factors important for small and marginal farmers, so it is augmented here with Personal Innovativeness, Perceived Risk and Perceived Cost to better explain platform adoption in rural India (Al-Saedi et al., 2020; Shi et al., 2022; Upadhyay & Kaur, 2026) and is analysed through a two-stage Structural Equation Modelling–Artificial Neural Network (SEM–ANN) procedure coupled with Importance Performance Map Analysis (Sabbir et al., 2020; Yuan et al., 2024).

Despite digital agricultures' expansion, farmers' intentions to adopt digital input-purchasing platforms in Natural Farming remain poorly understood. Adoption research largely emphasises conventional agricultural technologies, overlooking platform-specific behavioural factors. While Natural Farming's environmental, economic, and policy dimensions are documented (Bharucha et al., 2020; Koner & Laha, 2021; Kumar et al., 2023; Saride & Sharad, 2024; Shanmuka et al., 2025), evidence on digital platform adoption, remains scarce. This study therefore extends UTAUT to identify behavioural factors influencing Natural Farming farmers' intentions to adopt a digital input-purchasing platform in Andhra Pradesh. Seven hypotheses are examined: Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions and Personal Innovativeness positively influence behavioural intention, whereas Perceived Risk and Perceived Cost are expected to act negatively upon it.

METHODOLOGY

To ensure adequate representation of Natural Farming farmers, multi-stage stratified random sampling was used. In each district, the agricultural division with the largest area under the Andhra Pradesh Community-Managed Natural Farming programme was selected first. Gram Panchayats, each with at least 50 registered Natural Farming farmers, were then randomly chosen from every selected division. Finally, farmers were randomly drawn from village-level *Rythu Sadhikara Samstha* registers, stratified by length of Natural Farming experience (under four years versus four years or longer). Across 17 districts, the largest-APCNF-area division in each was selected (17 divisions, 440 gram panchayats); of 810 farmers approached, 15 were excluded for incomplete or invalid responses, retaining 795. Because the division with largest APCNF area was chosen per district, the sample favours areas of more established Natural Farming activity, under-representing those with fewer farmers.

An a priori sample size calculation was conducted using G*Power 3.1.9.7. The analysis was specified under F-test family, using linear multiple regression with seven predictors, an alpha level of 0.05, statistical power of 0.80, and a medium effect size of f squared equal to 0.15 (Yang et al., 2024). These parameters indicated a minimum required sample size of 103 participants.

Data collection ran from July to November 2024 using a structured questionnaire. Its first section outlined a hypothetical, generic digital platform for procuring Natural Farming inputs; the platform let farmers browse and select ready-made inputs, view product and price details, order, pay, arrange delivery and tracking, and access information in Telugu. The Second section gathered respondents' demographic and farm-level details; and a third measured 27 reflective indicators corresponding to seven constructs and to behavioural intention, each assessed on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Every indicator was adapted from previously validated instruments (Venkatesh et al., 2003; Luarn & Lin, 2005; Venkatesh et al., 2012; Ahn et al., 2016; Hu et al., 2019). The questionnaire was translated into Telugu and back into English, and refined through a pilot exercise involving 20 farmers who were not included in the final dataset.

Prior to multivariate analysis, a series of preconditions were verified (Leong et al., 2020). As all constructs were self-reported at one time, common method bias was assessed using Harman's single-factor test, which returned 26.1% (below 50%) and full-collinearity VIFs (1.013–2.024) stayed below 3, indicating minimal distortion. The Shapiro–Wilk test indicated that data departed from normality (Chin et al., 2015); the scatter of residuals pointed to homoscedasticity; and Variance Inflation Factors, all below three, indicated an absence of multicollinearity (Hew & Kadir, 2016). The Artificial Neural Network was therefore paired with SEM to capture any non-linear and non-compensatory relationships and to rank predictors, rather than on basis of normality result (Lee et al., 2022).

The analytical workflow unfolded across three phases. First, Partial Least Squares Structural Equation Modelling in SmartPLS 4 assessed indicator reliability, internal consistency, convergent and discriminant validity and path coefficients, drawing on 5,000 bootstrap resamples. In second phase, a multi-layer perceptron ANN was estimated in IBM SPSS, taking all seven predictors as inputs and behavioural intention as output. The network comprised one hidden layer of four neurons, with a sigmoid activation function in hidden and output layers, the input variables were standardised,

and network was trained using the gradient-descent algorithm. In third phase, Importance Performance Map Analysis in SmartPLS 4 transformed total effects into importance and performance values on a 0-to-100 scale.

RESULTS

The 795 participants were predominantly aged 30 to 39 years (40.88%) and male (65.79%). With respect to education, 35.22% had attained a degree or a higher credential. Marginal and small farmers holding less than three acres made up 87.30% of sample, mirroring wider composition of agriculture in Andhra Pradesh, and a majority reported four to eight years of experience with Natural Farming (56.86%).

Measurement model assessment

Determination of the reflective measurement model began with indicator reliability (Table 1), which captures how much of an items' variance is attributable to its underlying construct (Hair et al., 2019); loading greater than 0.708 is acceptable, the point at which a construct explains over 50% of an indicators' variance (Hair et al., 2021). The second step concerns internal consistency reliability, which measures how strongly indicators of the same construct correlate with each other (Hair et al., 2021). Output from the PLS algorithm confirmed robust construct reliability across the model, as every Cronbachs' alpha and composite reliability coefficient surpassed 0.70 (Leong et al., 2020). Finally, convergent validity was assessed with average variance extracted (AVE), reflecting how well a construct explains its indicators' variance (Hair et al., 2021). AVE values above 0.50 confirmed satisfactory convergence, establishing construct validity (Fornell & Larcker, 1981).

Discriminant validity is the fourth step; it captures how far one construct is empirically separable from the others within the structural model (Hair et al., 2021). As shown in Table 2, each Heterotrait–Monotrait (HTMT) ratio lies beneath the 0.90 threshold (Henseler et al., 2015; Hair et al., 2021), confirming that the model satisfied discriminant validity.

Discriminant validity used bootstrapped 95% CIs from 5,000 subsamples. Under the HTMT inference criterion (Henseler et al., 2015), no interval included 1, so each construct pair is empirically distinct. The ratios linking Personal Innovativeness with Effort Expectancy and Behavioural Intention are relatively high as innovative farmers find such tools easier, but their value still exclude 1, so discriminant validity holds.

Structural model and hypothesis testing

With every predictor returning a Variance Inflation Factor under three, multicollinearity was ruled out. Table 3 sets out the structural path coefficients. Behavioural intention was significantly and positively shaped by Personal Innovativeness ($\beta = 0.483$, $p<0.001$),

Table 1. Reliability, validity and outer loadings of constructs

Construct	Cronbach α	CR	AVE	Items	Outer loadings
Behavioural Intention	0.87	0.91	0.72	BI1–BI4	0.78, 0.81, 0.87, 0.91
Effort Expectancy	0.89	0.93	0.82	EE1–EE3	0.91, 0.93, 0.86
Facilitating Conditions	0.81	0.87	0.63	FC1–FC4	0.76, 0.72, 0.82, 0.85
Perceived Cost	0.82	0.88	0.71	PC1–PC3	0.86, 0.79, 0.87
Performance Expectancy	0.88	0.92	0.73	PE1–PE4	0.86, 0.88, 0.78, 0.88
Personal Innovativeness	0.73	0.88	0.79	PI1–PI2	0.92, 0.85
Perceived Risk	0.81	0.88	0.71	PR1–PR3	0.89, 0.83, 0.80
Social Influence	0.85	0.89	0.67	SI1–SI4	0.79, 0.74, 0.88, 0.85

CR = composite reliability; AVE = average variance extracted.

Table 2. Heterotrait–Monotrait ratio of correlations

	BI	EE	FC	PC	PE	PI	PR
EE	0.61						
	(0.54, 0.68)						
FC	0.48	0.50					
	(0.40, 0.56)	(0.43, 0.57)					
PC	0.37	0.33	0.18				
	(0.28, 0.46)	(0.25, 0.42)	(0.10, 0.27)				
PE	0.51	0.43	0.22	0.71			
	(0.43, 0.59)	(0.35, 0.52)	(0.14, 0.30)	(0.63, 0.77)			
PI	0.83	0.84	0.58	0.34	0.51		
	(0.77, 0.88)	(0.77, 0.91)	(0.49, 0.66)	(0.24, 0.44)	(0.42, 0.60)		
PR	0.13	0.30	0.10	0.10	0.13	0.23	
	(0.06, 0.23)	(0.21, 0.39)	(0.06, 0.18)	(0.05, 0.18)	(0.06, 0.22)	(0.12, 0.32)	
SI	0.04	0.03	0.04	0.10	0.04	0.04	0.04
	(0.03, 0.11)	(0.02, 0.11)	(0.04, 0.10)	(0.05, 0.19)	(0.03, 0.12)	(0.03, 0.13)	(0.03, 0.10)

BI = Behavioural Intention; EE = Effort Expectancy; FC = Facilitating Conditions; PC = Perceived Cost; PE = Performance Expectancy; PI = Personal Innovativeness; PR = Perceived Risk; SI = Social Influence.

Table 3. Structural path coefficients and hypothesis testing results

Hypothesis	Path	β	95% CI (bootstrap)	f^2	p value	Result
H1	PE → BI	0.165	[0.090, 0.244]	0.028	<0.001	Significant
H2	EE → BI	0.100	[0.015, 0.183]	0.010	0.020	Significant
H3	SI → BI	0.021	[–0.051, 0.081]	0.001	0.549	Not Significant
H4	FC → BI	0.120	[0.055, 0.188]	0.023	<0.001	Significant
H5	PI → BI	0.483	[0.400, 0.566]	0.240	<0.001	Significant
H6	PR → BI	–0.024	[–0.069, 0.029]	0.001	0.331	Not Significant
H7	PC → BI	0.040	[–0.021, 0.104]	0.002	0.211	Not Significant

Table 4. Artificial Neural Network sensitivity analysis and IPMA

Predictor	Mean importance	Normalised (%)	IPMA Importance	IPMA Performance
Personal Innovativeness	0.39	100	0.472	69.2
Performance Expectancy	0.18	47	0.222	74.8
Effort Expectancy	0.14	36	0.092	65.4
Facilitating Conditions	0.12	30	0.125	65.1
Perceived Cost	0.09	24	0.05	75.6
Perceived Risk	0.04	11	–0.021	54.1
Social Influence	0.03	7	0.024	70.3

Performance Expectancy (β = 0.165, p<0.001), Facilitating Conditions (β = 0.120, p<0.001) and Effort Expectancy (β = 0.100, p<0.05), which lent support to hypotheses H1, H2, H4 and H5. By contrast, Social Influence (β = 0.021, p>0.05), Perceived Risk (β = –0.024, p>0.05) and Perceived Cost (β = 0.040, p>0.05) were insignificant, so hypotheses H3, H6 and H7 were rejected. Overall, the structural model explained 51.8% of variance in behavioural intention (R^2 = 0.518). Predictive relevance was assessed with the PLSpredict procedure (Shmueli et al., 2019), using ten-fold cross-validation with ten repetitions. All four behavioural intention indicators returned positive Q^2 predict values (BI-1: 0.39, BI-2: 0.24, BI-3: 0.43 and BI-4: 0.36), confirming the model's predictive relevance.

Artificial Neural Network and importance-performance analysis

Averaged over the ten-fold cross-validation, the Root Mean Square Error was 0.102 during training and 0.094 during testing, signalling that the network generalized effectively without overfitting and normalized importance from sensitivity analysis (Table 4). A subsequent Importance Performance Map Analysis, run in SmartPLS 4, appraised the importance and performance of all seven constructs simultaneously (Alhumaid et al., 2021). This analysis placed Personal Innovativeness foremost in importance, trailed by Performance Expectancy, Facilitating Conditions, Effort Expectancy, Perceived Cost, Social Influence and Perceived Risk. A side-by-side comparison of importance rankings yielded by PLS-SEM, Artificial Neural Network and Importance Performance Map Analysis techniques is presented in Table 5.

Table 5. Convergent importance rankings across three methods

Construct	IPMA	PLS-SEM	ANN
Personal Innovativeness	1	1	1
Performance Expectancy	2	2	2
Facilitating Conditions	3	3	4
Effort Expectancy	4	4	3
Perceived Cost	5	5	5
Social Influence	6	7	7
Perceived Risk	7	6	6

IPMA = Importance Performance Map Analysis; PLS-SEM = Partial Least Squares Structural Equation Modelling; ANN = Artificial Neural Network.

DISCUSSION

The results identify Personal Innovativeness as the foremost factor behind the intention to adopt digital platforms among Natural Farming farmers in Andhra Pradesh, echoing Alharbi and Sohaib (2021); Sonu and Jha (2025); Singh et al. (2026). Farmers are more inclined to use digital platforms when they believe these technologies are beneficial and capable of producing intended results. The pattern is consistent with Mangudhla et al. (2026), which identifies individual adaptive capacity as a principal force shaping adaptation behaviour. This underscores the need for responsive extension practices that help farmers adopt digital technologies.

Performance Expectancy has a significant and positive association with behavioural intention, aligning with Cimino et al. (2024). Natural Farming farmers show greater willingness to adopt digital platforms when they perceive these tools as useful for achieving desired outcomes. A comparable significant and positive effect was observed for Effort Expectancy, supporting Shi et al. (2022); platforms perceived as straightforward and easy to operate are more readily adopted. These findings favour practical demonstrations, farmer training and user-friendly interfaces. Social Influence was insignificant (Li et al., 2024), so adoption depends less on social validation than on direct utility.

Facilitating Conditions has a positive and significant effect on behavioural intention, implying that technology-enabling services, including digital payment facilities, capable platforms and wider internet access, are instrumental in motivating Natural Farming farmers to embrace digital platforms, corroborating Jain et al. (2025).

Extension systems must therefore provide connectivity, advisory support and institutional assistance, and strengthen digital literacy to turn access into sustained platform use.

Perceived Cost does not significantly affect behavioural intention. This suggests that perceived financial barriers may be less influential when farmers recognise the benefits of digital platforms and that perceived value can outweigh associated costs. This underscores the need to communicate the broader value of digital technologies. Wang et al. (2026), reported that the adoption of digital technology by Chinese farmers responds more to access and complementary services than to direct expense. Perceived Risk is similarly non-significant, in agreement with Zeng et al. (2016), reflecting the possibility that progress in digital technology has made associated risks more manageable as users become more knowledgeable and better prepared to handle them.

Though non-significant in the SEM, Perceived Cost retained a moderate normalised importance (24%) in the ANN, suggesting a non-linear influence a linear model would not capture (Lee et al., 2022; Yuan et al., 2024; Soomro et al., 2025; Yu et al., 2026; Pragnya et al., 2026). One plausible interpretation is that cost becomes salient only at levels higher than those experienced by most respondents in this sample; however, present analysis did not directly test for such a threshold, this reading remains suggestive rather than confirmed. With small and marginal farmers at 87.30% of the sample, the chief drivers appear to be farmer disposition and infrastructure rather than cost affordability.

Taken together, PLS-SEM, ANN and IPMA indicate that Personal Innovativeness is crucial in influencing the behavioural intention of farmers to embrace digital platforms, consistent with Alharbi and Sohaib (2021). Farmers inclined to experiment with new digital technologies are more likely to recognise their advantages, reinforcing the need for farmer-centred training, advisory support, digital literacy and enabling institutional conditions.

CONCLUSION

This research demonstrates that, among the factors shaping Natural Farming farmers' intention to adopt digital platforms for sourcing Natural Farming inputs, Personal Innovativeness ranks as the most influential, followed by Performance Expectancy, Effort Expectancy and Facilitating Conditions. Enriched by the addition of Personal Innovativeness, Perceived Cost and Perceived Risk, extended framework shows considerable explanatory strength in accounting behaviour intentions towards digital platforms among smallholder Natural Farming communities. The practical implications are spending on rural digital infrastructure, provision of affordable internet connectivity and design of incentive-based policy instruments should be treated as essential foundations for digital transitions in agriculture. To strengthen farmers' behavioural intention in a way that is both substantive and inclusive, technology developers and venture initiators need to build platforms that are responsive to innovative perspectives and resource constraints of Natural Farming practitioners.

DECLARATIONS

Ethics approval and consent of participation: The research advisory committee of Rajendra Mishra School of Engineering Entrepreneurship, Indian Institute of Technology, Kharagpur, West Bengal, India waived the ethical approval. Participation was voluntary, and verbal informed consent was obtained from all respondents. The confidentiality and anonymity of participants were strictly maintained throughout the research process.

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Authors' contribution: Aravind Kumar Saride and Mrigank Sharad conceived the study, undertook data collection and analysis, preparing original draft. Mrigank Sharad provided supervision, carried out review and editing of manuscript. Both authors read and approved the final version.

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Research Article

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Assessment of Climate Change Vulnerability among Smallholder Farmers in Cooch Behar, West Bengal

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HIGHLIGHTS

- Educational status and family size were the strongest predictors of climate vulnerability and adaptive response whereas educational status had the strongest negative correlation with both vulnerability and adaptive response indices.
- Income, land holding and expenditure lost statistical significance in regression despite strong correlation with vulnerability.

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Keywords: Adaptive response, Climate change, Composite vulnerability, Smallholder farmers, Climate-resilient households.

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ABSTRACT

Climate change disproportionately affects smallholder farmers, yet assessments of climate vulnerability remain limited for under-studied regions such as Cooch Behar in West Bengal. This study assessed climate-change vulnerability and adaptive response among 120 smallholder households selected through multistage sampling during 2025 in two blocks of Cooch Behar. Composite Vulnerability and Adaptive Response Indices were constructed by normalising indicators within the exposure sensitivity adaptive capacity framework (higher scores indicate greater vulnerability and greater adaptive response, respectively). The 19 independent variables were correlated with each of the two indices, and multiple regression was used to determine the significant ones. The strongest relationship with both indices was with land holding, income, expenditure and educational status, the latter correlations being non significant with family size and extension contact. Vulnerability was significantly predicted by educational status alone ($R^2 = 0.520$) while educational status, land holding and family size predicted adaptive response ($R^2 = 0.788$). The findings highlight education as a practical policy consideration for building climate-resilient smallholder households and demonstrate the utility of composite indices for identifying vulnerable households.

INTRODUCTION

Climate change is one of the most acute problems facing global agriculture, with smallholder farming systems in developing countries being most vulnerable to its negative effects (Shitu et al., 2018; Kumar et al., 2023). The changing precipitation patterns, higher temperatures, more extreme weather events and erratic monsoon behaviour in South Asia have already adversely affected agriculture, which remains the livelihood for majority of the rural population (Yadav, 2022). India, being a predominantly agricultural country is especially susceptible to these shifts, with almost 50% of the population still engaged in agriculture, most of which is rain-fed and small-scale (Mishra et al., 2025). Cooch Behar is located in the sub-Himalayan foothill area of North Bengal and possesses unique agro-climatic conditions arising from its proximity to the Himalayas, high annual rainfall, a network of rivers and predominantly alluvial soils (Basak, 2026). Farmers in this district

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are predominantly smallholders with dispersed land holdings that are highly vulnerable to climatic changes (Mishra et al., 2026). Increasing variability in rainfall distribution has changed traditional crop sequences, while flood events, riverbank erosion and occasional dry spells during critical crop-growth phases have jeopardised livelihood security (Ashoka et al., 2022; Neha et al., 2024). The study will help fill this gap in the literature on climate vulnerability in West Bengal, as Cooch Behar is a relatively under-studied area compared to other parts of the state, although it is an important agricultural region (Sodhi et al., 2023). The concept of vulnerability to climate change is a multidimensional phenomenon and is generally defined as the result of exposure, sensitivity and adaptive capacity (Serkendiz & Tatli, 2023). According to Zhai and Lee (2024), exposure is the level of climatic stress that a system must endure, sensitivity is the degree to which the system is susceptible to climatic stress, and adaptive capacity is the ability of a system to modify and cope in response to climatic stress. Combined assessment of these dimensions is more comprehensive than the evaluation of climatic exposure alone, because it includes the socio-economic, institutional and infrastructural aspects that affect farmers' vulnerability to shocks and impacts due to climate change, and their capacity to recover (Singh et al., 2025). Farmers may efficiently adapt to and reduce the consequences of climate change by putting precise conservation agriculture strategies into practice (Shitu & Nain, 2024). In this context a spatial vulnerability assessment is especially useful because vulnerability is rarely even over a geographical area. However, within relatively small administrative units, vulnerability can vary due to soil-type, availability of irrigation water, intensity of use, road accessibility and socio-economic status (Kumar et al., 2026). The use of composite index techniques in concert with field-based socio-economic data can help researchers determine vulnerable areas and help inform more targeted and efficient policy action.

METHODOLOGY

The study was conducted in Cooch Behar district of West Bengal, which lies in the sub-Himalayan foothill agro-climatic zone of North Bengal and is climatically sensitive owing to high rainfall, a dense river network and predominantly alluvial soils (Basak, 2026). An ex-post-facto research design was adopted and a multistage sampling procedure was used to the selected sample. Cooch Behar-II and Dinhata-II blocks were purposively selected on the basis of agro-climatic diversity and exposure to floods, river-bank erosion and rainfall variability; villages and farming households were then randomly selected within those blocks, Khagribari and Singimari Paschimpar villages were selected randomly, while Durganagar and Hokadaha-I were selected from each blocks randomly. From each villages, thirty respondents were randomly selected. The final sample comprised 120 farming households.

Primary data were collected through a pre-tested interview schedule administered to the sampled farmers. Secondary data on rainfall, land use and demographics were obtained from district records and supplemented by literature and expert consultation during 2025. The Vulnerability Index and the Adaptive Response Index were constructed independently of the nineteen predictor variables later used in the correlation and regression analyses. Following the exposure–sensitivity–adaptive capacity framework (Serkendiz & Tatli, 2023; Zhai & Lee, 2024), indicators of exposure (e.g., rainfall variability), sensitivity (e.g., frequency of flood and dry-spell events) and adaptive capacity (e.g., irrigation access, adoption of climate-resilient practices, coping mechanisms) were elicited for every household. To ensure that the various variables measured on different scales contributed similarly to the total scores, the various component indicators were subjected to a min-max normalisation process by (Iyengar & Sudarshan, 1982), and then the normalised sub-indicators were added together to create the composite scores at the household level, the Vulnerability Index and the Adaptive Response Index. None of these nineteen independent variables described were included in the construction of these indices, but were used, as reported in the Results, to examine correlations with and statistically explain the variance in the two indices.

Data were coded and analysed with conventional statistical software SPSS version 27. The bivariate relationship between the nineteen independent variables and the Vulnerability and Adaptive Response indices was determined using Pearson's product moment correlation coefficient were computed between each of the nineteen independent variables and the two indices.. The significant determinants of each index were then identified using multiple linear regression analysis and then performed. The general form of the models was:

$$Y = \beta_o + \beta_1 X_1 \bullet + \beta_2 X_2 + \ldots + \beta_{19} X_{19} + \varepsilon$$

Where, Y denotes the Vulnerability Index or the Adaptive Response Index. Unstandardised coefficients (B), standard errors, standardised beta coefficients (β) and t-values were obtained. Statistical significance was assessed at the 5 per cent level.

RESULTS

Correlation between independent variables and the vulnerability and adaptive response indices

Table 1 presents the Pearson correlation coefficients between the nineteen independent variables and the two outcome indices. Age (X1) and years of farming experience (X4) were positively and significantly associated with both indices. Educational status (X2) exhibited the strongest negative correlations with vulnerability (r = - 0.487) and adaptive response (r = - 0.598) for all the socio-personal variables. Land holding (X5), annual household income (X6), annual expenditure (X7) and material possession (X8) likewise showed highly significant negative correlations. Information-seeking behaviour (X11), management orientation (X17) and awareness of climate change (X19) were also negatively related to both indices. Family size (X3), extension contact (X9), access of information sources (X10), innovative proneness (X12), change resistance (X13), risk-bearing ability (X14), scientific orientation (X15) and economic motivation (X16) did not display statistically significant bivariate associations.

Predictors of the vulnerability index: Multiple regression

The multiple regression model for the Vulnerability Index explained 52.0 per cent of the total variance (Table 2). Two

Table 1. Correlation between independent variables and vulnerability and adaptive response indices

Independent variable	Vulnerability Index (X20)	Adaptive Response Index (X21)
Age (X1)	0.190*	0.260**
Educational status (X2)	–0.487**	–0.598**
Family size (X3)	0.035	–0.020
Years of experience in farming (X4)	0.207*	0.288**
Land holding (X5)	–0.547**	–0.733**
Annual household income (X6)	–0.531**	–0.727**
Annual expenditure (X7)	–0.517**	–0.717**
Material possession (X8)	–0.291**	–0.420**
Extension contact (X9)	0.030	–0.013
Access of information sources (X10)	–0.142	–0.143
Information seeking behaviour (X11)	–0.210*	–0.245**
Innovative proneness (X12)	0.088	0.091
Change resistance (X13)	–0.037	–0.024
Risk bearing ability (X14)	–0.117	–0.103
Scientific orientation (X15)	–0.155	–0.147
Economic motivation (X16)	–0.125	–0.102
Management orientation (X17)	–0.187*	–0.227*
Experienced change (X18)	–0.128	–0.167
Awareness regarding climate change (X19)	–0.234*	–0.266**

Note: * $p < 0.05$; ** $p < 0.01$. n = 120.

predictors were statistically significant at the 5 per cent level: educational status (X2; $\beta = -0.373$, $t = -4.680$) exerted a negative influence, while family size (X3; $\beta = 0.171$, $t = 2.090$) exerted a positive influence. No other variables reached statistical significance ($|t| < 1.96$). Although annual household income, land holding and annual expenditure displayed relatively large coefficient magnitudes, they were not statistically significant.

The multiple regression model for the Vulnerability explained 52.0 per cent of the total variance (Table 2). Two predictors of the Vulnerability Index were statistically significant; educational status (X2) had a negative significant ($\beta = -0.373$, $t = -4.680$) and the family size (X3) had a positive significant ($\beta = 0.171$, $t = 2.090$) showed a significant influence (Figure 1). There were no other variables that were significant ($|t|<1.96$). Annual household income (X6, $\beta = -0.905$), land holding (X5, $\beta = -0.276$) and annual expenditure (X7, $\beta = 0.728$) had the highest coefficient magnitudes in absence of significance. Other factors such as age, awareness, access to information, scientific orientation and behaviour characteristics like economic motivation, risk-bearing capacity, and innovative proneness exhibited slight and insignificant effects.

Predictors of the adaptive response index: Multiple regression

The multiple regression model, which was used to identify the determinants of the Vulnerability accounted for 78.8 per cent of the total variance as shown in Table 3. There were three predictors that were statistically significant for the Adaptive Response Index (Figure 2). Educational status (X2) showed the strongest negative influence ($\beta = -0.462$, $t = -8.652$), followed by land holding (X5, $\beta = -0.304$, $t = -2.265$). The number of family members (X3) had a significant positive effect ($\beta = 0.167$, $t = 3.051$). All other 16 variables were non-significant with $|t| < 1.96$. The largest coefficients were for annual household income (X6, $\beta = -0.825$), annual expenditure (X7, $\beta = 0.443$), but these two factors were not significant. Other variables such as age, awareness, innovative proneness and information seeking behaviour were found to have small without any significant effect.

DISCUSSION

Economic resource variables land holding, income and expenditure; displayed the strongest bivariate associations with both vulnerability and adaptive response, consistent with Ghosh and Ghosal (2020) in the neighbouring sub-Himalayan foothills of West Bengal. The strongest non-material correlate was educational status,

Table 2. Multiple regression analysis of factors influencing the Vulnerability Index

Independent variable	B	SE	β	t	p-value
Age (X1)	–0.0009	0.0008	–0.221	–1.164	0.247
Educational status (X2)	–0.0037	0.0008	–0.373	–4.680**	<0.001
Family size (X3)	0.0052	0.0025	0.171	2.090*	0.039
Years of experience in farming (X4)	0.0006	0.0007	0.141	0.756	0.451
Land holding (X5)	–0.0100	0.0073	–0.276	–1.380	0.171
Annual household income (X6)	–0.0020	0.0017	–0.905	–1.172	0.244
Annual expenditure (X7)	0.0019	0.0018	0.728	1.011	0.314
Material possession (X8)	0.0003	0.0012	0.026	0.280	0.780
Extension contact (X9)	0.0049	0.0027	0.213	1.802	0.075
Access of information sources (X10)	–0.0040	0.0025	–0.195	–1.646	0.103
Information seeking behaviour (X11)	–0.0003	0.0010	–0.029	–0.347	0.729
Innovative proneness (X12)	0.0018	0.0042	0.061	0.436	0.664
Change resistance (X13)	–0.0038	0.0045	–0.113	–0.840	0.403
Risk bearing ability (X14)	–0.0004	0.0017	–0.029	–0.246	0.806
Scientific orientation (X15)	–0.0017	0.0013	–0.120	–1.351	0.180
Economic motivation (X16)	–0.0009	0.0036	–0.028	–0.236	0.814
Management orientation (X17)	0.0004	0.0010	0.035	0.373	0.710
Experienced change (X18)	0.0003	0.0004	0.105	0.862	0.391
Awareness regarding climate change (X19)	–0.0016	0.0011	–0.179	–1.467	0.145

Model summary: R = 0.721; $R^2 = 0.520$; Adjusted $R^2 = 0.428$; SE = 0.0268; n = 120.

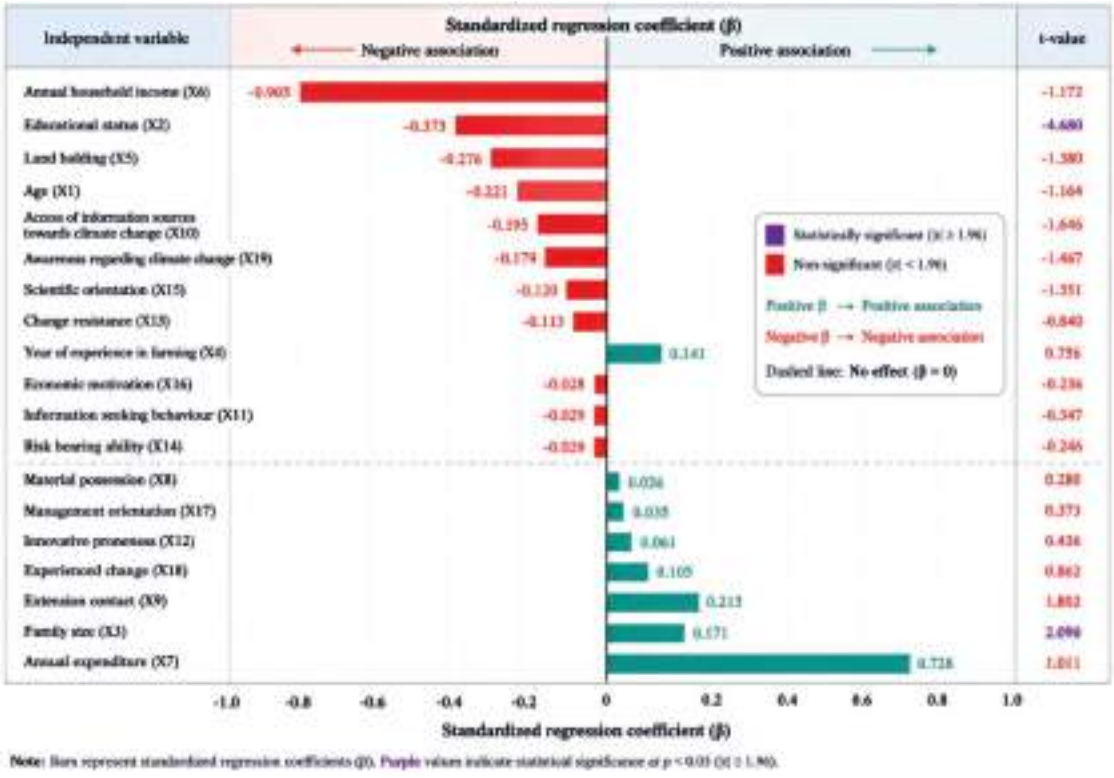


Figure 1. Multiple regression analysis of factors influencing vulnerability index

Note: Bars represent standardized regression coefficients (β). Purple values indicate statistical significance at $p < 0.05$ ($|t| \geq 1.96$).

Table 3. Multiple regression analysis of factors influencing the Adaptive Response Index

Independent variable	B	SE	β	t	p-value
Age (X1)	–0.0019	0.0014	–0.171	–1.349	0.180
Educational status (X2)	–0.0124	0.0014	–0.462	–8.652**	<0.001
Family size (X3)	0.0139	0.0046	0.167	3.051**	0.003
Years of experience in farming (X4)	0.0010	0.0013	0.089	0.712	0.478
Land holding (X5)	–0.0299	0.0132	–0.304	–2.265*	0.026
Annual household income (X6)	–0.0049	0.0031	–0.825	–1.597	0.113
Annual expenditure (X7)	0.0031	0.0034	0.443	0.919	0.360
Material possession (X8)	0.0003	0.0022	0.009	0.146	0.884
Extension contact (X9)	0.0016	0.0050	0.025	0.320	0.749
Access of information sources (X10)	–0.0022	0.0045	–0.039	–0.486	0.628
Information seeking behaviour (X11)	–0.0012	0.0018	–0.037	–0.660	0.511
Innovative proneness (X12)	–0.0074	0.0076	–0.092	–0.972	0.333
Change resistance (X13)	0.0003	0.0082	0.003	0.036	0.971
Risk bearing ability (X14)	0.0008	0.0030	0.021	0.267	0.790
Scientific orientation (X15)	–0.0011	0.0024	–0.028	–0.473	0.638
Economic motivation (X16)	–0.0003	0.0066	–0.004	–0.048	0.962
Management orientation (X17)	0.0002	0.0018	0.008	0.123	0.903
Experienced change (X18)	0.0003	0.0007	0.038	0.462	0.645
Awareness regarding climate change (X19)	–0.0028	0.0020	–0.112	–1.368	0.174

Model summary: R=0.886; R^2=0.788; Adjusted R^2=0.744; Standard error of estimate=0.0487. n=120.

which correlated with Jatav (2024) who found illiterate farmers in Uttar Pradesh to be more vulnerable than their literate counterparts. The slight positive association between age and farming experience and vulnerability is in contrast to Sarkar et al. (2026) who found younger farmers adopting more easily, which may be interpreted as the older farmers continuing to follow traditional farming methods but not as a reversal of risk. The modest associations in awareness were similar to Patel et al. (2023) who noted that monetary motivation was a more significant driver of adaptation among Indian farmers than climate knowledge.

In the multivariate models, educational status and family size significantly predicted the Vulnerability Index, while educational status, land holding and family size significantly predicted the Adaptive Response Index. These results are consistent with Jatav (2024) in underscoring the sustained negative association of education with vulnerability. The positive coefficient of family size

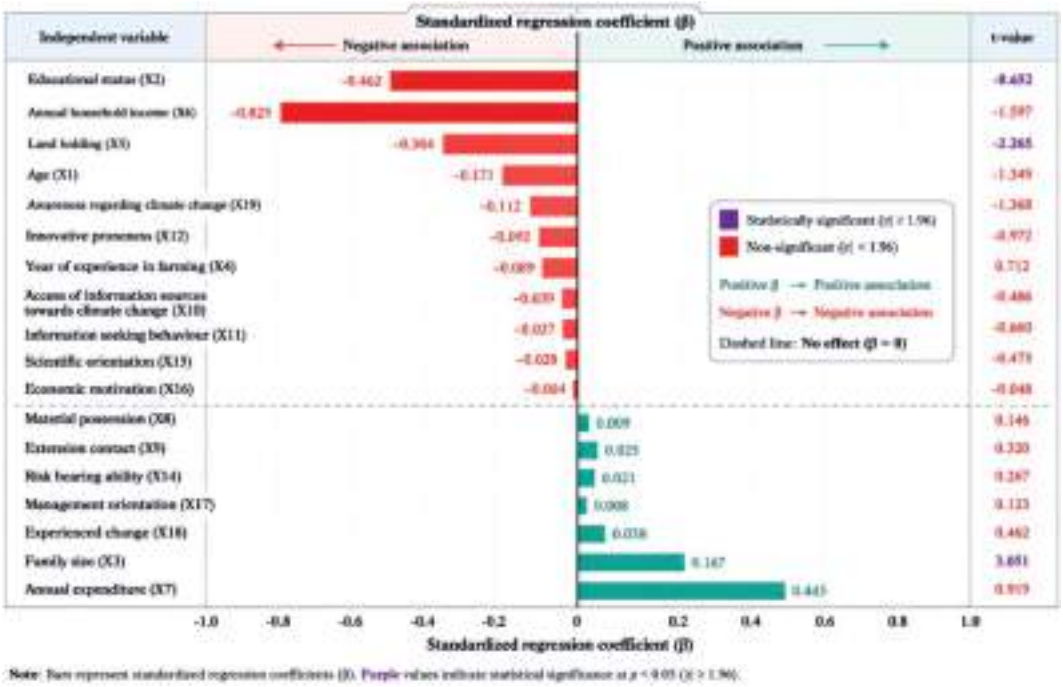


Figure 2. Multiple regression analysis of factors influencing adaptive response index

Note: Bars represent standardized regression coefficients (β). Purple values indicate statistical significance at $p < 0.05$ ($|t| \geq 1.96$).

suggests that a larger dependency burden may constrain adaptive investments, although larger households can also supply labour (Sarkar et al., 2026). Although land holding, income and expenditure were strongly correlated with both indices, they lost independent statistical significance once entered jointly.

Behavioural and psychological variables were generally weak and non-significant, suggesting that their influence, if any, is largely indirect. Methodologically, the composite-index approach employed here is consistent with previous applications of composite vulnerability indices to Indian farm households (e.g., Balaganesh & Sendhil, 2025). Overall, economic and educational determinants of vulnerability appear broadly similar across agro-climatic regions of India, whereas age and household-structure effects appear more context-specific.

CONCLUSION

The study examined the climate-change vulnerability of smallholder farmers in Cooch Behar, West Bengal, using composite Vulnerability and Adaptive Response Indices constructed from household-level exposure, sensitivity and adaptive-capacity indicators. Most sampled households fell into the medium vulnerability category, and educational status, family size, and land holding emerged as the most consistent statistical determinants of both indices, while income and expenditure, though strongly correlated, lost independent significance due to multicollinearity. These findings, consistent with recent evidence from other Indian agro-climatic regions, position education as a central policy lever for vulnerability reduction and highlight household structure and asset base as important, non-behavioural drivers requiring targeted intervention. The study reinforces the value of composite indices for identifying vulnerable households and offers an evidence base for designing region-specific adaptation strategies.

DECLARATIONS

Ethical consideration and consent to participate: All procedures performed in studies involving human participants were in accordance with the ethical standards of social research. The Divisional review board, Agricultural Extension Division, of UBKV, Cooch Behar waived the ethical approval vide reference no. UBKV/Agril. Extn./204/206 dated 18.08.2026. All respondents participated voluntarily after receiving an explanation of the research objectives, the benefits of the research, and assurances of data confidentiality. The verbal consent of respondents was obtained and their identity is kept confidential and is used only for academic purposes.

Conflict of interest: The authors have declared that no conflict of interest, financial or non-financial, exists that could affect the implementation, analysis, or reporting of the results of this research.

Consent for publication: The authors give their consent for publication of the manuscript in the journal, if accepted.

Data Availability statement: The data generated and analyzed in this project are not publicly available due to participant level information, ethical and confidentiality issues. The associated author will provide the dataset, upon reasonable request, subject to relevant institutional and ethical constraints.

Authors' contribution: Anubhab Karjee conducted the field investigation, data collection, statistical analysis. Kausik Pradhan supervised the study and contributed to research design and interpretation of results. Swapnamay Ghosh, Praveenkumar Marimuthu, Chigilipalli Mounika and Atreyee Sarkar assisted in literature review, data interpretation, manuscript preparation and editing. All authors read and approved of the final manuscript.

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Extension, Resources and Institutional Support Associated with Oil Palm Farmers' Adaptive Capacity in Riau, Indonesia

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HIGHLIGHTS

- Accessible and dialogical agricultural extension positively predicted the adaptive capacity of oil palm smallholders in Tapung, Riau, Indonesia.
- Household resources were the strongest predictor of adaptive capacity, with household income contributing far more than formal education.
- Private company support contributed more than government support to the institutional environment around farmers.
- Extension methods, household resources and institutional support jointly explained 37.3% of the variance in adaptive capacity among 203 oil palm farmers.

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Keywords: Adaptive capacity, Advisory services, Household income, Indonesia, Institutional support, Oil palm, Smallholders.

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ABSTRACT

Agricultural extension may strengthen farmers' responses to production, market and information change, but its contribution is rarely separated from supporting institutions. This cross-sectional study examined how extension methods, household resources and institutional support predicted adaptive capacity among oil palm farmers in three villages of Tapung Subdistrict, Indonesia, from December 2023 to April 2024. Of 214 farmers interviewed, 11 incomplete questionnaires were excluded and 203 complete cases were analysed using partial least squares structural equation modelling with 5,000 bootstrap samples, PLSpredict and the cross-validated predictive ability test. Extension methods (β=0.106; p=0.016) and household resources (β=0.492; p<0.001) positively predicted adaptive capacity. Institutional support was positive (β=0.151; p=0.032), but its bias-corrected interval included zero; therefore, H3 was inconclusive. Separating the resource construct showed that household income carried the association (β=0.483; p<0.001), whereas formal education did not (β=0.022; p=0.764). The model explained 37.3% of adaptive-capacity variance. All indicator-level Q^2predict values were positive, and PLS-SEM outperformed the linear benchmark for four of six indicators. The findings suggest combining accessible, dialogical extension with financially feasible recommendations, while coordinated public–private support requires further testing.

INTRODUCTION

Indonesia's oil palm sector supports rural livelihoods, and smallholders manage a substantial share of the planted area (BPS-Statistics Indonesia, 2023). Riau Province is the country's largest oil palm producing region, yet smallholders operate amid climate variability, volatile prices, productivity gaps and changing

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sustainability requirements (Novira, 2023; Paterson, 2023; Reich et al., 2025). Adjustment depends on the information farmers receive, on household liquidity and on the advisory services within reach (Maguire-Rajpaul et al., 2020; Ogundeji et al., 2022).

Adaptive capacity is the set of resources, skills and institutional relations that allow a farm household to anticipate change, absorb its effects and reorganise its practices (Manevska-Tasevska et al., 2021; Bartelet et al., 2023). Resources, learning and surrounding institutions shape it together. Education and income improve farmers' ability to interpret information and absorb adjustment costs, while information access and institutional connections widen the range of responses available (Maguire-Rajpaul et al., 2020; Atube et al., 2021; Ogundeji et al., 2022; Yadav and Ghosh, 2023). Where advice is unreachable or detached from the decisions farmers face, those resources stay unused.

Participatory and farmer field school approaches strengthen farmers' innovativeness and enable locally relevant decisions (van den Berg et al., 2020; Osumba et al., 2021; Dosso et al., 2023; Nain et al., 2024). Digital and conventional channels raise knowledge when they stay accessible and tied to farmers' circumstances (Antwi-Agyei & Stringer, 2021; Niranjan et al., 2023; Maurya et al., 2026). Where public advisory capacity is limited relative to the farming population, private companies and government programmes together form a pluralistic extension environment (Kamruzzaman et al., 2021; Godara et al., 2024a; Godara et al., 2024b). In oil palm the two are entangled: scheme farmers are advised through their company contract, while independent growers depend on public services (Sibhatu et al., 2025). The present analysis keeps them apart. Extension methods denote the accessibility, dialogical quality and participatory design of advisory delivery (Dosso et al., 2023); institutional support denotes the organisational resources companies and public agencies supply to sustain those processes (Kangogo et al., 2020; Kamruzzaman et al., 2021). Studies that merge the two cannot show whether adaptive capacity follows from the quality of communication or from the institutions behind it, so extension managers have no clear target.

Much adaptive capacity research remains descriptive, profiling farmers socioeconomically or sorting them into low, medium and high categories (Vijayabhinandana et al., 2022; Sthitaprajna and Shasani, 2026). Such work identifies education, information use and extension participation as correlates of adaptation, but says little about the mechanisms an extension organisation can change, and the joint effect of extension methods and institutional partnerships is still untested among oil palm smallholders. Separating the two constructs identifies where extension managers should invest, and out-of-sample assessment tests whether the relationships hold beyond the sample (Shmueli et al., 2019; Liengaard et al., 2021). This study tests three hypotheses: extension methods positively influence adaptive capacity (H1); farmer household resources positively influence adaptive capacity (H2); and institutional support positively influences adaptive capacity (H3).

METHODOLOGY

A cross-sectional survey was conducted from December 2023 to April 2024 in Petapahan, Sari Galuh and Kenantan villages, Tapung Subdistrict, Kampar Regency, Riau Province. The villages were selected purposively because oil palm was an important livelihood. The reference population comprised 188,694 oil palm-farming households in Kampar Regency. Slovin's formula with a 7% tolerance yielded approximately 203. Without a complete village sampling frame, accessible farmers who actively managed oil palm farms were recruited by convenience sampling. Of 214 farmers interviewed to allow for incomplete questionnaires, 11 incomplete records were excluded, leaving 203 cases. The non-probability design limited statistical generalisation beyond the analysed sample.

Structured interviews used indicators adapted from studies of advisory delivery, institutional support and adaptive capacity (Maguire-Rajpaul et al., 2020; Dosso et al., 2023; Manevska-Tasevska et al., 2021). The questionnaire was pilot-tested with 15 oil palm farmers from neighbouring villages who were excluded from the main sample. The pilot assessed clarity, wording, response suitability and contextual relevance; ambiguous items were revised before enumerator training. Items used four-point scales from 1 (very low/never) to 4 (very high/always); education was coded 1–5 and monthly income in rupiah. Fourteen respondents did not report income. The missing-data mechanism was not formally tested; median imputation was used pragmatically because income was right-skewed.

Adaptive capacity was reflective, with six indicators covering technical, business, networking and digital-information responses. Extension methods combined information accessibility, dialogue and participation. Household resources combined education as human capital for interpreting information and income as financial capacity for funding adjustments; institutional support combined company and government support. Of 22 initial indicators, nine were removed when weights were non-significant and loadings below 0.50, or over 85% of responses occupied one category. Conceptual coverage was re-checked, leaving 13 indicators.

PLS-SEM was estimated in SmartPLS 4 (Ringle et al., 2024) using path weighting and 5,000 two-tailed percentile-bootstrap resamples, with bias-corrected intervals as sensitivity checks (Hair et al., 2022). For full-collinearity assessment, each construct was regressed on all remaining constructs in turn; all VIFs were below 3.3 and were evaluated separately from routine inner-model VIFs (Kock, 2015). PLSpredict (Shmueli et al., 2019) and CVPAT (Liengaard et al., 2021) used 10 folds and 10 repetitions.

RESULTS

Measurement quality

Adaptive capacity met the requirements for internal consistency and convergent validity. Cronbach's alpha was 0.803, rho A was 0.827, composite reliability was 0.859 and average variance extracted was 0.507. All six loadings were positive and significant. Three loadings fell below 0.708. They were retained because their removal would not have raised composite reliability or average variance extracted, both of which already met their thresholds, and because they carried distinct business capacity content (Hair et al., 2022). Indicator VIF values ranged from 1.298 to 1.875, indicating no critical collinearity (Table 1).

The formative composites also satisfied the assessment criteria. All formative indicators had VIF values below 1.13.

Table 1. Reflective measurement of adaptive capacity

Indicator	Loading	t-value	p-value	VIF
Farm-scale development	0.615	12.563	<0.001	1.334
Livelihood diversification	0.591	9.001	<0.001	1.298
Digital information use	0.707	16.043	<0.001	1.479
External cooperation	0.734	22.124	<0.001	1.650
Manual weed management	0.780	23.007	<0.001	1.875
Refugia-based pest control	0.816	33.545	<0.001	1.797

Source: Primary survey (2024), SmartPLS 4 output. *Note:* VIF=variance inflation factor; AVE=average variance extracted. *Reliability:* Cronbach's alpha=0.803; rho_A=0.827; composite reliability=0.859; AVE=0.507; n=203. Refugia-based pest control refers to flowering border plantings that shelter the natural enemies of pests.

Information accessibility and dialogical communication made significant relative contributions to extension methods. Participation-building had a non-significant weight but a significant absolute loading of 0.590 and was retained to preserve the participatory component. Income dominated household resources; education had a weak relative contribution but a significant absolute loading and was retained for conceptual coverage. Both company and government support contributed significantly to institutional support (Table 2).

Structural relationships and predictive validity

The predictors jointly explained 37.3% of adaptive-capacity variance (adjusted R^2=0.364; Table 3). Household resources had the largest coefficient and a medium effect size. Extension methods had a positive coefficient but negligible effect size (f^2=0.017). H1 and H2 were supported by p-values and both confidence-interval procedures. Institutional support was positive and met the pre-specified percentile-bootstrap criterion for H3, but its bias-corrected lower bound marginally included zero; H3 is therefore reported as inconclusive. Routine inner-model VIF values of 1.033 to 1.370 indicated no critical predictor collinearity. Separately, full-collinearity VIF values below 3.3 provided no strong indication of common method bias. The standardised root mean square residual (SRMR) was 0.067. Three robustness checks were run. Entering household income and formal education as separate single-item predictors left income strongly significant (β=0.483; p<0.001) and education not (β=0.022; p=0.764), with explained variance unchanged at 37.4%. Removing the two agronomic indicators from adaptive capacity strengthened extension methods (β=0.143; p=0.015) but left institutional support non-significant (β=0.096; p=0.225) and weakened internal consistency (alpha=0.676). Removing digital information use held extension methods steady (β=0.115; p=0.014) and made institutional support significant under both interval procedures (β=0.189; p=0.009). The extension and income relationships hold throughout; the institutional-support path moves with the specification.

All six adaptive-capacity indicators had Q^2predict values above zero. PLS-SEM produced lower root mean squared error (RMSE)

Table 2. Formative composite assessment

Construct	Indicator	Weight	p(weight)	Loading	p(loading)	VIF
Extension methods	Information accessibility	0.563	0.009	0.674	<0.001	1.026
	Dialogical communication	0.575	0.023	0.736	<0.001	1.104
	Participation-building	0.334	0.233	0.590	0.007	1.116
Household resources	Formal education	0.073	0.549	0.395	<0.001	1.123
	Household income	0.974	<0.001	0.998	<0.001	1.123
Institutional support	Private-company support	0.799	<0.001	0.883	<0.001	1.032
	Government support	0.476	0.005	0.617	<0.001	1.032

Source: Primary survey (2024), SmartPLS 4 bootstrap output. *Note:* VIF=variance inflation factor. Non-significant weights were retained only when their absolute loadings were significant and conceptual coverage would otherwise be reduced. Of the nine indicators removed during specification, three belonged to extension methods (material relevance, practical-material clarity, multi-party communication), two to institutional support (farmer-group support, university support) and four to the resource construct (non-formal training, farming experience, farmer-group participation, age). Near-uniform response shares were 94.1% for farmer group membership and 86.2% for training attendance; the removal rule is given in the methodology.

Table 3. Structural model for adaptive capacity

Hyp.	Relationship	β	t	p	Percentile 95% CI	BCa 95% CI	f^2
H1	Extension methods → Adaptive capacity	0.106	2.417	0.016	[0.026, 0.198]	[0.016, 0.188]	0.017
H2	Household resources → Adaptive capacity	0.492	6.480	<0.001	[0.340, 0.635]	[0.329, 0.626]	0.282
H3	Institutional support → Adaptive capacity	0.151	2.151	0.032	[0.020, 0.297]	[–0.0004, 0.277]	0.027

Source: Primary survey (2024), SmartPLS 4 bootstrap output. *Note:* Hypothesis decisions used the two-tailed percentile interval; BCa=bias-corrected and accelerated confidence interval. H3 met the percentile criterion but is reported as inconclusive because the BCa interval included zero. R^2=0.373; adjusted R^2=0.364; SRMR=standardised root mean square residual=0.067; n=203.

Table 4. Out-of-sample prediction of adaptive capacity

Indicator	Q^2predict	PLS RMSE	LM RMSE	PLS MAE	LM MAE	Lower error
Farm-scale development	0.121	0.510	0.516	0.358	0.359	PLS
Livelihood diversification	0.065	0.737	0.742	0.567	0.572	PLS
Digital information use	0.144	0.523	0.528	0.425	0.434	PLS
External cooperation	0.186	0.486	0.488	0.378	0.387	PLS
Manual weed management	0.183	0.496	0.491	0.398	0.396	LM
Refugia-based pest control	0.299	0.509	0.505	0.389	0.366	LM

Source: Primary survey (2024), SmartPLS 4 PLSpredict output. *Note:* PLS=partial least squares; LM=linear model; RMSE=root mean squared error; MAE=mean absolute error; Q^2predict=predictive relevance; CVPAT=cross-validated predictive ability test. Construct Q^2predict=0.332. CVPAT: PLS vs indicator average, loss difference=–0.057, $p<0.001$; PLS vs LM, difference=–0.002, $p=0.685$.

and mean absolute error (MAE) than the linear-model benchmark for four indicators, indicating medium predictive power. At construct level, Q^2predict was 0.332 (Table 4). CVPAT showed significantly lower prediction loss than the indicator-average benchmark, whereas the small advantage over the linear model was not statistically significant.

DISCUSSION

Household resources show the strongest association with adaptive capacity, and the formative weights place almost all of that association on household income. Income lets farmers absorb adjustment costs and carry short-term risk. Education helps them read new information but does not supply the same financial room to act on it. The construct is therefore best read as a measure of household income. This reading fits evidence that education, income and information use shape adaptation among farmers (Maguire-Rajpaul et al., 2020; Atube et al., 2021; Yadav and Ghosh, 2023; Sthitaprajna & Shasani, 2026). The programme implication is differentiation: farmers with little liquidity need practical, low-cost recommendations and a route to finance.

Extension methods have a positive but small effect. Accessibility and dialogue carry the strongest relative weights, and participation keeps a substantial absolute loading. Extension therefore works through exchange between adviser and farmer. Accessible advice cuts the cost of searching for information, and dialogue ties technical content to the conditions of a particular farm. Participation then lets farmers try a recommendation and adjust it. Osumba et al. (2021); Dosso et al. (2023) and Maurya et al. (2026) report the same mechanisms where participatory approaches and digital advisory systems are in place. Extension operates on farmers' decision capacity, and the small effect size ($f^2=0.017$) reflects that limit: farmers who decide to adjust can act only within the resources at hand. Extension packages work best when accessible, dialogical communication comes with recommendations farmers can afford to follow. Removing the agronomic practice indicators raises that coefficient, locating extension's contribution in the informational, networking and business dimensions of adaptive capacity.

Institutional support is formed by company and government contributions, with company support carrying the greater relative weight. Sitting close to the farm in the value chain, companies pass technical advice and market information to farmers through the commercial relationship. Government support carries a broader mandate and reaches any single commodity less intensively. These weights describe contribution to the composite and imply no ranking of institutional performance. H3 is inconclusive, so institutional support is best treated as a plausible enabling factor awaiting a better-powered test. Most respondents farmed independently, only 22.2% holding a company scheme contract, so company support here reflects advisory and market contact reaching farmers outside contractual plasma arrangements. The two roles should therefore be coordinated: companies can supply specialised, value-chain-linked assistance, while public agencies stay responsible for minimum service standards, the neutrality of advice, and farmers outside company schemes (Kangogo et al., 2020; Ma & Rahut, 2024; Shitu et al., 2026).

The model combines moderate explanatory power with positive out-of-sample relevance, although CVPAT showed no significant advantage over the linear benchmark, so the predictive claim is a modest one. Communication quality operates within the limits set by farmers' material resources and the institutions they can reach. Five limits qualify these results. The cross-sectional design cannot establish causal direction, and reverse causation is most plausible on the income path. Purposive site selection and convenience recruitment prevent statistical generalisation to all oil palm farmers in Kampar Regency. The household-resource composite is dominated by income. Two adaptive-capacity indicators record what farmers do, while the construct is defined as what they are able to do, and manual weeding may partly reflect limited purchasing power for herbicide among independent growers (Sibhatu et al., 2025). The missing-data mechanism for 14 imputed income values was not formally tested, and the pilot test involved only 15 farmers from neighbouring villages. Adding access to finance and farm assets, and following farmers over time, would address the causal direction and the narrow resource measure.

CONCLUSION

Accessible, dialogical and participatory agricultural extension contributes to oil palm farmers' adaptive capacity, though it explains less of that capacity than household income does. Company and government support may provide an enabling institutional foundation, but that relationship shifts with how adaptive capacity is measured and cannot yet be treated as established. Affordability should be considered when extension recommendations are designed, and whether screening for it improves uptake is a question for future intervention studies. Whether linking advisory contact to credit and market information raises adaptive capacity was not tested here and merits direct evaluation. Because extension relates more closely to the informational, networking and business dimensions of

adaptive capacity than to specific field practices, public and company services should each take a different part of that work.

DECLARATIONS

Research ethics statement: Participation in this study was voluntary. All respondents received written and verbal information about the purpose of the study, the voluntary nature of participation and their right to withdraw at any stage, and informed consent was obtained from every respondent before the interview. No identifying information was recorded, respondent identities were anonymised throughout data processing and reporting, and the data were used exclusively for the research purposes described. The study was carried out under IPB University research Decree No. 483/IT3.D10/PT.01.03/P/B/2023. The signed IJEE Research Ethics Statement, in the prescribed format, accompanies this submission.

Consent for publication: Not applicable; no identifiable personal information is reported.

Conflict of interest: The authors declare that they have no conflict of interest. The research was conducted in the absence of any commercial, financial or personal relationships that could be construed as influencing the design, implementation, analysis, interpretation or reporting of the study.

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Research Article

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Income-Generating Activities and Multidimensional Empowerment of Rural Women in Watrap Block, Tamil Nadu

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HIGHLIGHTS

- Income-generating activities increased overall empowerment by 16.47 percentage points among rural women.
- Psychological empowerment improved most, whereas political empowerment remained comparatively limited.
- Human-rights awareness and technology-related decisions recorded the strongest indicator-level gains.
- Education and landholding were the strongest socioeconomic correlates of overall empowerment.

ARTICLE INFO

Keywords: Gender equity, Livelihood diversification, Market participation, Rural entrepreneurship, Self-help institutions.

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ABSTRACT

The study was conducted during 2026 in three villages of Watrap block, Virudhunagar district, Tamil Nadu, to assess multidimensional empowerment among rural women participating in income-generating activities and examine its socioeconomic associations. A descriptive-correlational, cross-sectional design with retrospective pre-post assessment was adopted. Approximately 5% of eligible women were sampled from village-specific lists, yielding 130 respondents from Ammapatti, Kunnur and Vadukapatti; the unequal allocation reflected differences in village sampling-frame sizes. Empowerment was measured using a 30-item, five-dimensional schedule covering psychological, decision-making, social, economic and political domains, adapted with minor modifications from an existing empowerment scale and administered through a pre-tested interview schedule. Retrospectively reported overall empowerment increased by 16.47 percentage points after participation. Psychological empowerment recorded the largest gain (20.46), followed by social (18.08), economic (15.29), decision-making (15.00) and political empowerment (13.54). The largest indicator-level gains were observed in human-rights awareness (30.77), technology-adoption decisions (26.92) and access to modern technology (25.39). Education ($r=0.479$) and landholding ($r=0.532$) were positively associated with overall empowerment ($p<0.01$). Given the retrospective design, absence of a comparison group and restricted study area, findings represent perceived changes and associations rather than causal effects.

INTRODUCTION

Women's empowerment reflects the expansion of agency—the capacity to define goals, make meaningful choices and act upon them. Recent frameworks distinguish intrinsic agency, including confidence and autonomous motivation, from instrumental agency expressed through decisions and control of resources, and collective agency exercised through groups and public institutions (Donald et al., 2020; Malapit et al., 2019). In agriculture, empowerment is therefore broader than employment or income. It includes participation in production and household decisions, access to productive resources and services, control over income, leadership, mobility and influence within community institutions (Alkire et al., 2013). Because the meaning and quality of decision-making vary

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across social settings, multidimensional assessment is preferable to treating a single economic indicator as sufficient evidence of empowerment (Seymour & Peterman, 2018; Yount et al., 2019). Rural women contribute substantially to crop and livestock production, processing, wage employment and household enterprises, but their work frequently coexists with unequal ownership of land, restricted mobility, weak market access and a disproportionate burden of unpaid care. The Food and Agriculture Organization (2023) reported that gender inequalities in agrifood systems constrain women's productivity, income, resilience and institutional voice. Economic opportunities can support agency, but gains depend on whether women control earnings and productive assets and can influence strategic household decisions. Accordingly, higher household income alone may not translate into empowerment when prevailing norms determine who manages resources and represents the household in markets or public institutions (Duflo, 2012). Self-help groups, microenterprises and livelihood collectives have become important channels for rural women to obtain credit, acquire skills, build networks and enter income-generating activities. A systematic review concluded that women's economic self-help programmes generally improved economic and political empowerment, although effects varied according to programme design and local context (Brody et al., 2017; Gupta, et al., 2023). Indian evidence similarly showed that group-based livelihood interventions enhanced savings, enterprise participation and social interaction, but did not automatically transfer control over resources or decisions (Deininger & Liu, 2013; Pertin et al., 2025). Recent extension studies documented empowerment gains among rural women entrepreneurs, fisherwomen and women engaged in aquaculture, while also identifying persistent limitations in market authority, institutional participation and control over income (Das et al., 2023; Kumari et al., 2025a; Rajkumar et al., 2024). Agricultural extension can convert livelihood participation into sustained agency by combining technical instruction with functional literacy, enterprise planning, financial management, market negotiation and leadership development. Gender-sensitive and participatory extension improves the responsiveness of services to women's needs (Nain & Kumar 2010; Amanah et al., 2026; Singh et al., 2022, 2023). Training programmes are more useful when curricula are locally relevant, experiential and connected with follow-up support (Kumari et al., 2025b). Digital platforms may widen access to advice and services (Maurya et al., 2026), while meaningful empowerment also requires confidence and literacy to use information independently (Kumari et al., 2026: Kujur et al., 2026a). Multidimensional tools are important for assessing entrepreneurial capabilities and outcomes among rural women (Tripathy et al., 2024).

METHODOLOGY

The study was conducted during 2026 in Virudhunagar district of Tamil Nadu to examine multidimensional empowerment among rural women participating in income-generating activities (IGAs). Virudhunagar district and Watrap block were purposively selected because of substantial participation of rural women in livelihood enterprises. Watrap block comprised 27 villages, of which Ammapatti, Kunnur and Vadukapatti were selected through simple random sampling. The sampling frame included 2,762 women engaged in IGAs. An approximately 5% sampling fraction was applied to the eligible women in each selected village, resulting in 15 respondents from Ammapatti, 102 from Kunnur and 13 from Vadukapatti, giving a total sample of 130 respondents. The unequal distribution reflected differences in the number of eligible women across the three village sampling frames rather than deliberate oversampling. The sample size followed the operational design of the parent M.Sc. study and was not derived from a prospective statistical power calculation. A descriptive-correlational cross-sectional design with a retrospective pre-post assessment was adopted. During a single interview, respondents reported their current empowerment status and retrospectively assessed their status before participation in IGAs. Consequently, the design measures perceived change and does not establish causal effects because no comparison group, random assignment or prospective baseline assessment was available. Recall bias, response-shift effects and social-desirability bias were therefore considered while interpreting the findings. Primary data were collected through personal interviews using a structured and pre-tested interview schedule, supplemented with relevant district- and block-level secondary records. Women's empowerment was measured using a 30-item schedule adapted with slight modifications from an existing empowerment scale of Tayde and Chole, 2007. The instrument covered psychological (5 items), decision-making (4), social (8), economic (8) and political (5) empowerment. Dimension-wise empowerment indices were calculated as: (obtained score/maximum obtainable score) × 100. The available study records did not report a sample-specific internal-consistency coefficient, test-retest reliability or separate psychometric validation of the modified instrument; this was therefore treated as a measurement limitation. Data were analysed using frequency, percentage, mean and standard deviation. Pearson's product-moment correlation was used to examine bivariate associations between overall empowerment and 12 selected socioeconomic, psychological and communication characteristics. Because some predictors were categorical or ordinal, their coefficients were interpreted cautiously as exploratory associations rather than causal determinants. Statistical significance was assessed at the 5% and 1% probability levels.

RESULTS

The findings demonstrated a broad positive shift in women's empowerment after participation in income-generating activities. The composite increase across the five dimensions was 16.47 percentage points, indicating that enterprise engagement was associated with changes extending beyond earnings. However, the magnitude of improvement varied considerably across the five dimensions. Psychological empowerment recorded the largest gain of 20.46 percentage points, increasing from 34.30 before participation to 54.76 after participation. Social empowerment increased by 18.08 points, from 45.57 to 63.65, followed by economic empowerment (15.29 points; 37.78 to 53.07) and decision-making empowerment (15.00 points; 36.72 to 51.72). Political empowerment showed the smallest absolute gain of 13.54 points and remained the lowest-scoring domain after participation, increasing from 8.30 to 21.84 (Figure 1).

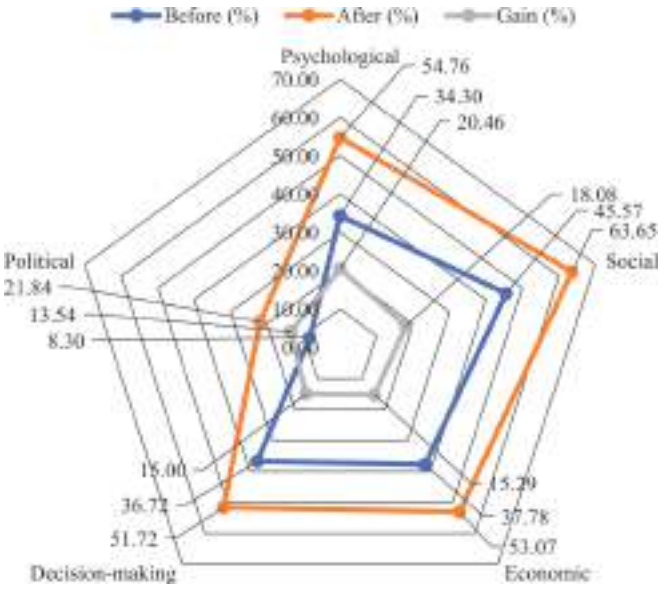
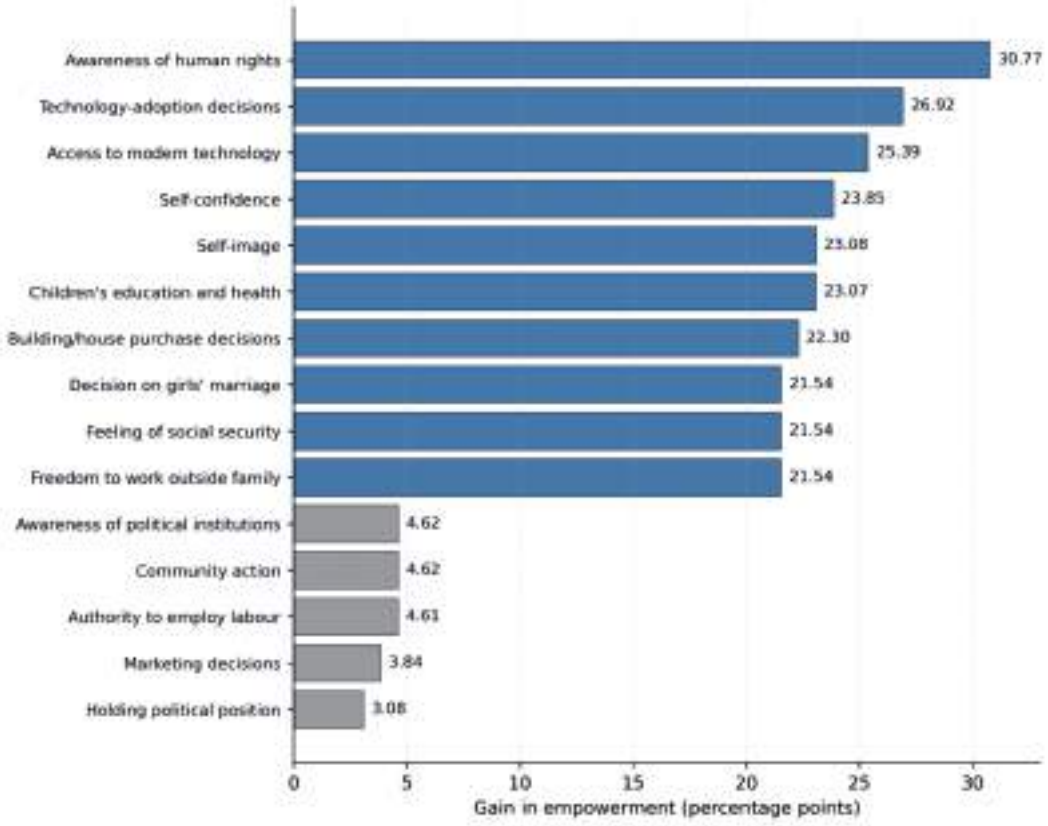


Figure 1. Empowerment scores before and after income-generating activities

The dimension-wise pattern shown in Figure 1 was further examined at the indicator level to identify the specific areas contributing most and least to the observed gains (Figure 2). Within psychological empowerment, self-confidence showed the largest gain of 23.85 percentage points, followed by self-image (23.08 points) and self-reliance (21.54 points). Career ambition increased by 17.69 points, while courage improved by 16.15 points. These findings indicate that participation in income-generating activities was particularly associated with improvements in women's perceived competence, self-worth and independence. Decision-making empowerment showed greater variation across individual indicators. Participation in decisions concerning children's education and health recorded a gain of 23.07 percentage points, representing the highest improvement within this dimension. Independent decisions related to personal and economic activities increased by 15.39 points, while participation in livelihood and enterprise decisions increased by 14.61 points. In contrast, participation in household expenditure decisions increased by only 6.92 points. Thus, the gains were more pronounced in welfare-oriented and livelihood-related decisions than in routine household financial decisions. A similar variation was observed in the social and economic dimensions. Within social empowerment, access to modern technology recorded the largest gain of 25.39 percentage points. Freedom to work outside the family, feeling of social security, and participation in decisions regarding girls' marriage each increased by 21.54 points. Self-education improved by 20.00 points, whereas participation in community action increased by only 4.62 points. Economic empowerment showed stronger gains in technology- and asset-related decisions than in market and labour control. Participation in decisions concerning adoption of modern technology in the home or enterprise increased by 26.92 percentage points, followed by decisions regarding purchase of a building or house (22.30 points), operation of a personal bank account (18.46 points), freedom to select a job (17.69 points), and personal savings in fixed deposits (16.92 points). In contrast, authority to employ labourers increased by only 4.61 points and participation in marketing decisions by 3.84 points. Political empowerment showed the greatest contrast between awareness-related and participation-

Figure 2. Selected highest and lowest indicator-level empowerment gains



related indicators. Awareness of human rights increased by 30.77 percentage points, representing the largest indicator-level gain observed in the study. Awareness of legislation for women and freedom to participate in active politics each increased by 14.61 points. However, awareness of political institutions increased by only 4.62 points, while holding a political position improved by merely 3.08 points. Overall, Figure 2 indicates that the strongest indicator-level improvements were concentrated in human-rights awareness, technology-related decision-making, access to modern technology and psychological attributes, whereas marketing authority, community action, labour supervision and formal political representation showed comparatively limited gains.

Bivariate correlation analysis identified education and landholding as the strongest correlates of overall empowerment. Education had a positive and highly significant relationship with empowerment ($r=0.479$, $p<0.01$). Educated women are generally better positioned to understand financial records, use information, interact with institutions and assess enterprise opportunities. Education may also strengthen confidence in communication and awareness of rights. Landholding showed the highest coefficient ($r=0.532$, $p<0.01$), suggesting that control of or access to productive assets substantially conditions women's ability to benefit from income-generating activities. Land can provide a production base, collateral, status and greater influence in household economic decisions. Family occupation ($r=0.185$, $p<0.05$) and economic motivation ($r=0.175$, $p<0.05$) were positively and significantly related to empowerment. Although these coefficients were modest, they indicate that livelihood context and the desire for economic advancement supported women's agency. Families already connected with agriculture, trade or enterprise may provide knowledge, networks and acceptance of productive roles. Economic motivation may encourage women to seek information, persist through constraints and reinvest in their activities. Age ($r=0.139$), marital status ($r=0.086$), family size ($r=0.117$), annual income ($r=0.048$), extension participation ($r=0.156$), training participation ($r=0.081$), social participation ($r=0.159$) and mass-media exposure ($r=0.159$) were positive but statistically non-significant. The non-significance of annual income reinforces the multidimensional nature of empowerment: a higher household income does not necessarily imply that women control it. Similarly, training and extension contact may have varied in duration, quality or relevance, limiting their measurable association with overall empowerment. The positive directions nevertheless suggest potential value that may become significant when services are more intensive, gender-responsive and linked to enterprise follow-up.

DISCUSSION

The study found higher retrospectively reported empowerment after IGA participation, with the largest difference in the psychological domain. This measured pattern is consistent with studies reporting positive associations between livelihood engagement and women's autonomy, social interaction and economic well-being (Rajkumar et al., 2024; Kumari et al., 2025a) and with evidence that self-help programmes can operate through financial familiarity, peer solidarity and wider social networks (Brody et al., 2017). One possible interpretation is that regular participation in productive activity may strengthen perceived competence and self-recognition before changes become visible in formal institutional roles. However, the present study did not directly measure the mechanisms producing these differences, and its retrospective design cannot demonstrate temporal or causal pathways.

The observed economic pattern also distinguished access from control. Women reported relatively larger gains in technology adoption, banking, savings and selected asset-related decisions, but much smaller gains in marketing and labour-employment decisions. This descriptive contrast suggests that participation in economic activity can coexist with limited authority over commercial decisions. Similar studies have noted that group-based livelihood

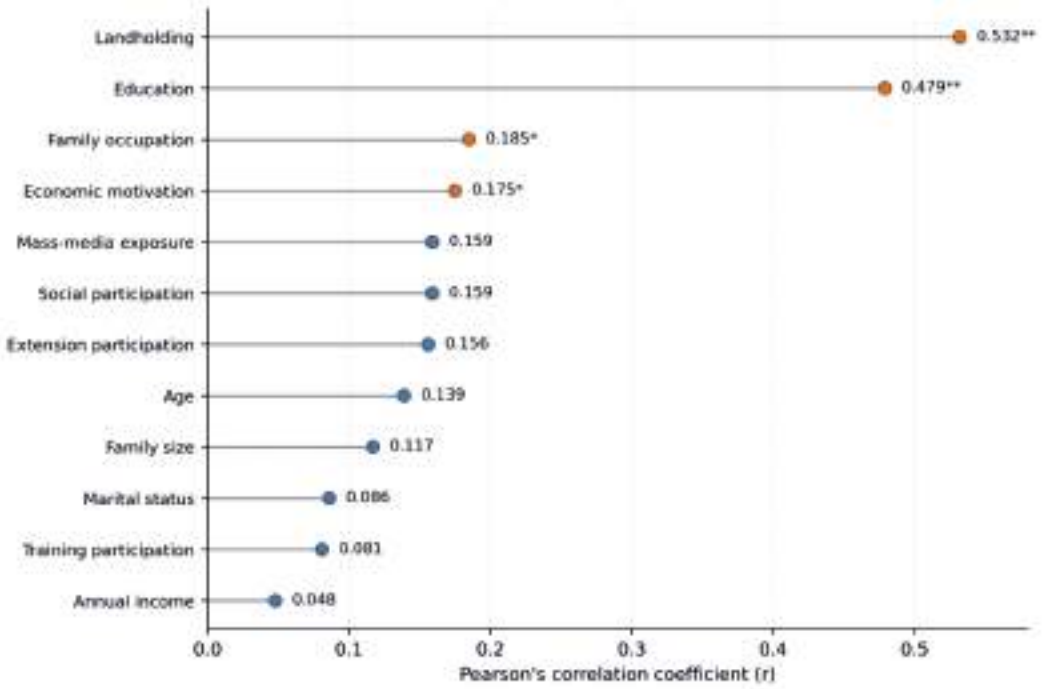


Figure 3. Magnitude and significance of socioeconomic correlates ** Significant at $p<0.01$; * significant at $p<0.05$; NS = non-significant.

interventions may improve income and reduce vulnerability without automatically redistributing control over productive resources or sales proceeds (Deininger & Liu, 2013). Agency frameworks likewise distinguish resources, decision-making and collective influence because progress in one domain does not necessarily imply progress in another (Malapit et al., 2019; Yount et al., 2019). The present data did not directly measure who negotiated prices, controlled sales proceeds or decided reinvestment; these mechanisms are therefore plausible explanations rather than study findings and should be examined directly in future research.

Political empowerment displayed a similarly uneven pattern: human-rights awareness showed a large reported gain, whereas awareness of political institutions and formal political representation changed comparatively little. A plausible explanation is that awareness can develop through information exchange and group interaction, while formal leadership may additionally depend on institutional opportunities, networks, time and household support. These factors were not directly measured in the present study and should not be inferred as established causes. Research on rural and tribal women nevertheless indicates that education, resource access, economic inclusion and community participation can interact with institutional barriers (Kujur et al., 2026b). Gender-responsive extension may therefore be examined in future intervention studies as a mechanism for linking women's groups with Gram Sabhas, Panchayati Raj Institutions and producer organisations (Amanah et al., 2026).

Landholding and education had the largest positive bivariate coefficients with overall empowerment. These findings indicate association within the study sample, not independent effects. Education may plausibly support functional literacy, communication, record keeping and use of technical, financial and legal information, whereas landholding can represent access to productive resources and household economic security. The Food and Agriculture Organization (2023) similarly identifies unequal resource rights as an important constraint on women in agrifood systems. The weak bivariate association with annual income is also consistent with the conceptual distinction between household economic resources and women's own agency (Donald et al., 2020; Duflo, 2012). Because the present analysis was unadjusted, potential confounding among education, landholding, income and other household characteristics cannot be excluded. The coded family-occupation coefficient is particularly sensitive to the treatment of nominal categories and is therefore not interpreted as evidence of an independent socioeconomic effect.

The non-significant bivariate coefficients for training and extension participation should not be interpreted as evidence that advisory services are ineffective. The study measured participation but did not quantify the duration, content, intensity, quality or follow-up of those services. Thus, explanations based on programme quality remain hypotheses rather than findings. Prior work indicates that locally relevant, experiential training and participatory extension can strengthen learning and enterprise planning (Singh et al., 2022, 2023), while digital platforms may expand access when users possess the literacy and autonomy needed to act on information (Godara et al., 2024; Kumari et al., 2026; Maurya et al., 2026). Future studies should use prospective longitudinal or matched comparison designs, apply analytical methods appropriate to the measurement level of each predictor, report psychometric evidence for the empowerment scale, and examine differences by enterprise type, duration and scale.

CONCLUSION

Among the 130 women sampled from Ammapatti, Kunnur and Vadukapatti villages of Watrap block, retrospectively reported empowerment was higher after participation in income-generating activities, but the pattern was uneven across dimensions. Psychological and social domains showed larger reported gains than political participation and strategic commercial control. Human-rights awareness, technology-related decisions, self-confidence and access to modern technology showed the largest indicator-level differences, whereas marketing authority, labour supervision, community action and formal political representation showed limited change. Education and landholding had the strongest positive bivariate associations with overall empowerment, but these associations should not be interpreted as causal determinants. For similar rural livelihood settings, extension and enterprise programmes may usefully integrate functional literacy, access to productive assets, market and financial skills, leadership development and institutional participation. Confirmation of these patterns requires prospective studies with validated measurement, suitable comparison groups and analytical methods matched to variable type.

DECLARATIONS

Ethical approval and consent to participate: The study was conducted in accordance with ethical principles applicable to research involving human participants. Before data collection, all respondents were informed about the purpose of the study, the voluntary nature of participation, confidentiality of the information provided and their right to withdraw at any stage. Informed consent was obtained from all participants prior to the personal interviews. The study was approved by Department of Extension Education, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482004, Madhya Pradesh, India

Data availability statement: The data supporting the findings of this study may be made available by the corresponding author upon reasonable request.

Conflicts of interest statement: The authors declare that they have no conflict of interest.

Authors' contribution: V. Pavithra contributed to investigation, data collection, data curation, analysis and preparation of the original draft. Sonam Agarwal contributed to conceptualization, methodology, supervision, validation and review and editing of the manuscript. Seema Naberia contributed to methodology, supervision, validation and review and editing. Chandrika Sharma contributed to investigation, data curation and review and editing. Sanjana Srivastava contributed to data curation, validation and review and editing. Prashish Singh contributed to formal analysis, interpretation of findings, visualization and review and editing.

Consent for publication: All authors read and approved the final version of the manuscript and consented to its publication.

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Standardization of a Scale to Assess the Impact of Wildlife-Induced Crop Damage among Tribal Farmers

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HIGHLIGHTS

- Developed and standardised a 17-item scale for assessing the impact of wildlife- induced crop damage among tribal farmers.
- The scale demonstrated high reliability (0.914) with strong internal consistency.
- Four dimensions, namely, economic, nutritional, psychological and institutional impacts, were identified from exploratory factor analysis.

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Keywords: Human–wildlife conflict, Tribal farmers, Extension interventions, Crop damage, Scale standardization, Psychometric validation.

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ABSTRACT

The increasing incidence of animal attacks on crops has emerged as a major challenge for tribal farmers, necessitating a systematic evaluation of perceptions regarding their impact. The study, conducted in 2025, developed and validated a standardised Likert-type scale to measure the impact of wildlife crop damage among the tribal farmers. An initial set of 44 items was considered on the basis of literature review and expert consultation. Fourteen judges evaluated the statements' relevancy, and based on predefined criteria (MRS ≥ 4.00, RP ≥80 per cent, RW ≥0.80), 28 statements were retained. These statements were administered to 150 tribal farmers chosen from Attappady. Item analyses were undertaken using the critical ratio (t-test), and reliability analyses resulted in the elimination of 11 items, yielding a final scale comprising 17 statements. The scale confirmed a high internal consistency with a Cronbach's alpha value of 0.914. Exploratory factor analysis confirmed the adequacy of the data (KMO + 0.795) and identified four components – nutritional, economic, psychological and institutional impacts – which explained 78.95 percent of total variance. The developed scale was found to be a reliable and valid instrument for examining the multidimensional impact of wildlife-induced crop damage among the tribal farmers.

INTRODUCTION

Human-wildlife conflict has emerged as an important barrier in the agrarian context, especially among the tribal farmers who are living in the forest-adjacent region. In recent years, this issue has been increasing in various parts of India, mainly due to land-use changes, habitat destruction and declining availability of natural forage (Madhusudan, 2003; Rao et al., 2002). The crop loss resulting from attacks by wild animals such as elephants, monkeys and pigs adversely affects agricultural productivity and creates multidimensional challenges, including economic vulnerability, food insecurity and psychological stress among the tribal farming households (Rathi et al., 2021).

Existing literature states that wildlife-induced damage to crops reduces the farm income and threatens the long-term sustainability of smallholder agriculture. In many tribal regions, losses caused by wildlife often surpass those resulting from climate variability and pest infection (Meena et al., 2022). These difficulties were further complicated due to inadequate institutional support, delay in the

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compensation, and lack of effective preventive measures, including fencing. Although previous studies have documented the economic loss or socio-psychological consequences of wildlife-induced crop damage, most have analysed these dimensions independently, without integrating them into a comprehensive analytical framework. Given the nature of the problem is inherently multidimensional, a systematic approach is required to measure its varied impact. Tribal farmers who depend on agriculture for both income and household consumption face compound risk, with the loss in the crop directly affecting food availability and livelihood continuity. Despite its relevance, there is a lack of standardised and validated measurement tools to assess the overall impact on crop cultivation due to animal attacks from the perspectives of tribal farmers.

Against this background, the present study explores, how can the multifaceted effects of wildlife-induced crop damage among the tribal farmers be effectively conceptualised and assessed by employing a valid and reliable scale? Accordingly, the study conceptualises the effect of wildlife-induced crop damage among tribal farmers as a latent multidimensional construct indicating the perceived adverse consequences experienced by tribal farming households because of the recurrent wildlife incursions into their farming area. Unlike direct measures of crop loss that quantify the economic loss, the construct captures farmers' perceptions of how repeated wildlife-induced crop damage impacts their livelihoods, household well-being, and interactions with institutional support systems. The construct is theoretically bounded to the perceived consequences of wildlife-induced crop damage on farming households and excludes ecological aspects of wildlife conservation, animal behaviour, or attitudes towards wildlife protection. Further, the study intends to develop the scale items that are culturally appropriate and validate their content through expert assessment and pilot testing. Even though the suggested instrument does not directly serve the needs as an evaluation tool, it is intended to facilitate future assessments by producing systematic and comparable evidence (DeVellis, 2012). Since these impacts are likely to be interrelated rather than directly observable, the construct is treated as multidimensional, and its underlying dimensions are identified through Exploratory Factor Analysis (EFA) during the scale-development process.

METHODOLOGY

The research was undertaken to develop and standardise a scale for measuring the perceived impact of wildlife-induced crop loss among the tribal farmers. An exploratory research design was adopted, and the Likert summated rating method (Likert, 1932) was employed for constructing the scale, as it is widely employed for measuring the individual difference in perceptions and attitudes. The procedures suggested by Reddy et al. (2023) and Shukla et al. (2026) were adopted for scale development.

Initially, 44 statements were identified representing various dimensions of animal attacks on crop based on the literature review (Gatew & Azadge, 2025; Rathi et al., 2021; Thakur et al., 2022; Galley & Anthony, 2024) and consultation with experts in agriculture. These statements were subjected to content validation by a panel of 14 judges who assessed the relevance and clarity. Microsoft Excel was used for analysing each statement.

Following established procedures in agricultural extension scale development studies (Shanila & Helan, 2025; Shukla et al., 2026; Pathak et al., 2026), statements with MRS $\geq$4.00, RP $\geq$80%, and RW $\geq$0.80 were retained for further examination. An MRS of 4.00 indicates that, on average, the expert panel rated the statement as 'Relevant' or 'Most Relevant', thereby suggesting adequate content validity. Similarly, an RP of at least 80% and an RW of 0.80 or above indicate a high degree of agreement among experts with regard to the relevance and appropriateness of the statements for measuring the construct.

The validated statements were administered to a total of 150 tribal farmers from the Attappady block of Kerala. The Attappady block of Palakkad district was purposively chosen, as it is one of the largest tribal settlements in Kerala and experiences frequent incidents of wildlife-induced crop damage due to its proximity to forest areas. The block comprises three panchayats, namely Agali, Sholayur, and Pudur, and all were included, as they represent the major tribal farming regions within the block. From each panchayat, 50 tribal farmers were selected using simple random sampling from the list of eligible farming households, resulting in a total sample of 150 respondents. The respondents included in the present study were required to satisfy the following criteria: (i) belong to a recognised tribal community, (ii) be actively engaged in crop cultivation, and (iii) have experienced wildlife-induced crop damage during recent cropping seasons.

The sample size exceeded the recommended minimum of five respondents per item for exploratory factor analysis; hence, it is considered to be adequate in general. The responses obtained from them were scored, ranging from 5 to 1, respectively. On the basis of procedures put forward by Edwards (1957), the item analysis was carried out. The respondents were organised in descending order on the basis of total scores, and the upper 25 per cent and lower 25 per cent were identified as high and low groups, respectively. The significant variations between the mean scores of these two groups for each statement were tested by applying an independent samples t-test. Further, Cronbach's alpha coefficient was employed to analyse the internal consistency of the scale. Sample adequacy was examined through Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity. Thus, the validity and reliability of the scale were confirmed through content validation, item analysis, internal consistency assessment and exploratory factor analysis. Principal component analysis with varimax rotation was applied to identify the underlying domains of the scale. Microsoft Excel 2019 for relevancy score estimation and for other statistical analyses were conducted using IBM SPSS Statistics, version 23.

Prior administrative permission for conducting the study was obtained from the Nodal Officer (Sub-Collector, Ottappalam), followed by approval from the Integrated Tribal Development Project (ITDP), Agali, to undertake the research among the tribal communities of Attappady. Prior informed consent was obtained from all respondents before the interviews, and participation in the study was entirely voluntary. The respondents were informed about the objectives of the study and assured that the information collected would be used solely for academic purposes.

RESULTS

The scale development process followed four main stages: relevancy testing, item analysis, reliability assessment and exploratory factor analysis. The results obtained in each stage are presented in the following section.

Relevancy test

Based on the 44 statements representing different dimensions of impact on crops due to animal attacks, they were subjected to the relevancy testing. These statements were examined by a panel of 14 experts from various fields such as economics, agricultural extension, and tribal economics. The judges were required to rate each of the statements on a five-point continuum ranging from Most Relevant to Not Relevant. The responses were then quantified, and the relevancy of each statement was computed by applying the following indices.

Relevancy weightage (RW)

$$RW = \frac{\{(MR*5) + (R*4) + (UR*3) + (LR*2) + (NR*1)\}}{\text{Maximum possible score}} \quad ...(1)$$

$$RP = \frac{\{(MR*5) + (R*4) + (UR*3) + (LR*2) + (NR*1)\}}{\text{Maximum possible score} * 100} \quad ...(2)$$

$$MRS = \frac{[(MR*5) + (R*4) + (UR*3) + (LR*2) + (NR*1)]}{\text{Number of Judges}} \quad ...(3)$$

Where, MR = Most Relevant; R = Relevant; UR = Undecided; LR = Less Relevant; NR = Not Relevant.

The maximum possible score was calculated as,

Maximum possible score = Number of judges x Maximum score = 14 x 5 = 70

The results are given in Table 1. Based on the predetermined criteria, 28 items were retained for subsequent item analysis. The MRS values of the retained statements range from 4.21 to 4.93, while the RP and RW values fall between 84.29 and 98.57 per cent and 0.84 and 0.99, respectively. The high MRS, RPM and RW values obtained for these statements indicate a strong level of agreement among the experts with respect to the relevance and appropriateness of the statements for measuring the perception of tribal farmers.

Item analysis

For evaluating the discriminating ability of the statements, item analysis was performed by employing the critical ratio method. On the basis of standardised procedures put forward by Edwards (1957), the respondents were divided into high and low groups, and the significance of the difference between these groups was tested by conducting an independent sample t-test.

Following the criterion proposed by Bird (1940), statements with t-values less than 1.75 (irrespective of negative signs) were taken into consideration to have a poor discriminating power and were excluded from the scale. Only those statements having a value more than 1.75 were included, as they effectively differentiated among the sample tribal farmers with high and low levels of perceived impact. Accordingly, four statements (statement numbers 11, 12, 23, and 27) were eliminated due to inadequate discrimination, while the remaining 24 statements scoring a t-value above 1.75 were retained for further refinement. Table 1 displays the 28 statements with MRS, RP and RW and their t-value.

Reliability analysis

The reliability of the scale was examined employing the Cronbach's alpha coefficient to determine the internal consistency of the items. Initially, the reliability was tested for the 24 statements which were retained after item analysis. Seven statements were

Table 1. Relevancy and item analysis of selected statements measuring the impact of animal attacks on crops among tribal farmers

Item No.	Statement	MRS	RP (%)	RW	t-value
1	The compensation provided for crop losses due to animal attacks is inadequate.	4.93	98.57	0.99	14.877
2	My income from farming has reduced significantly due to animal damage	4.86	97.14	0.97	26.717
3	Animal menace has discouraged investment in improved seeds or fertilizers.	4.86	97.14	0.97	4.442
4	I have abandoned or reduced cultivation in high-risk areas due to repeated attacks	4.71	94.29	0.94	6.384
5	Government agencies do not provide sufficient support to prevent crop damage caused by wild animals.	4.64	92.86	0.93	8.319
6	Have reduced the quantity of food available to my family	4.64	92.86	0.93	19.461
7	Repeated animal attacks have reduced my investment in farming.	4.57	91.43	0.91	9.679
8	Recurrent damage reduces the diversity of crops I can grow	4.50	90.00	0.90	13.908
9	Men and elderly members face added workload due to guarding or replanting damaged crops	4.43	88.57	0.89	13.011
10	Crop loss affects my household's nutritional intake and food variety	4.43	88.57	0.89	18.340
11	Repeated crop losses cause frustration and mental stress	4.36	87.14	0.87	13.231
12	I often feel anxious about possible animal attacks during the cropping season	4.36	87.14	0.87	10.310
13	Staying awake at night to guard fields causes fear and exhaustion	4.29	85.71	0.86	5.373
14	Crop destruction by animals forces my household to depend more on purchased food	4.21	84.29	0.84	6.148
15	Frequent animal attacks on crops lead my household to adopt less preferred or lower-quality foods.	4.93	98.57	0.99	10.689
16	Crop loss from animal attacks reduces the household's ability to store sufficient food for future consumption.	4.86	97.14	0.97	28.824
17	The community lacks a common platform to discuss and report wildlife damage	4.43	88.57	0.89	7.803

Note: MRS = Mean Relevancy Score; RP = Relevancy Percentage; RW = Relevancy Weightage.

identified as inconsistent on the basis of corrected item-total correlation and the Cronbach's alpha if item-deleted values, and these statements were subsequently eliminated from the scale. The reliability analysis was then repeated with the remaining 17 statements to ensure the consistency of the refined scale. The Cronbach's alpha value obtained for the final set of statements was 0.914, suggesting a high level of internal consistency across the statements (Nunnally, 1978). This suggests that the scale is reliable and appropriate for examining the effect of animal attacks on crops among the tribal farmers.

Scoring of the standardised scale

The final scale consists of 17 items, each item measured on a five-point continuum, having a total score ranging from 17 to 85, with a higher score indicating a greater perceived impact of wildlife-induced crop damage. The respondents were classified into low, medium, and high impact categories using the mean ± standard deviation method. Based on the observed mean score (70.50) and standard deviation (7.95), respondents scoring 62 or below were classified as having low perceived impact, those scoring 63–78 as having medium perceived impact, and those scoring 79 or above as having high perceived impact (Table 2). It was reported that 69.3 per cent of the respondents perceived a moderate impact, followed by 20.0 per cent and 10.7 per cent reporting low and high perceived impacts, respectively, indicating that wildlife-induced crop damage affected most tribal farmers to a moderate extent.

Table 2. Scoring Guidelines and Distribution of Respondents Based on the Standardized Scale

Impact Category	Total Score	Frequency	Percentage (%)
Low	≤ 62	30	20.0
Medium	63–78	104	69.3
High	≥ 79	16	10.7
Total	-	150	100.0

Source: Primary data, 2025

Exploratory factor analysis

Exploratory Factor Analysis (EFA) was undertaken on the final set of 17 statements for identifying the major dimensions of the construct. The Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were applied to confirm whether the data are suitable for factor analysis. Table 3 shows the results of the KMO and BTS results. The value of KMO was 0.795, confirming sample adequacy for factor analysis, while BTS was significant (χ^2 = 2655.905, $p < 0.001$), stating the existence of intercorrelations among the statements, and the correlation matrix was appropriate for the factor extraction.

Table 3. KMO and Bartlett's Result

KMO Measure of Sampling Adequacy.		.795
Bartlett's Test of Sphericity	Approx. Chi-Square	2655.905
	df	136
	Sig.	0.000

Principal Component Analysis (PCA) with Varimax rotation was employed for factor extraction. Based on the Kaiser criterion (eigenvalue > 1), four factors were extracted. These four factors together explained 78.95 per cent of the total variance, which exceeds the recommended threshold level of 60 per cent (Hair et al., 2010). The findings of total variance explained using PCA are given in Table 4.

Further, the scree plot (Figure 1) also supported the retention of four factors, as there was a clear point of inflection soon after the fourth component, indicating that additional factors contributed negligibly to the explained variance. The rotated component matrix revealed that all the included 17 statements had a factor loading greater than 0.50 on their respective components, indicating a well-defined factor structure. On the basis of the rotated component matrix, the 17 statements were grouped under four factors (Nutritional Impact, Economic Impact, Psychological Impact and Institutional Impact) according to their highest factor loading.

Table 4. Total variance explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.189	48.170	48.170	8.189	48.170	48.170	3.927	23.097	23.097
2	2.318	13.637	61.807	2.318	13.637	61.807	3.497	20.573	43.670
3	1.547	9.099	70.906	1.547	9.099	70.906	3.105	18.265	61.935
4	1.367	8.042	78.948	1.367	8.042	78.948	2.892	17.013	78.948
5	.798	4.693	83.641						
6	.693	4.078	87.719						
7	.432	2.543	90.262						
8	.353	2.077	92.339						
9	.305	1.795	94.134						
10	.283	1.666	95.800						
11	.209	1.229	97.030						
12	.150	.881	97.911						
13	.105	.619	98.530						
14	.095	.556	99.086						
15	.085	.500	99.587						
16	.049	.289	99.876						
17	.021	.124	100.000						

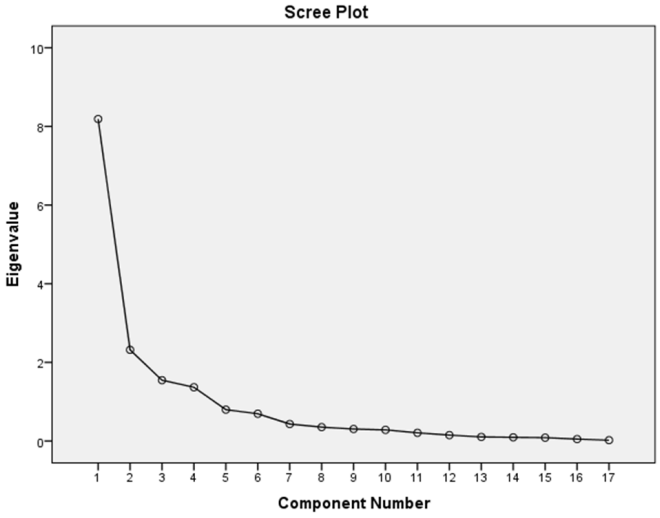


Figure 1. Scree plot

DISCUSSION

Initially, 44 statements were subject to expert judgement to refine the statements and enhance the content validity. Based on the thresholds for MRS, RP and RW, only 28 statements were included. The item analysis further refined the scale by excluding four statements that exhibited weak discriminating power and are excluded. The retained items demonstrate the ability to distinguish between farmers experiencing various degrees of impact, leading to the strengthening of the scale's construct validity. This finding aligns with the existing studies stating the importance of critical ratio analysis enhancing the precision of attitudinal measurement (Bird, 1940; Edwards, 1957).

The reliability analysis further confirmed the internal consistency of the scale, resulting in a final set of 17 items. The elimination of certain statements during the reliability testing suggests the scale purification increases the coherence without compromising content coverage. The high Cronbach's alpha value (0.914) indicates strong internal consistency among the retained statements. Such a high value is in accordance with the standards value suggested by Nunnally (1978) and DeVellis (2012), confirming that the scale is dependable for empirical application. The classification of respondents into low, medium, and high impact categories revealed that most tribal farmers perceived a moderate level of wildlife-induced crop damage, highlighting the widespread yet varying severity of its effects. This categorisation enhances the applicability of the scale for identifying vulnerable households and guiding targeted policy and extension interventions.

Exploratory factor analysis results reported four factor components, with 78.95 per cent of total variance explained. The sample adequacy and inter-item correlation were confirmed by the KMO and Bartlett's tests, supporting the appropriateness for undertaking the factor analysis (Kaiser, 1974; Bartlett, 1954). The extracted factors indicate the multidimensional nature of the impact of animal attacks, encompassing economic, nutritional, psychological and institutional dimensions. This was in line with the existing studies on human-wildlife conflicts, which observed that damage caused by animal attacks extended beyond the visible and immediate yield loss to affect the livelihoods, food security, and mental well-being (Barua et al., 2013).

The first factor identified is nutritional impact, indicating that crop damage directly has an impact on household food security, dietary diversity and food availability. This finding is particularly important among tribal households that rely on farm production for self-consumption. This aligns with the findings reported by Galley and Anthony (2024), who emphasised the close relationship between agricultural production and nutritional security in subsistence farming communities. Similar observations have been reported in rural communities of eastern Africa, where repeated wildlife incursions reduced food availability and increased household food insecurity among smallholder farmers (Hill, 2004).

The second major factor is that economic impact comprises reduced income, increased cultivation costs and changes in cropping patterns. Similar results were reported in the study by Thakur et al. (2022), who observed that wildlife-induced crop loss significantly impacts the rural household economies and livelihood sustainability.

Third, the psychological dimension reflects that the repeated exposure to animal attacks leads to stress, fear, anxiety and emotional distress among the farmers. This was substantiated by Barua et al. (2013), who highlighted the often-overlooked psychological burden associated with human–wildlife conflict. Comparable findings have also been reported in studies conducted in Africa, where persistent wildlife encounters generated fear, anxiety, and emotional distress among farming households living adjacent to such forest areas (Nyhus, 2016). The findings suggest that the effects of wildlife-induced crop damage are not limited to economic losses but also influence the mental well-being of affected households. Finally, the fourth-dimension deals with the institutional impact. This dimension reflects inadequate compensation mechanisms, limited preventive support measures and a common community platform pointing towards the gaps in addressing the wildlife-related issues. Similar findings were identified in the studies in Ethiopia and other developing countries, where inadequate compensation mechanisms, delayed institutional responses, and limited community participation reduced farmers' willingnes in wildlife management programmes (Gatew & Azadge, 2025; Nyhus, 2016).

CONCLUSION

The study establishes a reliable and valid scale to assess the impact of animal-induced effects on crops among the tribal farmers. The systematic refinement of statements through relevancy testing, item analysis, and reliability assessment ensures that the final 17-item scale precisely reflects the multidimensional nature of the problem. The identification of four underlying dimensions – nutritional impact, economic impact, psychological impact, and institutional impact – demonstrates that consequences of wildlife-induced damage extend beyond direct production losses. However, the findings are based on tribal farmers from the Attappady block of Kerala, and the factor structure was established using exploratory factor analysis only. Future studies may validate the scale across diverse geographical settings using Confirmatory Factor Analysis (CFA) to further establish its generalisability and robustness.

DECLARATIONS

Ethics approval and informed consent: Informed consent from the specialist possessing specialized knowledge were sought to obtain validation. From their feedback, a pilot study was carried out with randomly respondents.

Conflict of interest: The authors declare that this research was carried out without any financial contribution that could be considered as potential conflicts of interest. The authors further affirm that they independently reviewed, revised, and edited the manuscript throughout its preparation and accept the final content of this publication.

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Research Tool

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Development and Standardization of a Scale to Measure Farmers' Perception of Climate Change

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HIGHLIGHTS

- A 28-item Likert scale was developed and standardized to measure farmers' climate change perception across selected four dimensions with high internal consistency (Cronbach's alpha reliability coefficient of 0.875).
- Content and construct validities were established using expert relevancy scoring and item critical ratio testing.

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ABSTRACT

A standardized Likert Summated Rating Scale was developed during 2025 to measure the perception of farmers towards climate change across four chosen dimensions (Temperature and rainfall variability, Extreme weather events, Crop productivity, and Socio-economic impacts). Initially, 58 statements were framed based on Edwards' criteria, of which 20 statements were eliminated following the relevancy test with 68 expert judges. The remaining 38 statements were pilot tested among 60 respondents from a non-sample area. After conducting item analysis using the critical ratio (t-value) technique, 10 statements were discarded. The final scale consists of 28 statements (7 positive and 21 negative), reflecting the predominantly risk-oriented nature of climate change perception. The internal reliability was established using Cronbach's alpha, which showed a high reliability coefficient of 0.875. Further, the split-half reliability yielded Spearman-Brown and Pearson coefficients of 0.948 and 0.901, respectively, which established a high internal consistency. This scale provides a reliable tool for researchers, extension personnel, and policymakers to accurately assess farmers' perception, thereby facilitating targeted climate resilience and adaptation strategies.

INTRODUCTION

Agriculture is the backbone of the Indian economy, supporting the livelihoods of about 42.30 per cent of its population and contributing approximately 17.70 per cent to India's gross domestic product (GDP) (Economic Survey, 2025-26). However, in the current era of accelerating climate change, agriculture is the most vulnerable sector due to its direct dependency on local weather parameters. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), climate change refers to any identifiable shift in climate over time, arising from natural variability or human activities. Globally, anthropogenically induced warming has already driven a surface temperature increase of 0.85°C over the past century, with predictions estimating a further rise of at least 1.5°C by the end of the 21st century (IPCC, 2014). This increase in average global temperature significantly escalates the risks for rural populations, necessitating immediate adaptation strategies across climate-sensitive regions (IPCC, 2018).

Climate change consequences such as erratic precipitation, shifting seasons, and extreme weather events threaten long term

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agricultural sustainability (Nelson et al., 2009). This vulnerability is further amplified because 87.50 per cent of Indian farmers are small and marginal land holders, turning climate variability into a major challenge for national food and nutritional security (Mishra et al., 2024). According to global climate risk assessment, India ranks among the most vulnerable countries to climate change. Across its diverse mountainous, coastal, and arid ecological zones, this vulnerability manifests as accelerated land degradation, biodiversity loss, and loss of soil fertility leading to declining agricultural productivity and farmers' income (Mishra et al., 2024). The consequences of these climatic disturbances extend beyond agricultural production and affect household livelihood security, employment opportunities, and overall rural well-being. Such multifaceted impacts make climate change not merely an environmental concern but also a significant socio-economic challenge for farming communities (Phebe et al., 2024).

As climate change adaptation is fundamentally a cognitive and behavioral process, understanding these cognitive frameworks is a prerequisite for developing successful grassroots intervention and extension programmes. The effectiveness of climate adaptation initiatives largely depends on how farmers perceive climate-related risks and opportunities. Even within the same agro-ecological region, farmers often differ considerably in their interpretation of climatic changes, severity of impacts, and willingness to adopt adaptation measures. These differences in perception influence decision-making regarding crop management, resource allocations, technology adoption, and long-term livelihood strategies (Kumar & Saxena, 2024). Several climate-related perception scales have been developed for different populations and contexts (Van Valkengoed et al., 2021; Reddy et al., 2025; Pathak et al., 2026). However, most available instruments are either designed for specific climate adaptation programmes, assess only selected dimensions of perception, or are developed under different socio-economic settings. Therefore, there remains a need for a multidimensional, standardized scale suitable for assessing farmers' perception of climate change under Indian agricultural conditions, which could be used for designing need-based extension interventions and climate-resilient agricultural policies. The present study was undertaken to construct and standardize a reliable psychometric scale to measure the farmer's perception regarding climate change and its direct implications on their livelihoods.

METHODOLOGY

The scale was constructed using a systematic psychometric procedure involving item collection, relevancy analysis, item analysis, and reliability and validity assessment. The Likert's summated rating scale is a set of perception statements, all of which are considered of approximately equal perception value and to each of which subjects respond with degrees of agreement or disagreement carrying different scores (Likert, 1932). Perception, in this study was operationalized as the process by which a farmer registers and evaluates information received from the internal or external environment, consciously or unconsciously regarding climate change and it was measured across the four dimensions, namely, temperature and rainfall variability, extreme weather events, crop productivity & farming viability, and socio-economic & livelihood impact. Initially, 72 statements were collected and screened using the informal criteria suggested by Edwards (1957). Consequently, 14 statements were removed and 58 statements were selected (out of the initial 72) for relevancy analysis. The 58 statements were then sent to 150 experts purposively selected from Indian Agricultural universities, ICAR institutes, and related organizations. The experts possessed teaching, research or extension experience in the area of climate change, natural resource management, or related disciplines. The experts rated the relevancy of each statement on a three-point continuum- highly relevant, relevant, and least relevant (Thakur et al., 2017; Mukherjee et al., 2018). A total of 73 responses were received, of which five were excluded due to ambiguity and incomplete responses, and the remaining were considered for analysis. Relevancy Percentage (RP), Relevancy Weightage (RW), and Mean Relevancy Score (MRS) were computed for each statement. The Statements having RP > 70 per cent, RW > 0.7 and MRS > Overall Mean Relevancy Score (OMRS) of 2.33 were retained for item analysis (Mukherjee et al., 2018; Reddy et al., 2025). The 38 statements retained after relevancy analysis were pilot tested among 60 farmers from a non-sampled village of Kanpur district selected through simple random sampling. Responses were recorded on a five-point continuum ranging from strongly agrees to strongly disagree. Item analysis was performed using the critical ratio (t-value) technique suggested by Edwards (1957). Respondents were arranged according to their total scores and the upper 25 per cent and the lower 25 per cent groups were used as criterion groups for computing t-values. Statements with t-values equal to or greater than 2.05 (t critical for two tailed test) were retained in the final scale. The reliability of the developed scale was assessed using Cronbach's alpha and split-half reliability techniques. For split-half reliability, the statements were divided into two halves on the basis of random numbers and administered to the respondents. The reliability was estimated using Pearson correlation and Spearman-Brown coefficient (Edwards, 1957). Content validity was established through expert evaluation during relevancy analysis, while construct validity was assessed through item discrimination using the critical ratio (t-value) technique as shown below:

$$RP = \frac{\text{Frequency score of most relevant and relevant}}{\text{Total number of judges}} \times 100$$

$$RW = \frac{\text{Actual scores obtained for the statement}}{\text{Maximum possible scores obtained for the statement}} \times 100$$

$$MRS = \frac{\text{Actual scores obtained for the statement}}{\text{Number of judges responded}} \times 100$$

RESULTS

Relevancy analysis

The relevancy analysis was carried out to assess the suitability of the identified statements for inclusion in the perception scale. Responses obtained from 68 experts were analysed to compute

Relevancy Percentage (RP), Relevancy Weightage (RW), and Mean Relevancy Score (MRS) for each statement. The values of RP, RW, and MRS ranged from 62.90 to 96.77 per cent, 0.64 to 0.85, and 1.92 to 2.56, respectively. Based on these indices and expert suggestions, 38 statements were retained for item analysis after suitable modifications. The detailed relevancy indices of all statements are presented in Table 1.

Item analysis

The calculated t-values of the 38 statements ranged from 0.88 to 11.06. Based on the criterion of t ≥2.05, 28 statements were retained in the final scale, whereas 10 statements were discarded due to inadequate discriminatory power. The selected statements represented all four dimensions of the construct and constituted the final perception scale (Table 1).

Table 1. Relevancy indices of selected items for measuring perception of farmers towards climate change

S. No.	Statements	RW	MRS	RP	T value
	A) Temperature & Rainfall Variability (Effects on weather patterns, water availability, and farming conditions)				
1.	*Frequent temperature fluctuations throughout the year create anxiety. (-)	0.83	2.50	91.94	5.77*
2.	Erratic rainfall pattern is reducing the effectiveness of traditional irrigation methods. (-)	0.85	2.56	91.94	1.61
3.	*Early withdrawal of the monsoon creates confusion when planning for upcoming crop cycles. (-)	0.84	2.53	96.77	2.48*
4.	*Productivity of major crops is declining due to increasing temperature. (-)	0.82	2.47	93.55	5.90*
5.	The increasing number of heat waves in summer causes physical and mental exhaustion of farmers. (-)	0.84	2.53	93.55	1.56
6.	*The emergence of new weed species due to rising temperatures adds to growing uncertainty. (-)	0.78	2.36	87.10	3.77*
7.	*Unexpected rainfall does not seem to have any significant impact on crop yield. (+)	0.83	2.50	96.77	5.13*
8.	*Delayed onset of monsoon raises concerns about disruptions to cropping schedules (-)	0.84	2.52	95.16	6.83*
9.	Unpredictable rainfall during monsoons brings uncertainty in planning farming activities. (-)	0.79	2.37	87.10	1.97
10.	*Rising temperatures cause deep concern about their negative effect on livestock productivity. (-)	0.79	2.37	85.48	4.02*
11.	*The increasing frequency of livestock deaths due to heat stress is troubling. (-)	0.78	2.35	87.10	3.97*
12.	*Falling milk productivity in summer due to heat stress causes concern. (-)	0.83	2.48	93.55	11.06*
	B) Extreme Weather Events (Impact of extreme conditions on farming operations and productivity)				
13.	*Heavy rainfall floods severely disrupt farming logistics. (-)	0.83	2.50	88.71	4.25*
14.	Unpredictable weather events raise concern about crop failure. (-)	0.83	2.50	93.55	1.43
15.	*The occurrence of droughts does not cause real concern regarding long-term agricultural water availability. (+)	0.82	2.45	95.16	3.55*
16.	*Soil erosion during heavy rains affects soil health and productivity. (-)	0.81	2.44	90.32	6.39*
17.	*Extreme weather conditions like floods do not seem to have any significant impact on agricultural sustainability. (+)	0.79	2.37	90.32	4.45*
18.	*Frequent droughts raise concerns about the long-term sustainability of farming. (-)	0.79	2.37	88.71	3.95*
19.	The abandonment of agriculture due to weather-related uncertainties is deeply concerning. (-)	0.80	2.39	87.10	1.56
20.	*Rising fodder shortages due to droughts make livestock management extremely difficult. (-)	0.83	2.50	96.77	4.34*
21.	*Increasing number of livestock deaths due to weather extremes such as floods, feels discouraging. (-)	0.81	2.42	88.71	4.89*
	C) Crop Productivity & Farming Viability (Effects on yields, biodiversity, and financial sustainability)				
22.	*Declining crop yields create uncertainty about the future of agriculture. (-)	0.85	2.55	90.32	4.55*
23.	*Changes in crop ripening stage due to climate change feel discouraging. (-)	0.79	2.37	88.71	4.64*
24.	The inability of crop varieties to adapt to changing weather conditions raises concerns about future harvests. (-)	0.78	2.35	90.32	1.96
25.	Declining crop productivity due to climate change discourages the younger generation from farming. (-)	0.81	2.44	91.94	1.84
26.	*Farm productivity is expected to remain stable despite changing weather conditions. (+)	0.79	2.37	90.32	5.61*
27.	Farming is expected to adapt successfully to future climate changes. (+)	0.78	2.35	93.55	1.88
28.	*Advancements in farming techniques are expected to reduce the effects of climate change. (+)	0.79	2.37	85.48	5.52*
29.	*Disruptions in flowering cycles due to climate change create doubts about crop yields. (-)	0.81	2.42	90.32	3.10*
30.	*The loss of agricultural biodiversity due to climate change is deeply concerning. (-)	0.81	2.42	87.10	4.25*
31.	*The rising threat of pest outbreaks threatens the financial sustainability of farming. (-)	0.82	2.45	91.94	2.87*
	D) Socioeconomic & Livelihood Impact (Migration, income, and farmer perceptions)				
32.	Health risks posed by climate change to farming communities raise concerns. (-)	0.78	2.34	87.10	1.83
33.	*Climate-driven migration is contributing to abandonment of farmlands. (-)	0.80	2.40	90.32	3.09*
34.	*Climate change is contributing to a decline in annual farming income. (-)	0.78	2.34	88.71	2.80*
35.	*The growing unpredictability of weather has reduced confidence in agriculture. (-)	0.78	2.35	88.71	3.03*
36.	*Rural livelihoods appear largely unaffected by changing weather conditions. (+)	0.82	2.45	91.94	3.64*
37.	Constant changes in cropping patterns to cope with climate challenges create uncertainty about the future. (-)	0.78	2.34	90.32	0.88
38.	*Climate change does not appear to be the main reason for rural youth migration. (+)	0.78	2.34	90.32	2.43*

(* selected statement, + denotes positive Statements, – denotes negative statements)

Reliability and validity analysis

The developed scale was further standardized by establishing its reliability and validity. Reliability is the accuracy or precision of a measuring instrument (Kerlinger, 1973). The reliability analysis indicated a high level of internal consistency of the developed scale. Cronbach's alpha coefficient was found to be 0.875. The Pearson correlation coefficient between the two halves of the scale was 0.901, while the Spearman-Brown coefficient was 0.948 (Table 2). These values indicate that the scale possesses high reliability and internal consistency for measuring farmers' perception towards climate change.

Table 2. Split-half reliability test indices

	Reliability statistics
Cronbach's Alpha Value	0.875
Correlation Between Forms	0.901
Spearman-Brown Coefficient	0.948

Content validity is the representativeness or sampling adequacy of the content substance, the matter, and the topics of a measuring instrument. Content validity of the scale was ensured through expert evaluation during the relevancy analysis stage. Suggestions received from the experts were incorporated while refining the statements. Construct validity was established through item analysis, wherein only statements demonstrating adequate discriminatory power ($t \leq 2.05$) were retained. Thus, the final 28-item scale was considered both valid and reliable for measuring farmers' perception towards climate change.

DISCUSSION

The high reliability and validity coefficients obtained during the standardization process of the scale clearly demonstrate that the developed scale is a statistically sound and dependable instrument for measuring farmers' perceptions of climate change. The Cronbach's alpha value of 0.875 indicates a high level of internal consistency among the final 28 statements, confirming that the statements are well-aligned and measured the same underlying cognitive construct. Furthermore, the Spearman-Brown coefficient of 0.948 and the high Pearson correlation value of 0.901 verify the high stability and repeatability of the scale over time. These psychometric values are in complete agreement with the methodological parameters suggested by Edwards and Kilpatrick (1948), Cronbach (1946) and Thurstone and Chave (1929). Similar high reliability trends in climate-related scale development have also been reported by Pathak et al. (2026) and Reddy et al. (2025), who emphasized that rigorous item screening is crucial for capturing farmers' perceptions and responses to climate-related risks.

The retention of 28 statements across four distinct dimensions i.e., temperature and rainfall variability, extreme weather events, crop productivity, and socio-economic impacts, provides a holistic structure to the scale. By evaluating these specific dimensions, the tool captures not just the physical awareness of changing climate patterns, but also the farmers' understanding of subsequent field-level vulnerabilities and economic shocks. The elimination of 30 statements out of the initial 58 during the relevancy analysis and item analysis demonstrates the necessity of filtering out ambiguous or non-discriminating items. The remaining 28 statements are highly sensitive to individual differences in perception, which will allow researchers to differentiate clearly between highly perceptive, moderately perceptive, and low-perceptive groups within the farming community. The predominance of negatively worded statements reflects the inherently risk-oriented nature of climate change, which is consistent with empirical observations that farmers generally experience climate change through production risks, livelihood uncertainties, and weather-related disruptions rather than through perceived benefits. This structural soundness of the developed scale is in agreement with the findings of Shitu et al. (2018), Van et al. (2021), and Mallick et al. (2026) who noted that psychometric assessment tools were critical for diagnosing localized agricultural extension gaps, especially for a complex construct like climate change. This standardized approach ensures that the scale can be effectively used in future research and policy assessments related to perception of farmers towards climate change. The developed scale may also serve as a diagnostic tool for identifying perception gaps among different categories of farmers. Such information can help extension agencies prioritize interventions, improve climate communication strategies, and strengthen the adoption of climate-resilient agricultural practices. The scale can further be utilized for baseline assessments and monitoring changes in farmers' perception over time, thereby providing valuable feedback for extension planning and policy formulation.

CONCLUSION

A multi-dimensional Likert summated rating scale was systematically constructed and standardized in this study to evaluate the farmers' perception towards climate change. The scale comprises 28 statements capturing farmers' perceptions of climate-related risks and resilience. The final scale was systematically refined through expert relevancy analysis and pilot-study item analysis using the critical ratio (t-value) technique to ensure its high statistical reliability and discriminatory power under field conditions. This standardized scale holds immense practical utility for field researchers, policy workers, and frontline extension networks like Krishi Vigyan Kendras (KVKs). Utilizing this tool for baseline field studies will help extension personnel to easily understand the actual perception levels of local farmers before introducing a climate resilient technology or launching a climate smart agriculture programme. Ultimately, identifying these gaps will help in designing proper training programs and extension activities, for better adaptation and long-term livelihood security of the farming community.

DECLARATIONS

Ethics approval and informed consent: Informed consent from the specialist possessing specialized knowledge were sought to obtain validation.

Conflict of interest: The authors declare that this research was carried out without any financial contribution that could be considered as potential conflicts of interest. The authors further affirm that they independently reviewed, revised, and edited the

manuscript throughout its preparation and accept the final content of this publication.

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Research Tool

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Construction of Perception Scale to Measure the Agriculture–Human–Wildlife Conflict among Farming Communities

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HIGHLIGHTS

- A final Perception scale of 22 items was developed using CVR, CITC and reliability screening.
- EFA extracted four factors with initial eigenvalues greater than 1.0 and explaining 53.474% of the total variance
- Perceived conflict severity and risk were the dominant factors explaining the variation of 28.92%.

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ABSTRACT

Agriculture–Human–Wildlife Conflict (AHWC) in buffer zones of protected areas poses recurring economic and psychological burdens on farming households. Yet few context-specific multidimensional instruments have been reported to measure how farmers understand and evaluate this conflict. The study developed and validated a Farmers' Perception Scale towards AHWC (FPS-AHWC) among farming households residing in buffer zone villages. An initial pool of 52 statements was generated through literature review, expert consultation, and field-based enquiry. After the evaluation from nine experts, 43 statements were retained for field testing. The 43-item instrument was used to collect data from 200 farming households. Item-level screening using corrected item–total correlation (CITC) and alpha-if-item-deleted criteria reduced the scale to 22 items, with the overall Cronbach's α improving from 0.687 (43 items) to 0.886 (22 items; CITC range: 0.431–0.536). Exploratory Factor Analysis resulted in four interpretable factors, namely Perceived Conflict Severity and Risk (6 items, 28.91% variance), Perceived Effectiveness of Conflict-Mitigation Measures (7 items, 9.945%), Conservation and Coexistence Orientation (6 items, 7.99%), and Contextual Appraisal of Wildlife Presence (3 items, 6.61%), together explaining 53.47% of the total variance. The FPS-AHWC provides a validated diagnostic tool for assessing farmers' perceptions in buffer zones of protected areas.

INTRODUCTION

Agriculture–Human–Wildlife Conflict (AHWC) is one of the most consistent challenges faced by farming communities in the buffer zones of protected areas across India. The increase in the population of large wild animals under Project Tiger and the expansion of protected area networks have intensified interactions between wildlife and agricultural households, resulting in recurrent

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crop raiding, livestock depredation, property damage and in extreme cases, personal injury (Jhala et al., 2021). Households living in buffer zones of tiger reserves such as Ranipur Tiger Reserve (RTR), Chitrakoot, Uttar Pradesh, routinely encounter such losses, and these experiences affect attitudes toward conservation and livelihoods (Subedi et al., 2020). While the economic dimensions of AHWC have received considerable research attention, the perceptual dimension of AHWC, like how farmers understand, evaluate, and contextualise the conflict, is an important but under-measured construct. Perception encompasses a broader set of cognitive and evaluative orientations than tolerance. A farmer may tolerate limited livestock loss while perceiving carnivore presence as a serious and urgent threat. Another may hold conservation values but regard mitigation measures as ineffective. These distinctions matter for extension planning: programmes targeting mitigation uptake must address perceived effectiveness, whereas those aimed at reducing retaliatory behaviour must engage with perceived severity. An instrument that captures only tolerance collapses these dimensions. Agricultural extension contributes to human–wildlife coexistence by facilitating behavioural change, disseminating conflict-mitigation technologies, and building community capacity (Barua et al., 2013). Extension workers require a diagnostic tool that captures multiple perceptual dimensions rather than a single attitudinal summary (Verma et al., 2026b). Few context-specific multidimensional instruments have been reported for farming households in Indian protected-area buffer zones, and existing tools developed in Western or African contexts do not adequately capture the socio-ecological character of smallholder communities here (Kansky et al., 2016).

Existing measurement tools in the human–wildlife conflict literature have concentrated primarily on wildlife tolerance, broadly defined as a farmer's willingness to accept the presence of wildlife and bear associated costs without resorting to retaliatory or exclusionary behaviour (Slagle et al., 2013; Kansky et al., 2016; Verma et al., 2026a). While tolerance is an important construct, it does not capture the full range of perceptions that determine how farmers engage with, respond to, and communicate about AHWC. The present study treats perception as distinct from tolerance: perception refers to farmers' cognitive evaluation of conflict severity, perceived risk, and beliefs about mitigation effectiveness, conservation orientation, and contextual understanding of wildlife presence. Against this background, the present study developed and validated a Farmers' Perception Scale towards Agriculture–Human–Wildlife Conflict (FPS-AHWC) for use among farming households in buffer zones of protected areas, following a systematic four-stage psychometric protocol involving expert-based content validation, field-based item screening, reliability analysis, and Exploratory Factor Analysis.

METHODOLOGY

The study was conducted in the buffer zone villages of Ranipur Tiger Reserve, Uttar Pradesh. The buffer area comprises seven ranges: Manikpur I, Manikpur II, Markundi I, Markundi II, Karvi, Raipura, and Bargarh. Four ranges were selected purposively based on their proximity to the core area. Four villages were selected from each of Manikpur I and Markundi I, and six villages from each of Manikpur II and Markundi II, because of differences in area coverage, resulting in a total of 20 villages. From each village, 10 farming households were randomly selected, resulting in a final sample of 200 households. A cross-sectional household survey was conducted, and data were collected through personal interviews from March to April 2026. The FPS-AHWC was developed following a four-stage psychometric protocol. In Stage I, an initial pool of 52 statements was generated through systematic literature review, expert consultation, and field-based understanding of AHWC in buffer zone landscapes (Maurya et al., 2024). Statements were framed to capture perceived conflict severity and risk, beliefs about mitigation effectiveness, conservation orientation, coexistence attitudes, and contextual understanding of wildlife presence. In Stage II, the 52-item pool was submitted to a panel of nine experts comprising agricultural extension specialists, wildlife scientists, and forestry officers. Each expert rated each statement as 'Essential', 'Useful but not essential', or 'Not necessary'. Content Validity Ratio (CVR) was computed for each item using Lawshe's (1975) formula:

$$CVR = \frac{(ne - \frac{N}{2})}{\frac{N}{2}}$$

Where, ne = number of experts rating an item as essential and
N = total number of experts

For a panel of nine, the minimum acceptable CVR threshold is 0.78 (Lawshe, 1975). Nine statements fell below this threshold and were removed, yielding 43 statements for field testing. The 43-item instrument was administered to all 200 farming households using a five-point Likert response: 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree. In Stage III, the 43 retained items were considered for item-level reliability screening. Corrected item–total correlation (CITC) and Cronbach's alpha-if-item-deleted were computed for all items. Items with CITC below 0.30 or with alpha-if-deleted exceeding the overall scale alpha were removed. This process reduced the item pool from 43 to 22 items, with overall Cronbach's alpha improving from 0.687 to 0.886. In Stage IV, Exploratory Factor Analysis (EFA) was conducted on the 22-item scale using Principal Axis Factoring (PAF) with Direct Oblimin rotation in IBM SPSS. Factorability was assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity. Factors were retained based on an eigenvalue greater than 1.0 and substantive interpretability. A pattern-matrix loading threshold of $\geq$0.50 was applied for item interpretation. Oblique rotation was selected because moderate inter-factor correlations were anticipated, given that the perceptual dimensions of AHWC are theoretically related.

RESULTS

Content validation and item reduction

The nine-expert panel reviewed all 52 statements. CVR values ranged from 0.33 to 1.00. Nine statements failed to meet the minimum acceptable CVR threshold of 0.78 for a panel of nine experts and were removed (Table 1). The removed statements included items relating to wildlife rights, risk perceptions of non-livestock owners, legal adequacy, fuelwood use, personal economic valuation of wildlife, activity restrictions, local conservation laws,

Table 1. Expert validation score for initial perception statements (n = 9)

S. No.	Original Item Code	Field-test Code	ne	CVR	Decision
1	O1	P1	9	1.00	Retained
2	O2	P2	9	1.00	Retained
3	O3	P3	8	0.78	Retained
4	O4	P4	9	1.00	Retained
5	O5	P5	9	1.00	Retained
6	O6	—	7	0.56	Removed
7	O7	P6	8	0.78	Retained
8	O8	—	6	0.33	Removed
9	O9	—	7	0.56	Removed
10	O10	—	6	0.33	Removed
11	O11	P7	8	0.78	Retained
12	O12	P8	8	0.78	Retained
13	O13	P9	8	0.78	Retained
14	O14	P10	8	0.78	Retained
15	O15	P11	9	1.00	Retained
16	O16	—	7	0.56	Removed
17	O17	—	6	0.33	Removed
18	O18	—	7	0.56	Removed
19	O19	—	6	0.33	Removed
20	O20	—	7	0.56	Removed
21	O21	P12	9	1.00	Retained
22	O22	P13	8	0.78	Retained
23	O23	P14	9	1.00	Retained
24	O24	P15	9	1.00	Retained
25	O25	P16	8	0.78	Retained
26	O26	P17	8	0.78	Retained
27	O27	P18	8	0.78	Retained
28	O28	P19	8	0.78	Retained
29	O29	P20	8	0.78	Retained
30	O30	P21	8	0.78	Retained
31	O31	P22	8	0.78	Retained
32	O32	P23	9	1.00	Retained
33	O33	P24	8	0.78	Retained
34	O34	P25	9	1.00	Retained
35	O35	P26	8	0.78	Retained
36	O36	P27	9	1.00	Retained
37	O37	P28	9	1.00	Retained
38	O38	P29	8	0.78	Retained
39	O39	P30	9	1.00	Retained
40	O40	P31	8	0.78	Retained
41	O41	P32	9	1.00	Retained
42	O42	P33	9	1.00	Retained
43	O43	P34	9	1.00	Retained
44	O44	P35	9	1.00	Retained
45	O45	P36	9	1.00	Retained
46	O46	P37	8	0.78	Retained
47	O47	P38	9	1.00	Retained
48	O48	P39	8	0.78	Retained
49	O49	P40	8	0.78	Retained
50	O50	P41	9	1.00	Retained
51	O51	P42	9	1.00	Retained
52	O52	P43	9	1.00	Retained

Shaded rows indicate removed statements; Statements having CVR ≥ 0.78 were retained.

probability of wildlife interaction, and hunting prohibition. These items were judged by experts as insufficiently specific to the perceptual domains targeted by the scale or as measuring general conservation knowledge rather than context-specific AHWC perception. The remaining 43 statements were renumbered P1–P43 for field testing. Table 2 summarises the item-reduction sequence across all stages.

Reliability and item screening

The initial Cronbach's alpha for the 43-item pool was 0.687, indicating marginal internal consistency. In the second stage, each Item was screened using CITC and alpha-if-deleted criteria, resulting in 21 items with CITC values below 0.30 or with alpha-if-deleted exceeding the overall pool alpha. Removal of these items resulted in the final 22-item scale having Cronbach's alpha of 0.886. All retained items had CITC values between 0.431 (P14) and 0.536 (P27), and further deletion of any item also reduced alpha between 0.880 and 0.883, confirming that each item contributed meaningfully to scale reliability. Item-level reliability statistics for the final 22-item scale are presented in Table 3.

EFA adequacy and factor extraction

The KMO measure of sampling adequacy was 0.880, exceeding the recommended threshold of 0.70 and indicating that inter-item correlation patterns were suitable for factor analysis. Bartlett's test of sphericity was statistically significant ($\chi^2 = 2032.524$, df = 231, $p < 0.001$), confirming that the correlation matrix was not an identity matrix. Four factors with initial eigenvalues greater than 1.0 were extracted, explaining 53.474% of the total variance (Table 4). The inter-factor correlation matrix showed moderate positive associations among all four factors (range: 0.222–0.425), confirming the appropriateness of oblique rotation.

Factor interpretation

The rotated pattern matrix yielded a clean four-factor structure with no problematic cross-loadings (Table 5). Factor 1 (Perceived Conflict Severity and Risk) comprised six items (P4, P27, P32, P41, P1, P2; pattern loadings: 0.568–0.812). These items reflect farmers' fear of working near the reserve, the emotional distress associated with carnivore presence, the urgency of livestock depredation as a problem demanding institutional action, the perceived threat of carnivores to both livestock and people, and — through the reverse-coded P41 — the perceived balance between wildlife-related costs and benefits within a conflict-severity frame.

Factor 2 (Perceived Effectiveness of Conflict-Mitigation Measures) comprised seven items (P35, P34, P36, P38, P11, P12, P30; loadings: 0.604–0.727), capturing farmers' beliefs in compensation schemes, management responses to habituated wildlife, non-lethal protective tools, awareness-raising efforts, livestock insurance, perimeter fencing, and community involvement as conflict-reduction mechanisms. Factor 3 (Conservation and Coexistence Orientation) comprised six items (P33, P25, P14, P28, P15, P42; loadings: 0.578–0.785), reflecting support towards conservation efforts, acceptance of wildlife despite occasional conflict, personal responsibility for conservation, importance of biodiversity and rejection of adversarial attitudes toward wildlife.

Table 2. Item-reduction sequence across scale development stages

Stage	Initial Pool	Removed	Retained	Decision Criterion
Item generation (Stage I)	52	—	52	Literature, expert consultation, and field observation
Content validation through CVR (Stage II)	52	9	43	CVR < 0.78 for N = 9 experts (Lawshe, 1975)
Item screening through CITC (Stage III)	43	21	22	CITC < 0.30 or alpha-if-deleted > overall alpha
Final scale (Stages IV)	22	—	22	CITC: 0.431–0.536; á = 0.886

CVR = Content Validity Ratio; CITC = Corrected Item–Total Correlation.

Table 3. Reliability statistics before and after screening items (n = 200)

Item	CITC	α if Item Deleted	Decision
Before Item Screening: Overall Cronbach's α = 0.687; N of items = 43			
P1	0.478	0.671	Retained
P2	0.465	0.671	Retained
P3	-0.129	0.702	Removed
P4	0.478	0.671	Retained
P5	0.437	0.672	Retained
P6	-0.058	0.698	Removed
P7	0.154	0.684	Removed
P8	-0.057	0.698	Removed
P9	0.011	0.693	Removed
P10	-0.052	0.698	Removed
P11	0.410	0.669	Retained
P12	0.446	0.666	Retained
P13	0.025	0.693	Removed
P14	0.338	0.673	Retained
P15	0.417	0.668	Retained
P16	0.059	0.691	Removed
P17	0.102	0.688	Removed
P18	-0.012	0.695	Removed
P19	0.089	0.689	Removed
P20	-0.062	0.699	Removed
P21	-0.050	0.698	Removed
P22	-0.025	0.696	Removed
P23	0.418	0.673	Retained
P24	0.061	0.690	Removed
P25	0.400	0.670	Retained
P26	0.076	0.689	Removed
P27	0.485	0.671	Retained
P28	0.447	0.667	Retained
P29	-0.130	0.703	Removed
P30	0.421	0.667	Retained
P31	-0.004	0.695	Removed
P32	0.475	0.671	Retained
P33	0.437	0.667	Retained
P34	0.466	0.665	Retained
P35	0.456	0.665	Retained
P36	0.443	0.666	Retained
P37	0.070	0.690	Removed
P38	0.355	0.672	Retained
P39	-0.182	0.704	Removed
P40	-0.063	0.699	Removed
P41	0.470	0.671	Retained
P42	0.388	0.670	Retained
P43	0.448	0.672	Retained
After item screening: Overall Cronbach's α = 0.886; N of items = 22			
P1	.506	.881	Retained
P2	.508	.881	Retained
P4	.488	.882	Retained
P5	.482	.882	Retained
P11	.520	.880	Retained
P12	.495	.881	Retained
P14	.431	.883	Retained
P15	.467	.882	Retained
P23	.452	.882	Retained
P25	.498	.881	Retained
P27	.536	.880	Retained
P28	.524	.880	Retained
P30	.469	.882	Retained
P32	.530	.881	Retained
P33	.495	.881	Retained
P34	.533	.880	Retained
P35	.497	.881	Retained
P36	.476	.882	Retained
P38	.453	.882	Retained
P41	.518	.881	Retained
P42	.436	.883	Retained
P43	.471	.882	Retained

Table 3 contd...

CITC = Corrected Item–Total Correlation; α if deleted = Cronbach's alpha if the item is removed.

Table 4. KMO, Bartlett's test, and variance explained by the four-factor solution (n = 200)

Factor	Initial Eigenvalue	% Variance Explained	Cumulative %
KMO = 0.880; Bartlett's χ^2 = 2032.524, df = 231, p < 0.001			
Factor 1: Perceived Conflict Severity and Risk	6.362	28.916	28.916
Factor 2: Perceived Effectiveness of Conflict-Mitigation Measures	2.188	9.945	38.861
Factor 3: Conservation and Coexistence Orientation	1.760	7.999	46.860
Factor 4: Contextual Appraisal of Wildlife Presence	1.455	6.614	53.474

Extraction method: Principal Axis Factoring; Rotation method: Direct Oblimin; Eigenvalues are extraction sums of squared loadings.

Table 5. Rotated pattern matrix for the final 22-item scale (Principal Axis Factoring, Direct Oblimin rotation; n = 200)

Item	Factor	F1	F2	F3	F4	Extraction communality (h^2)
P4	Perceived Conflict Severity and Risk	.812				.613
P27		.765				.604
P32		.724				.588
P41		.687				.520
P1		.602				.439
P2		.568				.473
P35	F2: Perceived Effectiveness of Conflict-Mitigation Measures		.727			.508
P34			.711			.520
P36			.690			.470
P38			.653			.430
P11			.631			.441
P12			.626			.416
P30			.604			.427
P33	F3:Conservation and Coexistence Orientation			.785		.613
P25				.743		.552
P14				.706		.494
P28				.676		.525
P15				.613		.433
P42				.578		.367
P23	F4: Contextual Appraisal of Wildlife Presence				.875	.801
P43					.858	.803
P5					.811	.727

Only primary loadings ≥0.50 are shown.

Factor 4 (Contextual Appraisal of Wildlife Presence) comprised three items (P23, P43, P5; loadings: 0.811–0.875). This preliminary three-item dimension reflects farmers' broader appraisal of ecological drivers, perceived health implications, and locally perceived economic opportunities associated with wildlife presence. Although the items loaded strongly, the dimension should be interpreted cautiously and validated in larger and geographically diverse samples before definitive conclusions are drawn.

Final scale and scoring

The final FPS-AHWC comprises 22 items distributed across four factors: Factor 1 (6 items), explaining farmers' perceptions of fear, threat, emotional distress, and the perceived balance of wildlife costs and benefits within a conflict-severity frame**.** Factor 2 (7 items) explains farmers' beliefs in compensation, fencing, insurance, non-lethal tools, awareness, and community involvement as conflict-reduction mechanisms. Factor 3 (6 items) explains conservation support, coexistence acceptance, personal responsibility, and rejection of punitive attitudes toward wildlife**.** Factor 4 (3 items) explains farmers' appraisal of ecological drivers, perceived health implications, and locally perceived economic opportunities associated with wildlife presence. Because the FPS-AHWC captures distinct dimensions of AHWC perception, factor-wise mean scores are recommended for interpretation because factors are correlated but conceptually distinct. Higher scores on Factor 1 indicate greater perceived conflict severity and risk; higher scores on Factor 2 indicate stronger perceived effectiveness of conflict-mitigation measures; higher scores on Factor 3 indicate stronger conservation and coexistence orientation; and higher scores on Factor 4 indicate stronger contextual appraisal of wildlife presence. An overall composite score may be used cautiously for descriptive purposes, but factor-wise interpretation is recommended. All 22 items, factor assignments, and scoring directions are presented in Table 6.

DISCUSSION

The FPS-AHWC recognise the measurement gap in Indian agriculture-human–wildlife conflict research. Perception is a broad construct which include cognitive evaluation of severity of conflict, effectiveness of mitigation strategies, conservation orientation, and contextual understanding of wildlife presence. These dimensions are empirically distinct and independent of the four factors, showing that farmers can simultaneously perceive conflict as severe and support conservation, or appreciate mitigation options while regarding wildlife presence as contextually complex. Merging these dimensions into a single perception score decreases the diagnostic specificity needed to design targeted interventions. The systematic content validation was done using Lawshe's CVR with nine experts, who established face and content validity before field testing. The initial reliability of the 43-item pool (α = 0.687) reflects the comprehensiveness of the initial items, whereas the increase in Cronbach alpha to 0.886 following item screening is consistent with scale-construction studies in similar domains (Gupta et al., 2022; Prabex et al., 2025; Patra et al., 2026). An alpha of 0.886 substantially exceeds the 0.80 threshold generally considered acceptable for social science instruments (Kalkbrenner, 2021), and the narrow CITC range (0.431–0.536) confirms that all retained items contribute homogeneously. Factor 1 (Perceived Conflict Severity and Risk) represents the dominant component, resulting

Table 6. Final Farmers' Perception Scale towards AHWC (FPS-AHWC)

S.No.	Code	Statement
Factor 1: Perceived Conflict Severity and Risk (6 items)		
1	P4	In the vicinity of the protected area, farmers fear working in their fields during odd hours because of wild animals.
2	P27	Livestock depredation by wildlife is a serious problem that requires immediate action from authorities.
3	P32	The presence of carnivores causes emotional distress beyond economic losses to livestock.
4	P41	Wildlife causes more damage to livestock and property than the benefits it provides to the community.
5	P1	Crop raiding, livestock depredation, and property damage by wildlife contribute to conflicts between livestock owners and wildlife.
6	P2	Carnivore animals are a threat to livestock and people near the protected area.
Factor 2: Perceived Effectiveness of Conflict-Mitigation Measures (7 items)		
7	P35	Compensation for livestock losses from wildlife increases positive attitudes toward conservation.
8	P34	Problematic wildlife behaviours, such as becoming accustomed to humans, justify stronger conflict management.
9	P36	Non-lethal tools, such as guard dogs or lights, are effective for protecting livestock from predators.
10	P38	Educating livestock owners about preventing human–wildlife conflict would improve tolerance for wildlife.
11	P11	Promotion of livestock insurance schemes may reduce livestock owner–wildlife conflict.
12	P12	Proper fencing around the National Park may reduce livestock owner–wildlife conflict.
13	P30	Community involvement in conservation decisions improves tolerance for wildlife near parks.
Factor 3: Conservation and Coexistence Orientation (6 items)		
14	P33	Livestock owners should tolerate a small percentage of losses to wildlife as part of coexistence.
15	P25	I like having wildlife in nearby forests despite occasional conflicts.
16	P14	Wild animals that cause damage are pests and should be killed.
17	P28	Conserving wildlife is extremely important for maintaining biodiversity and ecosystem health.
18	P15	I am responsible for conserving wildlife around the park interface.
19	P42	The risk of livestock being injured or killed by wildlife is acceptable as part of living near protected areas.
Factor 4: Contextual Appraisal of Wildlife Presence (3 items)		
20	P23	Encroachment for settlement and agricultural production may provoke wild animals to raid crops or prey on livestock.
21	P43	Wildlife in nearby forests contributes positively to the local economy through ecotourism or other opportunities.
22	P5	There may be a chance of spreading zoonotic diseases due to wild animals.

in 28.916% of variance. High loadings on items related to fear (P4), emotional distress (P32), carnivore threat (P2), and the perceived cost–benefit. For many farming households, it is a significant psychological hazard and not merely an economic inconvenience. Many Extension efforts ignore the affective dimension of perceived severity of risk and design interventions that address only economic losses while leaving fear-related barriers to coexistence unaddressed (Hobson et al., 2024; Velamuri et al., 2024; Kademani et al., 2025; Verma et al., 2026a). Factor 2 (Perceived Effectiveness of Conflict-Mitigation Measures) captures beliefs about both technical and community-based mitigation strategies. The loading of community involvement (P30) alongside compensation, fencing, and non-lethal tools suggests that farmers in RTR buffer zones regard participatory governance as integral to effective mitigation. Extension efforts should therefore address both technical and institutional dimensions of conflict reduction (Barua et al., 2013).

Factor 3 (Conservation and Coexistence Orientation) reflects value-laden dimensions of AHWC perception. Its clean separation from Factor 1 confirms that perceived conflict severity and conservation orientation are empirically distinct. Farmers may simultaneously hold negative conflict perceptions and conservation-positive attitudes, a pattern that has practical implications for extension messaging: community norms and institutional engagement can reinforce conservation values even when conflict experiences are negative. Factor 4 (Contextual Appraisal of Wildlife Presence) is a preliminary three-item dimension covering encroachment as a conflict driver, economic benefits through ecotourism, and zoonotic disease risk. High pattern loadings (0.811–0.875) indicate strong inter-item coherence within this cluster, but its conceptual heterogeneity warrants caution in interpretation. Future studies with larger samples should examine whether this dimension holds consistently across different protected-area contexts. The inter-factor correlations (0.222–0.425) confirmed that the four dimensions are related but empirically distinct, justifying oblique rotation and supporting interpretation of the factors as correlated but non-redundant facets of AHWC perception. The scale was developed and validated in a single buffer zone context with a cross-sectional sample of 200 households, which constitutes the primary limitation. Generalisation of the factor structure to other protected areas, species assemblages, or ecological zones in India should not be assumed without further validation.

CONCLUSION

Developed through expert-based content validation (CVR with nine experts; 9 of 52 items removed), field-based item screening (Cronbach's β = 0.886 post-refinement), and Exploratory Factor Analysis on 200 farming households of Ranipur Tiger Reserve, Uttar Pradesh, the scale provides a validated diagnostic tool for extension workers and conservation planners. The four-factor structure reveals that perceived severity and beliefs about mitigation effectiveness are empirically separate constructs, with direct implications for extension programme design: interventions targeting mitigation uptake must address perceived effectiveness, while those aimed at reducing retaliatory behaviour must engage with the emotional and risk-related dimensions of conflict perception. Factor-wise scores allow practitioners to identify which perceptual

dimensions are most salient in a given community and to monitor attitude change following extension activities. Validation in other protected-area contexts across India is recommended to assess the generalisability of the factor structure and scoring norms.

DECLARATIONS

Ethics statement and consent to participate: The study was conducted in accordance with principals laid out in Helinski Declaration 1964 and its modifications. As the research was part of the project titled 'Assessment and Mitigation of Agriculture-Human-Wildlife Conflict in the Vicinity of National Park and Wildlife Sanctuaries of Uttar Pradesh' funded by the Uttar Pradesh Council of Agricultural Research (UPCAR), Lucknow the ethical issues were taken care by Departmental Advisory Board of Department of Agricultural Extension, BUAT, Banda from planning of the research to implementation. Participation was voluntary, and informed consent was obtained from all respondents. The confidentiality and anonymity of participants were strictly maintained throughout the research process.

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Research Tool

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Development of Multidimensional Sustainability Index for Women Self-Help Group Members in Rural Tamil Nadu

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HIGHLIGHTS

- Financial inclusion and economic sustainability emerged as the strongest dimensions of women SHG sustainability.
- Women SHG members exhibited a moderate level of multidimensional sustainability.
- The proposed MSI provides an objective tool for policy planning and rural development programmes.

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Keywords: Self-Help Groups, Sustainability, Rural women, Principal component analysis, Multidimensional sustainability.

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ABSTRACT

The significant role of Self-Help Groups (SHGs) in improving rural livelihoods and women's socio-economic status, limited empirical evidence exists on their multidimensional sustainability. A Multidimensional Sustainability Index (MSI) was constructed by utilizing PCA for examining the sustainability of women SHG members of Kancheepuram district in Tamil Nadu for 2025-2026. A multi-stage random sampling method was employed to collect the data from 320 women SHG members. Kaiser-Meyer-Olkin value (0.806) and the significant Bartlett's test of sphericity (= 3933.704, df= 780, $p<0.001$) indicated that the data was suitable for PCA analysis. Seven components contributed 53.04 percent of total variance. The average score of MSI was 0.5103 which suggested moderate sustainability. The weights contributing to the MSI was maximum in Financial Inclusion and Economic Sustainability (0.239) followed by Social Empowerment (0.148) and Managerial and Capacity Development (0.142). The study concluded that the proposed MSI provided a reliable framework for assessing the sustainability of women SHGs.

INTRODUCTION

Women's Self-Help Groups (SHGs) have gained significance in promoting of rural development and enhancing the socioeconomic status of rural women in India. Through mobilization of savings, access to institutional credit, entrepreneurship skills development, collective decision-making within groups, SHGs assist in improving the livelihoods and participation of women in the household and community activities. With the introduction of government programs like Self-Help Group-Bank Linkage Programme (SHG-BLP) and National Rural Livelihood Mission (NRLM) for rural women the reach of SHGs has been expanded further improving financial inclusion and livelihood opportunities. As per National Bank for Agriculture and Rural Development (2023) SHG-BLP is one of the successful tools to extend formal financial services to the financially weaker rural households. Although SHGs have contributed significantly to livelihood improvement and women's empowerment, a greater concern for SHGs is their long-term

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sustainability. It is not only about the financial performance of groups but also about the social cohesion, institutional support, leadership qualities, managerial competency, entrepreneurship capabilities, psychological health, and members' adaptation capacity to the changed environment. Both sustainable livelihood framework and women's empowerment theory explain that outcomes of sustainable livelihood arise from combination of financial, human, social, institutional and psychological capital; hence sustainability among women members of SHGs is understood as multidimensional construct and not as the economic indicator alone. Studies have shown that SHGs are positively impacting financial inclusion, income generation, entrepreneurship, household participation in decision making (Kobba et al., 2021; Al-Kubati, 2023; Arunkumar et al., 2023; Shrivastava et al., 2023; Angel Priya & Banumathi, 2024; Pandhare, 2024). In addition, SHG programmes promote women's empowerment through collective action, social participation, and improved decision-making capacity (Brody et al., 2017). Group participation in SHGs strengthens women's agency and household welfare (Kumar et al., 2022; Raghunathan et al., 2023); Similar positive impacts have been observed in Nepal and Kenya in areas like leadership, participation and institutional sustainability of women's groups (Shrestha, 2022; Njoroge et al., 2025). But most of these studies focus on SHG sustainability based on a few indicators like saving, income generation, loan repayment and empowerment.

The construction of sustainability indices for SHGs have been scarce. Das and Guha (2019) developed a sustainability index for SHGs in Assam by focusing primarily on organisational and financial indicators at the group level, with limited attention to member-level attributes such as psychological empowerment, institutional linkages, entrepreneurial capacity, and resilience. Principal Component Analysis (PCA) has been recognised as an effective statistical approach for assigning objective weights to multiple indicators while constructing composite indices (Kalaiarasi, 2022; Ngasainao & Jha, 2025). However, statistically weighted multidimensional sustainability indices at the individual member level remain limited, particularly in Tamil Nadu. Unlike earlier studies that assessed sustainability at the group level, the present study develops a Principal Component Analysis (PCA)-based Multidimensional Sustainability Index (MSI) to assess sustainability at the individual member level, quantify the relative contribution of each sustainability dimension, and test the hypothesis that sustainability among women SHG members is multidimensional.

METHODOLOGY

The study was conducted in the rural areas of Kancheepuram district, Tamil Nadu during 2025-2026 Study was conducted with the objective to study the status of sustainability women Self Help Group (SHG) members. Kancheepuram district was selected because women SHGs were actively functioning under the Mahalir Thittam and National Rural Livelihood Mission (NRLM) schemes. A multistage random sampling technique was followed. Three blocks with a higher number of functional women SHGs were selected randomly. Lists of SHGs functioning for more than three years were obtained from Mahalir Thittam, SHG federations, and the Department of Rural Development. A total of 320 women SHG members were selected for Principal Component Analysis (PCA), as a minimum sample size of 300 is generally considered adequate for obtaining stable factor solutions.

The sustainability of women SHG members was assessed using 40 indicators grouped under seven dimensions namely financial inclusion and economic sustainability, social empowerment, managerial and capacity development, institutional linkages, entrepreneurial sustainability, psychological empowerment and resilience and sustainability outlook. The indicators were identified through extensive review of literature on SHG sustainability and women empowerment and refined through consultations with agricultural extension experts. The structured interview schedule was pre-tested with women SHG members outside the study area to assess the clarity, relevance, sequencing, and feasibility of the statements. Based on the feedback received, ambiguous or difficult-to-understand statements were revised before finalising the structured interview schedule. Responses were on three-point continuum: Strongly Agree (3), Agree (2) and Strongly Disagree (1). Cronbach's alpha was 0.707 for the overall reliability of the structured interview schedule. The reliability coefficients of the seven dimensions ranged from 0.758 to 0.883 indicating acceptable internal consistency. The data suitability for PCA was confirmed with the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity.

$$w_i = \frac{L_i \times E_j}{\Sigma(L_i \times E_j)}$$

Where, w_i represents the weight assigned to the ith indicator, L_i is the factor loading, and E_j is the eigenvalue of the corresponding component. The observed values were normalized using the Min–Max method:

$$Z_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)}$$

Where, Z_{ij} = normalized value of the ith indicator for the jth respondent, X_{ij} = observed value, and min (X_i) and max (X_i) denote the minimum and maximum values of the ith indicator, respectively.

$$MSI = \sum_{i=1}^{n} w_i Z_{ij}$$

The MSI scores were subsequently used to assess the sustainability level of women SHG members and to determine the relative contribution of each sustainability dimension.

RESULTS

Reliability assessment and suitability of data for principal component analysis

The average scores were between 2.002 and 2.033 the respondents largely agreed with the sustainability assertions. Institutional Linkage has the greatest mean score, followed by entrepreneurial sustainability, while psychological empowerment has the lowest mean score. The standard deviations were small across dimensions, demonstrating modest heterogeneity in respondents' perception, and indicating a consistency in the results

Table 1. Descriptive Statistics of Sustainability Dimensions

Dimension	Mean	Standard Deviation (SD)
Financial Inclusion & Economic Sustainability	2.011	0.822
Social Empowerment	2.030	0.825
Managerial & Capacity Development	2.029	0.824
Institutional Linkage	2.033	0.822
Entrepreneurial Sustainability	2.032	0.825
Psychological Empowerment	2.002	0.821
Resilience and Sustainability Outlook	2.027	0.824

acquired from the research population. The descriptive statistics show that all seven sustainability aspects were covered with similar response patterns. The mean scores across the categories were generally comparable, showing that sustainability among women SHG members was not limited to a single factor but represented a balanced performance across the financial, social, institutional, managerial, entrepreneurial, psychological, and resilience aspects. This distribution offered a good foundation for multivariate investigation of the underlying structure of sustainability.

The descriptive statistics of the seven dimensions of sustainability are shown in Table 1. The mean values for each dimension of sustainability ranged from 2.002 to 2.033 on a three-point scale which suggested that respondents tended to agree with the statements of the different sustainability dimensions. Institutional Linkage got the highest mean value (2.033) followed by Entrepreneurial Sustainability (2.032), Social Empowerment (2.030), Managerial and capacity development (2.029), Resilience and sustainability outlook (2.027), financial inclusion and economic sustainability (2.011) and psychological empowerment (2.002).

Standard deviation of all dimensions ranged from 0.821 to 0.825, which implies a moderate variance among responses across all dimensions. The reliability of sustainability scale was computed using Cronbach's alpha coefficient. Table 2 provides the information on the same. The value of Cronbach's alpha was varied from 0.758 to 0.883 whereas the overall sustainability scale composed of 40 items gave a reliability coefficient of 0.707. In all dimensions, financial inclusion and economic sustainability had the highest internal consistency (= 0.883) followed by Institutional Linkage (= 0.803), Social Empowerment (= 0.788). Other dimensions had Cronbach's alpha value more than 0.75, implying a good internal consistency. Overall reliability coefficient of 0.707 revealed that the sustainability scale has an acceptable reliability to measure the multi-dimensional sustainability of women Self-Help Group members and proved the construct to be used in Principal Component Analysis and index construction.

Table 2. Reliability of the Sustainability Scale

Dimension	No. of items	Cronbach's Alpha
Financial Inclusion & Economic Sustainability	10	0.883
Social Empowerment	5	0.788
Managerial & Capacity Development	5	0.758
Institutional Linkage	5	0.803
Entrepreneurial Sustainability	5	0.769
Psychological Empowerment	5	0.768
Resilience and Sustainability Outlook	5	0.761
Overall sustainability scale	40	0.707

The appropriateness of the data for conducting PCA was tested using Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity prior to factor extraction (Table 3). It revealed that sampling adequate for multivariate analysis by yielding a KMO of 0.806 and that sufficient correlation exists between the variables in the study by the resulting significant value of Bartlett's Test of Sphericity ($p < 0.001$). The matrix hence can be concluded as suitable for the extraction of the underlying sustainability dimensions using the PCA.

Table 3. KMO and Bartlett's Test of Sphericity

Test	Value
Kaiser-Meyer-Olkin (KMO) Measure	0.806
Bartlett's Test Chi-square	3933.704
Degrees of Freedom	780
Significance (p-value)	0.000

Principal component analysis and development of the multidimensional sustainability index

Principal Component Analysis yielded seven components with eigenvalues larger than one, explaining a total variance of 53.043 percent (Table 4). Financial Inclusion and Economic Sustainability explained the biggest share of variation followed by Social Empowerment and Managerial and Capacity Development. The other components were Institutional Linkage, Entrepreneurial Sustainability, Psychological Empowerment and Resilience and Sustainability Outlook. The preserved components cumulatively explained the variation of the chosen measures that appropriately reflected the multifaceted character of sustainability among women SHG members. The component structure that was recovered indicated that each of the sustainability dimensions contributed separately to the overall construct but together are representative of the wider idea of sustainability. The components kept were in good agreement with the conceptual framework used for the investigation.

The weights of each sustainability dimension for the construction of the Multidimensional Sustainability Index (MSI) were estimated based on the factor loadings of the rotated component matrix and the respective eigenvalues of the retained components after the extraction of the principal components. Table 5 presents these statistically obtained weights. The weights reflect the proportionate importance of each sustainability facet to the overall sustainability index and were then used to calculate the weighted composite score for each responder. Financial Inclusion and Economic Sustainability earned the greatest weight (0.239) followed by Social Empowerment (0.148) and Managerial and Capacity Development (0.142). The other factors that also contributed to the composite score were; Institutional Linkage (0.135), Entrepreneurial Sustainability (0.120), Psychological Empowerment (0.111) and Resilience and Sustainability Outlook (0.105). The distribution of weights suggests that all seven aspects contributed to the evaluation of sustainability, but their proportional

Table 4. Principal components extracted through principal component analysis

Component	Eigenvalue	Variance Explained (%)	Cumulative Variance (%)
Financial Inclusion & Economic Sustainability	5.079	12.697	12.697
Social Empowerment	3.148	7.871	20.567
Managerial & Capacity Development	3.007	7.517	28.085
Institutional Linkage	2.871	7.177	35.262
Entrepreneurial Sustainability	2.538	6.346	41.608
Psychological Empowerment	2.352	5.880	47.488
Resilience and Sustainability Outlook	2.222	5.555	53.043

Table 5. PCA-derived Weights for the Multidimensional Sustainability Index

Dimension	Variance Explained (%)	Weight
Financial Inclusion & Economic Sustainability	12.697	0.239
Social Empowerment	7.871	0.148
Managerial & Capacity Development	7.517	0.142
Institutional Linkage	7.177	0.135
Entrepreneurial Sustainability	6.346	0.120
Psychological Empowerment	5.880	0.111
Resilience & Sustainability Outlook	5.555	0.105
Total	53.043	1.000

contribution varied according to the amount of variation explained by each component. The rotated component matrix showing the factor loadings of all 40 indicators on their respective components is provided in Table 7.

Sustainability status of women self-help group members

The scores of all sustainability categories were pooled and weighted using the PCA determined weights to produce the Multidimensional Sustainability Index. The aggregate mean MSI score was 0.5103 that indicates the studied women SHG members were moderately sustainable.

The distribution of respondents according to Multidimensional Sustainability Index is shown in Table 6. The respondents in the medium sustainability category were majority followed by the respondents in the high and low sustainability categories comparably few. Women SHG members had achieved a reasonable level of sustainability in the defined aspects, although individual performance disparities were still apparent, with the medium category dominating. The inclusion of responders in both the high and low sustainability categories showed variance in the extent to which sustainability had been attained among the members sampled.

Table 6. Sustainability Level of Women Self-Help Group Members Based on the Multidimensional Sustainability Index

Indicator		Mean MSI Score	
Multidimensional Sustainability Index (MSI)		0.5103	
MSI Score Range	Category	Frequency	Percentage
< 0.34	Low sustainability	35	10.94
0.34–0.66	Medium sustainability	243	75.94
> 0.66	High sustainability	42	13.12
Total		320	100

The observed distribution indicated that sustainability was a continuum rather than a homogeneous state among women SHG members. The categorisation offered a good framework for differentiating members according to their overall sustainability state and helped to identify groups needing additional developmental focus in future planning and programme execution.

The mean Multidimensional Sustainability Index (MSI) score of the respondents was 0.5103, indicating a moderate level of sustainability among the women Self-Help Group members. The distribution of respondents according to the MSI is presented in Table 6. A majority of the respondents (243; 75.94%) belonged to the medium sustainability category, followed by 42 respondents (13.12%) in the high sustainability category and 35 respondents (10.94%) in the low sustainability category. The results indicated that most women Self-Help Group members attained moderate levels of sustainability across the financial, social, managerial, institutional, entrepreneurial, psychological, and resilience dimensions. A comparatively smaller proportion of respondents was observed in the high sustainability category, while only 10.94 per cent of the respondents belonged to the low sustainability category. The distribution of respondents across the three sustainability categories demonstrated variation in the sustainability levels of the sampled women SHG members. The Multidimensional Sustainability Index effectively classified the respondents into low, medium, and high sustainability categories based on their composite sustainability scores (Ghai et al., 2026).

Rotated component matrix

The rotated component matrix (factor loadings) for all 40 sustainability indicators, obtained through Principal Component Analysis with Varimax rotation (Kaiser Normalization), is presented in Table 7, for greater transparency in the factor analysis underlying the Multidimensional Sustainability Index.

DISCUSSION

Women Self-Help Group (SHG) member's sustainability as a multidimensional construct with financial, social, managerial, institutional, entrepreneurial, psychological, and resilience sub-dimensions. The acceptable reliability score of measurement scale, adequacy of dataset to carry out PCA are the evidence in this respect. The successful extraction of seven principal component factors indicates that sustainability cannot be demonstrated by the economic outcomes alone but a interaction of several complementary dimensions. This is corroborated with the Sustainable Livelihood

Table 7. Rotated Component Matrix (Factor Loadings) for the 40 Sustainability Indicators

Principal Component	Indicators	Factor Loading Range	Identified Dimension
Component 1	FI1–FI10	0.643–0.731	Financial Inclusion & Economic Sustainability
Component 2	IL1–IL5	0.699–0.783	Institutional Linkage
Component 3	SE1–SE5	0.699–0.745	Social Empowerment
Component 4	ES1–ES5	0.679–0.744	Entrepreneurial Sustainability
Component 5	PE1–PE5	0.684–0.731	Psychological Empowerment
Component 6	MC1–MC5	0.663–0.744	Managerial & Capacity Development
Component 7	RS1–RS5	0.693–0.735	Resilience & Sustainability Outlook

Note: For better interpretation, only factor loadings ≥0.70 are presented. Varimax rotation with Kaiser Normalization was applied during PCA.

Frame work as there it suggests that sustainable outcome is produced through the interplay between human, social, human, institutional and psychological capital of the household. It is thus found by the Behera et al. (2026) that Principal Component Analysis can well reduce the large number of interrelated variables into limited factors/dimensions, and has proven the appropriateness in analyse multidimensional behaviour and socio economical trait.

The overall sustainability of women SHG members remains at a moderate level, indicating that SHGs improve livelihood opportunities but that greater efforts are still required to strengthen long-term sustainability through balanced development across all dimensions. Among the extracted dimensions, Financial Inclusion and Economic Sustainability contributes the highest proportion to the Multidimensional Sustainability Index because financial benefits such as regular savings, access to institutional credit, timely loan repayment, improved income, and financial discipline are immediate, tangible, and directly observable by members. These benefits strengthen household economic security and provide the foundation upon which other dimensions of sustainability gradually develop. Similar findings are reported by Angel Priya and Banumathi (2024) and Rajkumar et al. (2024), who identify financial inclusion and economic empowerment as the primary pathways through which SHGs improve women's livelihoods.

The dimensions of Social Empowerment and Managerial and Capacity Development emerge as the next major contributors to the sustainability index. These dimensions reflect the importance of collective participation, leadership development, capacity building, knowledge sharing, and continuous learning in strengthening women's social capital and managerial competence. Similar observations are reported by Kumar et al. (2022) Raghunathan et al. (2023) and Gupta et al., (2023).

Although Psychological Empowerment and Resilience and Sustainability Outlook contribute comparatively lower weights to the composite index, they remain essential for achieving long-term sustainability. Their comparatively lower contribution does not indicate lower importance; rather, it reflects the gradual nature of behavioural and psychological development. Unlike financial gains, which are realised immediately through SHG participation, psychological attributes such as self-confidence, self-efficacy, resilience, adaptability, and future orientation develop progressively through sustained involvement in SHGs and continuous social and institutional support. This interpretation is consistent with the Sustainable Livelihood Framework and Maslow's Hierarchy of Needs, which suggest that financial security forms the foundation for the gradual development of higher-order psychological capacities. Therefore, psychological empowerment and resilience become increasingly important in enabling women to cope with livelihood shocks, adapt to changing circumstances, and sustain long-term livelihood improvements.

The findings also agree with Ngasainao and Jha (2025), who advocate the use of multidimensional indices for livelihood assessment because they capture the combined influence of economic, social, institutional, and behavioural factors. Likewise, Maurya et al. (2025) demonstrate that Principal Component Analysis provides an objective method for assigning differential weights to socio-economic indicators. Therefore, the Multidimensional Sustainability Index developed in the present study provides a scientifically robust tool for researchers, extension professionals, policymakers, and development agencies to identify priority intervention areas and formulate evidence-based strategies for strengthening sustainable rural livelihoods among women SHG members.

CONCLUSION

The study reveals that sustainability among women Self-Help Group (SHG) members is multidimensional comprising financial, social, managerial, institutional, entrepreneurial, psychological and resilience dimensions. The Multidimensional Sustainability Index (MSI) provides an objective tool for sustainability assessment at the individual member level. Moderate sustainability status indicates the need for stronger institutional support, capacity building, enterprises promotion and development of resilience. The MSI can be integrated with NRLM monitoring to track members progress and used by SHG federations and NGOs to identify members who need targeted interventions. Extension agencies can also use the MSI to plan evidence-based training, resource allocation and livelihood support for improving long-term sustainability

DECLARATIONS

Ethics statement and consent to participate: The study was conducted in accordance with principals laid out in Helinski Declaration 1964 and its modifications. Department of Agricultural Extension and Communication, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu-603201, Tamil Nadu, India waived the ethical clearance. Participation was voluntary, and informed consent was obtained from all respondents. The confidentiality and anonymity of participants were strictly maintained throughout the research process.

Conflict of interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

Data availability statement: Data are available upon request from the corresponding as well as first author.

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Construction and Validation of a Livelihood Vulnerability Index for Agriculture-Human-Wildlife Conflict

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HIGHLIGHTS

- A scientifically validated Livelihood Vulnerability Index was developed for agriculture-human-wildlife conflict-affected farming households.
- The index comprised 57 sub-indicators under exposure, sensitivity, and adaptive capacity dimensions with reliability ($\alpha = 0.929$).
- The index provides a practical framework for identifying vulnerable households and prioritizing mitigation and livelihood support interventions.

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ABSTRACT

Agriculture-human-wildlife conflict (AHWC) can affect farming households through crop damage, livestock loss, protection costs and constraints on livelihood security. The study was undertaken in 2026 to develop and validate a Livelihood Vulnerability Index (LVI) for farming households exposed to AHWC. An initial pool of 79 sub-indicators was generated from literature review and expert consultation and organized a priori under exposure, sensitivity and adaptive capacity following the IPCC vulnerability framework. A relevancy schedule was circulated among 75 experts, of whom 45 returned complete responses. Sub-indicators were screened using Relevancy Weightage (RW), Mean Relevancy Score (MRS), Overall Mean Relevancy Score (OMRS) and Content Validity Ratio (CVR), with retention criteria of RW $\geq$ 0.80, MRS $\geq$ OMRS (2.40) and CVR $\geq$ 0.29. Fifty-seven sub-indicators were retained, 17 under exposure, 12 under sensitivity and 28 under adaptive capacity. The final instrument was arranged on a five-point continuum and pilot-tested with 50 farming households from a non-sample area. Cronbach's alpha was 0.929 for the overall index and 0.814, 0.812 and 0.864 for exposure, sensitivity and adaptive capacity, respectively. The findings supported the use of the index as a structured tool for field assessment of livelihood vulnerability associated with AHWC.

INTRODUCTION

Agriculture-human-wildlife conflict (AHWC) has become a major challenge for farming households living near forests and wildlife habitats. In many areas, wild animals frequently enter agricultural fields and cause damage to crops, livestock, and other farm resources. These incidents often result in economic losses, reduced farm productivity, and additional burden on farming families. Farmers also spend considerable time and resources on protecting crops and livestock from wildlife attacks. As a result, repeated wildlife conflicts affect not only agricultural production but also the livelihood security of rural households. Pereira et al. (2024) reported that human-wildlife interactions can increase livelihood vulnerability by affecting household resources, livelihood opportunities, and coping capacity. Vulnerability refers to the extent to which a household is likely to be affected by different

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stresses and its ability to cope with and recover from them. The Intergovernmental Panel on Climate Change (IPCC, 2007) explained vulnerability through three major dimensions, namely exposure, sensitivity, and adaptive capacity. Exposure refers to the degree of risk faced by household, sensitivity indicates the extent of its impact, and adaptive capacity represents the ability to cope with and recover from adverse situations. This framework has been widely used for vulnerability assessment. Minh et al. (2019) used the LVI to study household vulnerability under changing livelihood conditions. Similarly, Kumar and Mohanasundari (2025) assessed livelihood vulnerability among tribal communities using the LVI-IPCC framework. Zainab and Shah (2024) observed that the LVI and LVI-IPCC frameworks are widely used for assessment across different regions and sectors. Kumar et al. (2018) emphasized that livelihood vulnerability in wildlife-affected areas is influenced by ecological, social, and institutional factors. Indicator-based approaches have been widely used to assess livelihood risks and support evidence-based planning (Pandey & Jha, 2012). Mallappa and Gadde (2025) developed a tool to assess vulnerability among climate-sensitive farming communities based on the dimensions of exposure, sensitivity, and adaptive capacity. Sahu et al. (2026) emphasized the need for scientifically validated indices in agricultural research. However, most of the available vulnerability assessment tools have been developed primarily for climate change and other environmental stresses. The vulnerability tools reviewed for the study largely addressed climatic and environmental stresses, with limited attention to indicators specific to agriculture-human-wildlife conflict.

Human-wildlife conflict has been identified as a significant threat to rural livelihoods due to its adverse effects on crop production, livestock assets, household income, and food security (Rao et al., 2002). Similar observations have been reported by Meena et al. (2022) among households residing in the vicinity of Ranthambore Tiger Reserve. Despite the increasing impact of agriculture-human-wildlife conflict on farming households, a standardized and scientifically validated tool for assessing livelihood vulnerability in this context is not available. The study hypothesized that livelihood vulnerability arising from agriculture-human-wildlife conflict could be assessed through a multidimensional framework comprising exposure, sensitivity and adaptive capacity. The study was undertaken to develop and standardize a Livelihood Vulnerability Index for farming households affected by agriculture-human-wildlife conflict.

METHODOLOGY

The study was conducted in 2026 to construct and validate a Livelihood Vulnerability Index (LVI) for farming households affected by agriculture-human-wildlife conflict (AHWC). Relevant literature and consultation with subject matter specialists generated an initial pool of 79 sub-indicators. The dimensional structure was specified a priori from the IPCC vulnerability framework, and the sub-indicators were organized under exposure, sensitivity and adaptive capacity. A structured relevancy schedule containing the 79 sub-indicators was circulated among 75 experts. The panel comprised agricultural extension scientists and academicians, including Professors and Subject Matter Specialists, together with professionals having expertise in forestry and wildlife. From a total of 75 experts approached, 45 returned complete schedules, giving a usable response rate of 60.00 per cent. Incomplete schedules were excluded. Each sub-indicator was rated on a three-point continuum of Most Relevant, Relevant and Least Relevant, with scores of 3, 2 and 1, respectively. Relevancy Weightage (RW), Mean Relevancy Score (MRS) and Overall Mean Relevancy Score (OMRS) were computed (Sahu et al., 2026). Content Validity Ratio (CVR) was computed following Lawshe (1975), for this calculation, the Most Relevant response was treated as the essential-equivalent endorsement. For 45 experts, the minimum acceptable CVR was 0.29 at the 0.05 level (Ayre & Scally, 2014). Sub-indicators with RW $\geq$ 0.80, MRS $\geq$ OMRS and CVR $\geq$ 0.29 were retained. The OMRS was 2.40, resulting in 57 retained sub-indicators. The retained sub-indicators were arranged on a five-point continuum scored from 5 to 1. Higher scores for exposure and sensitivity represented greater livelihood vulnerability. Adaptive capacity operated in the opposite direction; hence, the scores of the 28 adaptive-capacity sub-indicators were reverse coded as X_R = 6-X, whereby scores of 5, 4, 3, 2 and 1 were converted to 1, 2, 3, 4 and 5, respectively. No additional normalization was applied because all sub-indicators used the same five-point scale. Mean scores were calculated separately for exposure, sensitivity and reverse-coded adaptive capacity, giving equal weight to the three dimensions. The Livelihood Vulnerability Index for the ith household was calculated as:

$$E_i = \frac{\sum_{j=1}^{17} X_{ij}}{17}$$

$$S_i = \frac{\sum_{j=1}^{12} X_{ij}}{12}$$

$$AC_i^R = \frac{\sum_{j=1}^{28} (6 - X_{ij})}{28}$$

$$LVI_i = \frac{E_i + S_i + AC_i^R}{3}$$

Where, E, S, and AC_R represent the mean exposure, sensitivity and reverse-coded adaptive-capacity scores, respectively. The index ranges from 1 to 5, with higher scores indicating greater livelihood vulnerability.

The finalized instrument was pilot-tested with 50 farming households from a non-sample area for reliability assessment. Internal consistency was assessed using Cronbach's alpha (Cronbach, 1951) for the overall index and separately for the three dimensions. The formulas used for relevancy and content-validity assessment were as follows:

$$\text{RW} = \frac{\text{MR} \times 3 + \text{R} \times 2 + \text{LR} \times 1}{\text{MPS}}$$

$$\text{MRS} = \frac{\text{MR} \times 3 + \text{R} \times 2 + \text{LR} \times 1}{\text{N}}$$

$$\text{OMRS} = \frac{\text{Sum of obtained Relevancy Score}}{\text{N} \times \text{S}}$$

$$CVR = \frac{Ne - N/2}{N/2}$$

Where, RW = Relevancy Weightage; MRS = Mean Relevancy Score; OMRS = Overall Mean Relevancy Score; CVR = Content Validity Ratio; MR, R and LR = Most Relevant, Relevant and Least Relevant responses; MPS = Maximum Possible Score; N = experts; and S = sub-indicators.

RESULTS

Relevancy analysis of sub-indicators

The relevancy assessment resulted in the retention of 57 of the 79 initially proposed sub-indicators, representing 72.15 per cent of the original pool. The overall mean relevancy score (OMRS) was 2.40. The screening retained 17 of 23 exposure sub-indicators, 12 of 16 sensitivity sub-indicators and 28 of 40 adaptive-capacity sub-indicators. Among the retained sub-indicators, Relevancy Weightage (RW) ranged from 0.82 to 0.93, Mean Relevancy Score (MRS) from 2.47 to 2.78 and Content Validity Ratio (CVR) from 0.29 to 0.60. The complete relevancy statistics and retention decisions for all 79 proposed sub-indicators are provided in Supplementary Table 1.

Table 1. Relevancy statistics and retention decisions for initial sub-indicators

S.N.	Code	RW	MRS	CVR	Decision
1.	EXP1	0.86	2.58	0.38	Retained
2.	EXP2	0.86	2.58	0.42	Retained
3.	EXP3	0.67	2.02	-0.24	Excluded
4.	EXP4	0.84	2.51	0.33	Retained
5.	EXP5	0.88	2.64	0.42	Retained
6.	EXP6	0.84	2.53	0.29	Retained
7.	EXP7	0.64	1.91	-0.47	Excluded
8.	EXP8	0.84	2.53	0.33	Retained
9.	EXP9	0.84	2.53	0.38	Retained
10.	EXP10	0.60	1.80	-0.56	Excluded
11.	EXP11	0.82	2.47	0.29	Retained
12.	EXP12	0.86	2.58	0.38	Retained
13.	EXP13	0.84	2.51	0.33	Retained
14.	EXP14	0.85	2.56	0.38	Retained
15.	EXP15	0.67	2.02	-0.24	Excluded
16.	EXP16	0.86	2.58	0.42	Retained
17.	EXP17	0.83	2.49	0.29	Retained
18.	EXP18	0.84	2.53	0.33	Retained
19.	EXP19	0.84	2.53	0.33	Retained
20.	EXP20	0.90	2.71	0.56	Retained
21.	EXP21	0.59	1.78	-0.51	Excluded
22.	EXP22	0.84	2.51	0.38	Retained
23.	EXP23	0.74	2.22	-0.07	Excluded
24.	S1	0.93	2.78	0.60	Retained
25.	S2	0.84	2.51	0.29	Retained
26.	S3	0.86	2.58	0.38	Retained
27.	S4	0.84	2.51	0.29	Retained
28.	S5	0.84	2.51	0.33	Retained
29.	S6	0.86	2.58	0.33	Retained
30.	S7	0.64	1.93	-0.33	Excluded
31.	S8	0.64	1.93	-0.38	Excluded
32.	S9	0.87	2.60	0.42	Retained
33.	S10	0.87	2.60	0.42	Retained
34.	S11	0.86	2.58	0.42	Retained
35.	S12	0.71	2.13	-0.24	Excluded
36.	S13	0.85	2.56	0.33	Retained
37.	S14	0.84	2.51	0.29	Retained
38.	S15	0.64	1.93	-0.42	Excluded
39.	S16	0.84	2.53	0.29	Retained
40.	AC1	0.82	2.47	0.24	Excluded
41.	AC2	0.84	2.53	0.33	Retained
42.	AC3	0.81	2.42	0.20	Excluded
43.	AC4	0.84	2.53	0.33	Retained
44.	AC5	0.86	2.58	0.47	Retained
45.	AC6	0.86	2.58	0.47	Retained
46.	AC7	0.88	2.64	0.42	Retained
47.	AC8	0.63	1.89	-0.42	Excluded
48.	AC9	0.84	2.51	0.33	Retained
49.	AC10	0.85	2.56	0.38	Retained
50.	AC11	0.64	1.91	-0.51	Excluded
51.	AC12	0.83	2.49	0.33	Retained
52.	AC13	0.85	2.56	0.38	Retained
53.	AC14	0.86	2.58	0.42	Retained
54.	AC15	0.66	1.98	-0.42	Excluded
55.	AC16	0.63	1.89	-0.47	Excluded
56.	AC17	0.84	2.53	0.33	Retained
57.	AC18	0.82	2.47	0.33	Retained
58.	AC19	0.85	2.56	0.33	Retained
59.	AC20	0.61	1.84	-0.56	Excluded
60.	AC21	0.83	2.49	0.33	Retained
61.	AC22	0.84	2.51	0.33	Retained
62.	AC23	0.85	2.56	0.38	Retained
63.	AC24	0.64	1.93	-0.33	Excluded
64.	AC25	0.85	2.56	0.33	Retained
65.	AC26	0.85	2.56	0.38	Retained
66.	AC27	0.84	2.53	0.33	Retained
67.	AC28	0.70	2.09	-0.24	Excluded
68.	AC29	0.87	2.60	0.38	Retained
69.	AC30	0.84	2.53	0.33	Retained
70.	AC31	0.83	2.49	0.33	Retained
71.	AC32	0.83	2.49	0.29	Retained
72.	AC33	0.87	2.60	0.42	Retained
73.	AC34	0.87	2.60	0.47	Retained
74.	AC35	0.86	2.58	0.33	Retained
75.	AC36	0.64	1.91	-0.38	Excluded
76.	AC37	0.87	2.62	0.47	Retained
77.	AC38	0.72	2.16	-0.33	Excluded
78.	AC39	0.84	2.51	0.33	Retained
79.	AC40	0.60	1.80	-0.51	Excluded

Table 1 contd...

(EXP = Exposure, S = Sensitivity, AC = Adaptive Capacity, RW = Relevancy Weightage, MRS = Mean Relevancy Score, CVR = Content Validity Ratio)

Exposure dimension

The exposure dimension retained 17 of the 23 proposed sub-indicators (73.91%), as presented in Table 2. The retained sub-indicators represented six indicators which were wildlife presence, crop raiding, livestock predation, conflict occurrence, cropping risk and grazing risk. Cronbach's alpha for the exposure dimension was 0.814, indicating satisfactory internal consistency.

Table 2. Validated sub-indicators under the exposure dimension

Code	Sub-indicator	Statement
Wildlife Presence		
EXP1	Field intrusion	Level of wildlife intrusion into cultivated fields
EXP2	Movement corridors	Presence of wildlife movement corridors near agricultural land
EXP4	Fear of wildlife presence	Level of fear experienced due to the presence of wildlife near agricultural fields
Crop Raiding		
EXP5	Crop damage	Severity of crop damage caused by wildlife
EXP6	Crop feeding	Extent of crop consumption by wildlife
EXP8	Repeated attacks	Frequency of recurring wildlife attacks on crops
Livestock Predation		
EXP9	Grazing attacks	Severity of wildlife attacks on grazing livestock
EXP11	Predation risk	Level of risk of livestock predation by wildlife
Conflict Occurrence		
EXP12	Seasonal incidents	Occurrence of wildlife conflicts during specific seasons
EXP13	Conflict hotspots	Degree of exposure to wildlife conflict-prone locations
EXP14	Wildlife congregation	Intensity of wildlife congregation near agricultural areas
Cropping Risk		
EXP16	Attractive crops	Extent of cultivation of crops preferred by wildlife
EXP17	Forest proximity	Degree of proximity of agricultural land to forest areas
EXP18	Cropping adjustment	Extent of changes made in cropping practices due to wildlife threats
EXP19	Crop substitution	Extent of adoption of alternative crops to reduce wildlife damage
Grazing Risk		
EXP20	Forest grazing	Level of livestock exposure through grazing near forest boundaries
EXP22	Predator sightings	Occurrence of predator sightings in grazing locations

Cronbach's α for the exposure dimension = 0.814.

Sensitivity dimension

The sensitivity dimension retained 12 of the 16 proposed sub-indicators (75.00%), as presented in Table 3. The retained sub-indicators represented four indicators which were production impact, protection burden, economic loss and livelihood dependence. Cronbach's alpha for the sensitivity dimension was 0.812, indicating satisfactory internal consistency.

Adaptive capacity dimension

Relevancy and content-validity assessment retained 28 of the 40 adaptive-capacity sub-indicators (70.00%), as presented in Table 4. The retained sub-indicators were distributed across ten indicators covering livestock management, physical protection, crop guarding, deterrent practices, institutional access, extension support, financial coping, compensation access, community cooperation and conflict

Table 3. Validated sub-indicators under the sensitivity dimension

Code	Sub-indicator	Statement
Production Impact		
S1	Yield reduction	Magnitude of crop yield reduction due to wildlife damage
S2	Growth damage	Severity of crop damage during the growth stage
S3	Harvest damage	Severity of crop damage during harvesting
S4	Repeated field damage	Magnitude of recurring damage in the same agricultural fields
Protection Burden		
S5	Guarding time	Burden of time devoted to protecting crops from wildlife
S6	Night vigilance	Burden of night-time crop protection activities
Economic Loss		
S9	Crop loss	Magnitude of crop production losses due to wildlife damage
S10	Livestock loss	Magnitude of livestock losses due to wildlife attacks
S11	Protection expenses	Magnitude of expenditure incurred on wildlife protection measures
Livelihood Dependence		
S13	Crop reliance	Degree of dependence on crop farming for livelihood
S14	Livestock reliance	Degree of dependence on livestock rearing for livelihood
S16	Income instability	Magnitude of instability in household income resulting from wildlife conflict

Cronbach's α for the sensitivity dimension = 0.812.

Table 4. Validated sub-indicators under the adaptive capacity dimension

Code	Sub-indicator	Statement
Livestock Management		
AC2	Shed safety	Adequacy of livestock shelters in preventing wildlife attacks
AC4	Herd supervision	Level of supervision of livestock during grazing to reduce wildlife predation risk
Physical Protection		
AC5	Farm fencing	Effectiveness of farm fencing in preventing wildlife intrusion
AC6	Physical barriers	Effectiveness of trenches and barriers in restricting wildlife movement
AC7	Barrier maintenance	Adequacy of maintenance of protective structures
Crop Guarding		
AC9	Manual guarding	Level of effort devoted to guarding crops against wildlife
AC10	Watch posts	Adequacy of watch posts for monitoring wildlife activity
AC12	Community guarding	Level of participation in collective guarding activities
Deterrent Practices		
AC13	Noise deterrents	Effectiveness of sound-based wildlife deterrents
AC14	Light deterrents	Effectiveness of light-based wildlife deterrents
Institutional Access		
AC17	Scheme awareness	Level of awareness regarding wildlife compensation and support schemes
AC18	Incident reporting	Level of reporting wildlife conflict incidents to authorities
AC19	Institutional response	Adequacy of response received from responsible agencies
Extension Support		
AC21	Awareness programmes	Extent of participation in wildlife awareness programmes
AC22	Training exposure	Extent of exposure to wildlife conflict mitigation training
AC23	Advisory services	Availability of advisory services on wildlife conflict management
Financial Coping		
AC25	Savings availability	Availability of household savings for coping with wildlife-related losses
AC26	Credit access	Accessibility of institutional credit during wildlife-related emergencies
AC27	Recovery ability	Capacity of the household to recover from wildlife-related losses
Compensation Access		
AC29	Claim awareness	Level of awareness regarding compensation claim procedures
AC30	Claim submission	Ease of submitting compensation claims
AC31	Payment timeliness	Timeliness of compensation payments received
AC32	Payment adequacy	Adequacy of compensation received for losses suffered
Community Cooperation		
AC33	Mutual support	Availability of support from community members during wildlife conflict situations
AC34	Information sharing	Level of information sharing regarding wildlife movement and threats
AC35	Collective protection	Level of participation in collective crop and livestock protection efforts
Conflict Awareness		
AC37	Wildlife awareness	Level of awareness regarding risks associated with wildlife conflict
AC39	Safety practices	Extent of adoption of recommended practices for reducing wildlife conflict

Cronbach's α for the adaptive capacity dimension = 0.864.

awareness. The adaptive capacity dimension incorporated not only household-level preventive and coping practices but also access to institutional, financial, informational and collective resources that may assist farming households in managing and recovering from wildlife-related losses. The dimension recorded a Cronbach's alpha coefficient of 0.864, indicating satisfactory internal consistency.

DISCUSSION

The three-dimensional structure of the index reflects an important feature of agriculture-human-wildlife conflict, households are affected not only by the frequency of wildlife encounters but also by the consequences of those encounters and the resources available to manage them. This interpretation is consistent with the vulnerability framework of IPCC (2007), in which exposure, sensitivity and adaptive capacity represent distinct but related aspects of vulnerability. Similar applications of this framework have been reported in livelihood studies by Hahn et al. (2009) and Pereira et al. (2024).

The exposure dimension represents the circumstances that bring farming households into contact with wildlife-related risk. Crop raiding, livestock predation, proximity to forest areas and repeated conflict events are especially relevant in farming systems situated close to wildlife habitats. Meena et al. (2022) reported comparable crop and livestock losses around Ranthambore Tiger Reserve, while Pereira et al. (2024) showed that repeated human-wildlife interactions can influence livelihood vulnerability across

protected-area landscapes. The retained exposure indicators extend assessment beyond the occurrence of a single loss and account for the setting and recurrence of conflict.

Sensitivity captures the extent to which wildlife conflict affects farm production and household livelihood. Yield reduction, livestock loss and protection expenditure represent direct effects, whereas time spent guarding fields and dependence on crop and livestock income reflect burdens that may persist beyond an individual conflict event. Barua et al. (2013) similarly described opportunity costs and other indirect effects of human-wildlife conflict. Including these aspects is useful because households exposed to similar wildlife pressure may experience different levels of livelihood disruption depending on their dependence on affected farm enterprises.

Adaptive capacity represents the means available to prevent losses, cope with conflict and recover afterwards. The retained indicators cover farm-level protection, access to extension and institutional support, financial coping, compensation, community cooperation and conflict awareness. These elements are relevant to agricultural extension because farmers' responses to wildlife conflict depend not only on individual practices but also on access to information, services and institutional support. Nyhus (2016) and Pereira et al. (2024) likewise emphasize the role of management and institutional arrangements in shaping responses to human-wildlife conflict. Verma et al. (2026) also highlighted adaptive coexistence behaviour as an important aspect of farmer's wildlife-conflict tolerance.

The reliability coefficients obtained for the three dimensions indicate satisfactory internal consistency, and the overall coefficient supports the use of the items as parts of a common livelihood-vulnerability instrument. Similar expert-based screening followed by reliability assessment has been used in tool-development studies (Shitu et al., 2018; Gupta et al., 2023; Vijayan et al., 2022; Vijayan et al., 2023; Mallappa & Gadde, 2025; Sahu et al., 2026). The present validation establishes content relevance and internal consistency of the instrument, its performance across different ecological and institutional settings remains to be examined through wider field application.

CONCLUSION

The developed index represents livelihood vulnerability arising from agriculture-human-wildlife conflict through 57 sub-indicators covering exposure, sensitivity and adaptive capacity. Its structure recognizes that households facing similar wildlife pressure may differ in the losses they experience and, in the resources, available to cope with those losses. The satisfactory reliability obtained for the overall instrument and each dimension supports its use for household-level field assessment. The index can help extension personnel, researchers and agencies identify whether vulnerability is associated mainly with repeated exposure, livelihood sensitivity or limited capacity to cope and recover. Such information can guide locally appropriate measures related to crop and livestock protection, advisory support, compensation access, financial coping and community action. Further application in different conflict settings can examine its wider usefulness.

DECLARATIONS

Ethics approval and informed consent: The study was conducted in accordance with principals laid out in Helsinki Declaration 1964 and its modifications. The ethical issues were taken care by Departmental Advisory Board of Department of Agricultural Extension, BUAT, Banda. Informed consent was obtained from the experts and farming households before data collection. The confidentiality and anonymity of participants were strictly maintained throughout the research process.

Conflict of interest: The authors declare no conflict of interest.

Consent for publication: All authors approved the final manuscript and consented to its publication.

Data availability statement: The data supporting the findings of this study are available from the corresponding author on reasonable request.

Authors' Contribution: Gyanendra Singh: Investigation, data collection, analysis and manuscript preparation; A. P. Verma: Conceptualization, supervision and manuscript review; B. K. Gupta: Methodology, supervision and review; Gaurav Shukla: Statistical analysis and validation; Rohit Chaudhary: Wildlife-domain inputs and manuscript review. All authors read and approved the final manuscript.

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A Way Forward towards Sustainable Youth Development and Empowerment by Contemplating the Impediments

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HIGHLIGHTS

- Advocates youth-centric and location-specific policy interventions to strengthen sustainable livelihood development and agricultural entrepreneurship.
- Identifies essential physical, technical, social, and institutional constraints that impede youth participation in sustainable agriculture.
- Suggests strengthening training infrastructure, market-oriented skill development, and institutional support systems to enhance youth empowerment.

ARTICLE INFO

Keywords: Agricultural skill development, Rank based quotient, Rural youth, Sustainable livelihood development, Technical constraints.

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ABSTRACT

Success in achieving food security, environmental sustainability and rural development depends on the active involvement of young people from rural areas in sustainable agriculture. This research examines the problems of sustainable farming and livelihood improvement among young people in the Terai region of West Bengal. Two blocks from Cooch Behar and Malda districts were selected using purposive and random sampling method and 200 respondents were selected. A structured interview schedule supplemented by field observations and open-ended youth suggestions was used to elicit perceived constraints. Constraints were classified under physical, technical, social and institutional dimensions and severity of the constraints were analysed using the Rank Based Quotient (RBQ) technique. The results showed that the biggest obstacle to youth involvement in sustainable agriculture were technical constraints. The main problem areas identified were lack of training institutions in the area, non-location specific training programs, poor connectivity between training agencies and rural youth and lack of infrastructure facilities. These are interrelated problem areas which hamper the interest and participation of youth in agricultural innovation. The study calls for region-specific Skill Development Programme and institutional support system for improving the sustainable livelihoods of the youth in the rural areas.

INTRODUCTION

In the changing agricultural scenario sustainability of agriculture and development of youth are intricately depending upon each other to contribute the livelihood of small holders in third world countries like India (Mohanty et al., 2025). The importance of youth participation in sustainable agriculture is well documented but still the limited involvement of youth in agriculture is raising the concern

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for the future of farming and livelihood (Rana et al., 2025). Sustainability is the ability to sustain oneself for a long enough period of time. Sustainable is a state of preservation or improvement of the resource productivity on a long-term basis to enable a family or communities to survive through chronic situation (Sajid et al., 2019). The term is referred to as livelihood as opposed to job or even source of income. To begin with, the majority of rural population are employed in farming either as farmers or farm workers or receive non-farm employment opportunities only seasonally and in most cases part time (Singh et al., 2023). Secondly, people and families derive their source of livelihood from various sources which constitutes the rural people of the world's livelihood basis (Joshi & Kashyap, 2020). Sustainable livelihood development has emerged as a crucial component of the global poverty eradication and improving economic development (Sati & Vangchhia, 2016; Kumar et al., 2023). To realize long-term economic stability and environmental health, sustainable livelihood development is critical (Pradhan et al., 2021). It puts into focus the latent potential of individuals in regard to their ability, social networks, physical and financial resources and the capacity to shape fundamental institutions (Dagar & Upadhyay, 2022). The aim of this paper is thus to explore these constraints (physical, technical, social and institutional) in greater depth and propose ideas on how to overcome them in order to achieve the overall goal of sustainable development.

METHODOLOGY

The study was conducted in two blocks of Cooch Behar district and two blocks of Malda district in 2022. The selection of such districts was based on the concept that the young people in the events were playing a very important role in making the farming business more profitable so that income and livelihood in the rural situation became better. In the case of the respondents of the present study, the respondents were selected by following multi stage sampling and simple random sampling method. The sampling procedure followed to select the district was purposive sampling and blocks from each district was simple random sampling. Eight villages were selected from the chosen blocks with the help of simple random sampling method. A detailed list of all the youth engaged in the farm was prepared in selected villages. Two hundred farm youth (including twenty-five youth from each village) were randomly selected as respondents of the current study from this exhaustive list. The data collected were then analysed, tabulated and summarised using the "Rank Based Quotient" (RBQ) technique developed by Sabarathnam (1988) which involves ranking of constraints and converting the ranks into one common index of perceived constraints. The procedure used was: (1) an extensive list of constraints under each of the 4 dimensions (physical, technical, social and institutional) was first formulated with the assistance of subject matter experts and literature review, and with some preliminary discussions with the farm youth; (2) each respondent was then asked to independently rank all constraints within a given dimension, from most serious (rank 1) to least serious (rank 4); (3) for each constraint, the number of respondents assigning a rank (fi) was tabulated and converted into an RBQ score using the formula given below; and (4) constraints were ordered within each dimension according to their RBQ score; with highest score as the most seriously perceived constraint. The formula used was:

$$RBQ\ (\%) = \frac{\sum_{i=1}^{n} fi(n+1-ri)}{N \times n} \times 100$$

Where, fi = the frequency of respondents assigning the i th rank to the constraint, ri = the rank position (1, 2, 3…n) assigned to the constraint, N = the total number of respondents, n = the number of ranks.

RESULTS

Physical impediments

Table 1 shows the skill development of rural youth in case of sustainable agricultural development is mostly impacted by the physical infrastructural facilities available at the grassroot level. The analysis inferred that absence of nearby training institutes is the foremost perceived constraint related to skill development of rural youth for sustainable agriculture development (83.30). Due to lack of good infrastructure for skill training (82.90) contributed many fold for enhancing the problematic ecosystem. Followed by the perceived problem of inadequate infrastructure facility nearby (71.70) for the rural youth. Further, scarcity of facilities for input procurement (35.30) and lack of transportation facilities (26.70) were found to be relatively less severe constraints.

Technical impediments

As seen in Table 1, non-location-specific and unrelated to rural youth needs of imparted trainings (94.88) was considered the worst technical constraint. Limited opportunities for updated agricultural knowledge and skills were next (63.25) followed by repetition of similar skill development programmes from different agencies (56.75). Difficulty in accessing land information, was the least severe constraint (35.00). The results showed that the current training programs do not meet the needs and demands of the local community and the new technologies in the farming sector, which limits their effectiveness for rural youth.

Social impediments

Table 1 shows that lack of relationship between training institutes and rural youth (96.49) was perceived as the most severe social constraint. Second, was the inability to accept changes in traditional and cultural practices (77.00), showing the role of social norms in the acquisition of new skills and technologies. Fraud, dishonesty and corruption in society (53.08), lack of supportive social services (52.33) constituted other constraints. Lack of motivation to learn new skills (43.59) and the presence of competition and envy (37.34) were lower ranked.

Institutional impediments

As shown in Table 1, the institutional constraint that was found to be the most problematic in skill development among the rural youth was limited infrastructure (91.64). Following this, a lack of monitoring following training (81.21) and challenge in accessing resources like funding and market information (77.07). The lack of market relevant short courses (64.00) was also identified as a key

Table 1. Impediments associated with skill development of farm youth

S.No.	Impediments	RBQ	Rank
	Physical Impediments		
1.	Absence of nearby training institute	83.30	1st
2.	Inadequate infrastructure facility nearby	71.70	3rd
3.	Lack of transportation facility	26.70	5th
4.	Scarcity of facility for input procurement	35.30	4th
5.	Lack of good infrastructure for skill training	82.90	2nd
	Technical Impediments		
1.	Limited opportunity for getting up-to-dateagricultural knowledge and skill	63.25	2nd
2.	Imparted trainings are not location specific andnot related to the young generation	94.88	1st
3.	Similar type of skill development programmesfrom different agencies	56.75	3rd
4.	Difficulty in accessing land information	35.00	4th
	Social Impediments		
1.	Inability to accept change in traditional andcultural practices	77.00	2nd
2.	Lack of supportive social services	52.33	4th
3.	Fraud, dishonesty, and corruption in the society	53.08	3rd
4.	Absence of motivation and willingness to acquirenew skills	43.59	5th
5.	Lack of relation between training institute andrural youth	96.49	1st
6.	Presence of competition & envy	37.34	6th
	Institutional Impediments		
1.	Difficulty in accessing resources such as financeand market information	77.07	3rd
2.	Limited youth groups andassociations/cooperatives	40.22	6th
3.	Inadequate and non- technical staff in the institute	40.36	5th
4.	Lack of market-relevant short courses offered	64.00	4th
5.	Lack of monitoring after training	81.21	2nd
6.	Focused on passive participation	25.58	7th
7.	Limited infrastructure	91.64	1st

concern. The other constraints such as poor technical staff (40.36), small size of youth groups and cooperatives (40.22) and passive participation (25.58) were seen as less serious.

Suggestions

Rural youths' recommendations for supporting the adoption of innovations in agriculture, including precision farming, reflected a visionary approach and problem-solving skills among young people. They recommended regular training sessions, model farms and field demonstrations, which indicates their preference for experiential and peer learning methods, as found by (Prajapati et al., 2025) that participatory learning platforms have a significant impact on smallholder's uptake. Another strong suggestion was on livelihood diversification, incorporating allied activities such as



Figure 1. Word Cloud of suggestion perceived by rural youth during the study for the sustainable livelihood development

hydroponics, aeroponics, mushroom cultivation, poultry farming, and other micro-enterprises along with traditional crop cultivation were to overcome economic vulnerability and seasonal migration by young people. The combination proved most successful when the less complex traditional strategies (such as organic composting) were supplemented with scientific tools. These types of combinations ensure that farming was more productive and that they retain the cultural identity and ecological sustainability (Malapane et al., 2024) assert that the knowledge systems of indigenous people could turn farming innovations more ecologically and culturally sustainable. Youth recognise that the challenges of non-coherent support networks and market access were barriers to scaled-up sustainable practices. This view corroborates arguments made by (Ezeudu & Obimbua, 2024) which highlighted the need for better market linkage and a coordinated institutional support in the development of sustainable agriculture particularly in developing countries.

DISCUSSION

The have multidimensional and interconnected nature and is most severe in the technical constraint. The prevalence of non-location-specific training programmes indicates that current training programmes in the study area might not adequately address their local farming context, resources and the livelihood goals of rural youth. This mismatch will most likely result in a diminished value for training which will limit the application of training in sustainable farming practices. The same findings were reported by Ramjiyani et al. (2015) and Kwenye and Sichone (2018) who observed that lack of technical guidance may dissuade the youth from taking part in the agricultural sector. Additional constraints were seen as physical such as lack of training institutions and poor infrastructure. The findings indicate that access to training facilities, particularly in rural areas where infrastructure and transportation are less developed, may lead to a greater amount of time and effort spent in participating in training. This means opportunities for ongoing training and access to new ideas in agriculture could be decreased. The result is similar to the one reported by Venkatesan et al. (2018).

The lack of linkages with training institutions and the rural youth was the most critical social constraint. The result could be due to poor communication and interaction between the extension agencies and rural youth in the study areas, which may make them less aware of the training opportunities and also make it difficult to gain continuous technical support. Similarly, the reluctant attitude towards change in the traditional farming methods suggests that the social norms could affect the adoption of better farming technologies. Similar results were obtained by Girish et al. (2019); Kobba et al. (2020); Rohila et al. (2021) and Subham et al. (2024).

The institutional set-up such as inadequate access to market information, finance, and support after the training has been delivered, and limited infrastructure, indicate that there are still obstacles to implementing acquired skills. The results suggest that training alone may not be enough to achieve the required results unless there is on-going technical guidance and increased coordination among extension, financial and market-support institutions. Kumar et al. (2023); Das et al. (2025); Sulistyowati et al. (2026) reported similar observations. As a result of the selected districts, the findings have shown the importance of extending the practice of strengthening location-specific trainings, coordination between institutions and improving the quality of rural training facilities for sustainable livelihood development of the youth in the rural areas.

There are some limitations of this study that need to be taken into account when interpreting the results. The two districts were purposively selected, and blocks and villages within the districts were randomly selected, therefore the results were drawn from a purposive geographic base, and are more representative of similar agro-socioeconomic settings in the Terai than of rural youth in general. In the RBQ technique, the ranking of constraints reflects respondents' perceived severity of each constraint relative to the others, rather than testing statistical relationships between the constraints, causal explanations as to why some constraints may be more severe, or the possibility of comparing across sub-groups of youth. No inferential statistics were used and the results should therefore be regarded as a constraint analysis based on current perceptions and for use with extension programming at the region level, not as a test of theoretical relationships. These findings can be extended to further studies employing inferential and comparative or longitudinal design that will explore the factors underlying constraint severity.

CONCLUSION

This study looked at the limitations which impede the sustainable livelihoods of rural youth in agriculture in Cooch Behar and Malda districts in West Bengal. The results showed that technical constraints were the most important obstacles; thus, there was a significant mismatch between the innovations available for agriculture and the ability of the rural youth to apply them successfully. Fewer young people are involved in agriculture due to poor access to relevant training, extension and modern technologies. Social and institutional factors are the constraints that further demoralize the farmers' investment in the long run because they make farmers less accessible to support systems, resources and opportunities. The findings reveal the importance of an all-encompassing approach that brings together technologies and innovations of precision agriculture, ongoing training and education, improved extension services, and local governance. An enabling environment for the participation of youth in agriculture is fundamental to sustainable rural development. As the districts were selected purposively, the findings should not be generalized beyond similar agro-ecological and socio-economic settings.

DECLARATIONS

Ethics approval and informed consent: This research was carried out in accordance with the principles of social science research, with the observance of ethical norms. The committee of Department of Agricultural Extension, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal waived the ethical approval. The procedure of the research was the personal interview method which all participants consented to and gave their informed consent before the research was conducted.

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Authors' contribution: Biman Maity conducted the field investigation, data collection, statistical analysis. Kausik Pradhan led the study and participated in research design and results interpretation. Chigilipalli Mounika, Marimuthu Praveenkumar, Swapnamay Ghosh, and Ajay Kumar Prusty helped in literature review, data interpretation, manuscript preparation and editing. Each author read and approved the last manuscript.

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Marketing, Communication and Production Constraints Faced by Vegetable Growers in Western Uttar Pradesh

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HIGHLIGHTS

- Price fluctuation and lack of remunerative prices emerged as the most severe marketing constraint among vegetable growers (CSI = 87.78%).
- Lack of technical and market-related information ranked first among communication constraints (CSI = 83.15%).
- High cost of fertilizers and nutrient management inputs were the leading production constraint (CSI = 87.04%).
- Economic motivation and information-seeking behaviour significantly reduced the overall constraint level.

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Keywords: Communication constraints, Constraint severity index, Marketing behaviour, Marketing constraints, Production constraints, Vegetable cultivation, Vegetable growers.

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ABSTRACT

Vegetable cultivation played a vital role in farm income, employment and nutritional security in India. Growers, however, faced multiple production and marketing challenges, yet evidence on their relative severity in Western Uttar Pradesh remained limited. The study was undertaken during 2025 to analyse marketing, communication and production constraints among vegetable growers and to examine factors influencing their overall constraint level. An ex post facto design was employed in Meerut and Bulandshahr districts of Western Uttar Pradesh. Data were collected from 180 growers through multistage sampling using a pre-tested interview schedule of established validity and reliability. Constraint Severity Index (CSI), Pearson correlation and stepwise regression were used. Price fluctuation and lack of remunerative prices was the most severe marketing constraint (CSI = 87.78%), lack of technical and market-related information the leading communication constraint (CSI = 83.15%) and high cost of fertilizers and inputs the foremost production constraint (CSI = 87.04%). Economic motivation, information-seeking behaviour, annual income and landholding significantly influenced the overall constraint level, jointly explaining 44.10 per cent of the variation. Stronger extension support, reliable market information and timely access to quality inputs are recommended.

INTRODUCTION

Vegetables contribute substantially to food and nutritional security, employment and farm income in India, and their high yield and profitability have drawn farmers towards vegetable-based diversification. India is the world's second-largest producer, and with growing health awareness and urbanisation, demand continues to rise (Noopur et al., 2023). Vegetable enterprises are internationally regarded as a high-value route out of rural poverty, though their profitability rests on functioning input, information and marketing institutions (Schreinemachers et al., 2018). Uttar Pradesh is a leading producing state, supplying urban centres across northern India.

Expansion in area has not been matched by improvement in profitability. Perishability makes growers dependent on reliable transport, storage, market infrastructure and timely price

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information; lacking these, produce is sold immediately after harvest at unfavourable prices. Kumar et al. (2019) reported inadequate market information, high transport costs, delayed payments, poor storage and price fluctuation as major constraints, and Anamika et al. (2023) reported price instability and lack of cold storage among tomato growers.

The difficulties extend well beyond marketing. Distant markets, trader exploitation and want of storage depress marketing performance (Raina et al., 2011; Mishra et al., 2012; Das et al., 2014), while low harvest prices, poor seed quality and rising labour costs are leading production constraints (Pandit & Basak, 2013; Yadav et al., 2018; Gireesh et al., 2019). Shah and Ansari (2020) show that lengthy channels and weak price information reduce marketing efficiency. Gupta et al. (2020) trace production shortfalls to inadequate technical knowledge and weak extension services, while Sahoo et al. (2023); Verma et al. (2025) and Chaudhary et al. (2025) report high input costs, labour shortage and limited information access. Institutional and digital correctives are proposed. Producer organisations are expected to shorten value chains and improve bargaining position, though thin capital and small scale limit their performance (Trebbin, 2014; Kumar et al., 2023), while uptake of information and communication technologies is itself conditioned by education, landholding and social participation (Mittal & Mehar, 2016; Panda et al., 2019). Tripathi et al. (2025) similarly report that limited awareness and poor price information restrict farmers' participation in electronic marketing platforms.

Such studies are numerous, yet the three domains are almost always examined separately, and communication has rarely been placed alongside marketing and production in a single severity framework. Evidence from elsewhere is also not readily transferable to the Western Plain Zone, whose setting is distinctive: assured canal and tubewell irrigation sustain near year-round supply, fragmented holdings keep marketable surplus low, and proximity to the Delhi National Capital Region gives access to large terminal markets reached mainly through dense layers of commission agents rather than organised aggregation. Severity in such a peri-urban, market-integrated setting is therefore likely governed by mechanisms different from those in interior and hill regions, where most comparable studies are located.

METHODOLOGY

The study was conducted during 2025 in the Western Plain Zone of Uttar Pradesh, using an ex post facto design, since the constraints investigated had already manifested and were not amenable to manipulation. A multistage sampling procedure was adopted. Meerut and Bulandshahr districts were selected purposively from Meerut Division for their area under vegetables, 20.98 thousand hectares in Bulandshahr and 18.00 thousand hectares in Meerut, the highest in the division (Directorate of Horticulture and Food Processing, 2025). Two blocks with the highest vegetable area were selected purposively per district, and three villages drawn randomly from each block's list of vegetable-growing villages, totalling twelve villages. From the village-wise list of growers marketing vegetables at the time of the survey, fifteen were selected randomly per village, giving 180 growers.

Data were collected through personal interviews using a structured interview schedule. Content validity was established through a panel of judges from agricultural extension education and vegetable science, and the schedule was pre-tested on thirty growers of a non-sample village, its internal consistency being satisfactory (Cronbach's alpha=0.82). Participation was voluntary, prior informed consent was obtained, and responses were kept anonymous. Data were obtained on selected socio-economic, communication and behavioural characteristics and on the constraints experienced. Annual income was recorded in lakh rupees per annum. Occupation was scored as farming alone (1), farming with allied enterprises (2) and farming with business or service (3). Annual expenditure denotes the cost of vegetable cultivation during the reference year, covering seed, fertiliser, plant protection chemicals, irrigation, hired labour, transport and market charges, and not total household consumption expenditure. Constraints were classified into marketing, communication and production dimensions and their severity measured on a three-point continuum of severe, moderate and minor, scored 3, 2 and 1 respectively. The Constraint Severity Index (CSI) was worked out as:

$$CSI = \frac{\text{Obtained score}}{\text{Maximum possible score}} \times 100$$

where obtained score is the cumulative score assigned by respondents and maximum possible score that attainable if all rated the constraint as severe.

Frequency, percentage, mean and standard deviation were used for descriptive analysis and Pearson's correlation coefficient for relationships with the overall constraint level. Stepwise regression was preferred because the analysis was exploratory and no theoretical ordering existed among the fourteen inter-correlated predictors; it yielded a parsimonious model rather than a test of a pre-specified causal structure. Only variables meeting the entry criterion ($p \leq 0.05$) were retained.

RESULTS

Constraints perceived by vegetable growers

The marketing, communication and production constraints perceived by the respondents, ranked on the basis of their CSI values, are presented in Table 1. Among the marketing constraints, price fluctuation and lack of remunerative prices ranked first (CSI = 87.78%; Mean = 2.63), followed by exploitation by middlemen and long marketing chains (CSI = 85.74%) and lack of cold storage and storage facilities (CSI = 83.70%). High cost and inadequacy of transportation facilities (CSI = 81.30%) and financial difficulties with delayed credit access (CSI = 76.85%) occupied the fourth and fifth positions, whereas lack of timely and reliable market information was placed last in this domain (CSI = 64.44%). In the communication domain, lack of technical and market-related information ranked first (CSI = 83.15%; Mean = 2.49), followed by inadequate extension contact and advisory support (CSI = 79.26%) and language barrier with technical complexity of information (CSI = 75.93%). Low literacy level hampering information uptake recorded the lowest severity in this domain (CSI = 61.30%). Among the production constraints, high cost of

fertilisers and nutrient management inputs ranked first (CSI = 87.04%; Mean = 2.61), followed by non-availability of farm labour at critical crop stages (CSI = 84.07%) and non-availability of quality seeds and planting material (CSI = 81.48%). Weather and climate-related risks were perceived as the least severe (CSI = 59.63%). Severity values of the remaining constraints in each domain are given in Table 1.

Determinants of overall constraint level

The correlation analysis, Table 2 revealed that education ($r = –0.452$, $p < 0.01$), landholding ($r = –0.415$, $p < 0.01$), annual income ($r = –0.432$, $p < 0.01$), economic motivation ($r = –0.601$, $p < 0.01$), information-seeking behaviour ($r = –0.459$, $p < 0.01$) and marketing behaviour ($r = –0.580$, $p < 0.01$) all exhibited significant negative relationships with the overall constraint level. Social participation ($r = –0.255$, $p < 0.05$), mass media exposure ($r = –0.371$, $p < 0.01$), information processing behaviour ($r = –0.343$, $p < 0.01$) and information sharing behaviour ($r = –0.277$, $p < 0.01$) also showed statistically significant negative associations. Age, occupation, family size and annual expenditure on vegetable cultivation did not exhibit significant relationships with the overall constraint level.

Stepwise regression analysis, Table 3 identified four characteristics as significant predictors of the overall constraint level. Economic motivation emerged as the strongest predictor ($\beta = –0.392$), followed by information-seeking behaviour ($\beta = –0.197$), annual income ($\beta = –0.140$) and landholding ($\beta = –0.132$). Together, these variables accounted for 44.10 per cent of the variation in the overall constraint level ($R^2 = 0.441$, Adjusted $R^2 = 0.425$; $F(4, 175) = 34.556$, $p < 0.001$).

Table 2. Relationship of respondents' characteristics with overall constraint level

Characteristics	Correlation coefficient (r)	p-value	Significance
Age	–0.112	0.133	NS
Education	–0.452	<0.001	**
Land holding	–0.415	<0.001	**
Occupation	0.108	0.148	NS
Family size	0.097	0.197	NS
Social participation	–0.255	0.016	*
Annual income	–0.432	<0.001	**
Annual expenditure	0.091	0.225	NS
Economic motivation	–0.601	<0.001	**
Mass media exposure	–0.371	<0.001	**
Information-seeking behaviour	–0.459	<0.001	**
Information processing behaviour	–0.343	<0.001	**
Information sharing behaviour	–0.277	<0.001	**
Marketing behaviour	–0.580	<0.001	**

Note: ** Significant at $p < 0.01$; * Significant at $p < 0.05$; NS = Non-significant.

DISCUSSION

Price uncertainty and structural weakness in the marketing chain dominate what growers in the zone experience as severity. Price

Table 1. Marketing, communication and production constraints faced by vegetable growers

S.No.	Constraint	Mean Score	SD	CSI (%)	Rank
A. Marketing constraints					
1	Price fluctuation and lack of remunerative prices	2.63	0.60	87.78	I
2	Exploitation by middlemen and long marketing chain	2.57	0.65	85.74	II
3	Lack of cold storage and storage facilities	2.51	0.68	83.70	III
4	High cost and inadequacy of transportation facilities	2.44	0.74	81.30	IV
5	Financial difficulties and delayed credit access	2.31	0.79	76.85	V
6	Poor market infrastructure (weighment, space, delays)	2.17	0.80	72.41	VI
7	Low and unstable market demand	2.07	0.79	68.89	VII
8	Lack of timely and reliable market information	1.93	0.82	64.44	VIII
B. Communication constraints					
1	Lack of technical and market-related information	2.49	0.71	83.15	I
2	Inadequate extension contact and advisory support	2.38	0.77	79.26	II
3	Language barrier and technical complexity of information	2.28	0.79	75.93	III
4	Limited access to media and digital communication platforms	2.12	0.83	70.56	IV
5	Poor mobile and internet network connectivity	1.98	0.81	65.93	V
6	Low literacy level hampering information uptake	1.84	0.81	61.30	VI
C. Production constraints					
1	High cost of fertilisers and nutrient management inputs	2.61	0.61	87.04	I
2	Non-availability of farm labour at critical crop stages	2.52	0.68	84.07	II
3	Non-availability of quality seeds and planting material	2.44	0.72	81.48	III
4	Capital shortage and limited access to credit	2.31	0.79	76.85	IV
5	Irrigation problems and erratic water supply	2.19	0.80	72.96	V
6	Lack of technical knowledge and modern farming skills	2.06	0.82	68.52	VI
7	Pesticide-related issues (availability and application)	1.91	0.82	63.70	VII
8	Weather and climate-related risks	1.79	0.81	59.63	VIII

Note: CSI = Constraint Severity Index = (Obtained Score / Maximum Possible Score) × 100; Severity scale: Severe = 3, Moderate = 2, Minor = 1.

Table 3. Stepwise regression analysis of predictors of overall constraint level

Predictor variable	B	SE	Beta (β)	t-value	p-value
Economic motivation	–0.379	0.068	–0.392	–5.542	<0.001
Information-seeking behaviour	–0.184	0.060	–0.197	–3.045	0.002
Annual income	–0.018	0.008	–0.140	–2.136	0.033
Land holding	–0.389	0.190	–0.132	–2.043	0.041

Note: Stepwise forward regression (p-entry = 0.05). R^2 = 0.441; Adjusted R^2 = 0.425; $F(4, 175) = 34.556$; $p < 0.001$.

fluctuation and the absence of remunerative prices (CSI = 87.78%) stand highest because supply arrives seasonally, the produce will not wait, and a smallholder bargaining alone has little to bargain with. Pandit and Basak (2013) and Mishra et al. (2012) report the same ordering, with low harvest prices and trader exploitation as dominant concerns. The severity attached to middlemen and long marketing chains follows from the same dependence, and Shah and Ansari (2020) note that lengthy channels cut sharply into net returns. That cold storage, transport cost and market infrastructure cluster near the top points to a post-harvest deficit rather than three separate difficulties. Kaur et al. (2022) and Mohan et al. (2023) trace substantial post-harvest losses to weak cold-chain facilities, and More et al. (2021) place transport and storage among the most pressing grower concerns, a pattern the present data reproduce for the Western Plain Zone.

Communication constraints, led by want of technical and market information (CSI = 83.15%) and thin extension contact (CSI = 79.26%), point to a knowledge gap that has proved durable. Vegetable cultivation asks for frequent and time-bound decisions on variety, pest management, irrigation and market timing; when the advice comes late, or not at all, decisions suffer and severity rises. Islam et al. (2019) find better-informed growers less constrained, and Gupta et al. (2020) treat weak extension contact as a central obstacle. Literacy ranks lowest in this domain (CSI = 61.30%), which suggests the difficulty lies on the supply side of extension rather than in what farmers can absorb, much as Mittal and Mehar (2016) argue that relevance of content, not receiving capacity, decides whether a channel delivers usable advice.

High fertiliser and input costs (CSI = 87.04%) and labour scarcity (CSI = 84.07%) reflect the input-intensive character of commercial vegetable growing and the steady movement of rural labour into non-farm work, felt most at transplanting, weeding and harvest. Shah and Ansari (2020) and Pandit and Basak (2013) report the same pressures. Difficulty in obtaining quality seed (CSI = 81.48%) compounds them, since the variety chosen settles both yield and market acceptability, as Kundu et al. (2020) and Saikia et al. (2024) also observe.

How severely growers feel these constraints appears to depend on what they command, what they know and what they are inclined to pursue. Economic motivation is the strongest predictor (β = –0.392): growers working to income targets negotiate the same environment more successfully, and that disposition can be cultivated. Information-seeking behaviour (β = –0.197) works alongside it, bringing growers to solutions already within reach. Annual income (β = –0.140) and landholding (β = –0.132) matter less, in keeping with Pandit and Basak (2013). That behaviour outweighs endowment is the useful finding, since extension can change orientation but not the size of a holding. Three implications follow: aggregation through producer collectives with adequate working capital, to shorten the marketing chain (Trebbin, 2014; Kumar et al., 2023); block-level advisory calendars carried by mobile and group media, the deficit being one of content supply; and entrepreneurship training treated as core rather than peripheral extension work. Three qualifications apply. The study covers two districts and growers already active in vegetable marketing, so it describes that population rather than the state; its cross-sectional design supports association but not causation; and stepwise selection, being statistical rather than theoretical, leaves the model exploratory until confirmed on an independent sample with formal diagnostic testing.

CONCLUSION

Vegetable cultivation in Western Uttar Pradesh is constrained simultaneously on the marketing, communication and production fronts. Price instability, dependence on intermediaries and the absence of storage depress realized returns; scarce and untimely technical and market advice weakens the quality of farm decisions; and rising input costs together with labour scarcity raise the cost of cultivation. Growers who are economically motivated, who actively seek information and who command larger holdings and incomes carry a visibly lighter constraint burden, which indicates that behavioural orientation matters as much as resource endowment. Extension strategy for the zone should therefore combine market-oriented advisory support and dependable price intelligence with measures that improve access to quality inputs and shorten the marketing chain, so that vegetable cultivation becomes more remunerative and resilient for the smallholder.

DECLARATIONS

Ethics approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Agricultural Extension, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250110, Uttar Pradesh, India waived the ethical approval. The purpose of the study was explained to every respondent, prior informed consent was obtained, participation was voluntary and the responses were kept anonymous and used solely for research purposes.

Consent for publication: All the authors have read the manuscript, approved its contents and consented to its publication.

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Research Note

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Awareness and Utilization of ICT Tools among KVK-Linked Progressive Farmers in Western Uttar Pradesh

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HIGHLIGHTS

- Progressive farmers showed a moderate level of awareness and utilization of ICT tools for agricultural information and advisory services.
- WhatsApp groups emerged as the most preferred ICT platform for agricultural information and advisory services.
- Active KVK linkage and social participation were the strongest drivers of ICT adoption among progressive farmers.

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ABSTRACT

The study was conducted in 2025 using an ex post facto research design to assess awareness and utilization of Information and Communication Technology (ICT) tools among progressive farmers associated with Krishi Vigyan Kendras in Ghaziabad and Hapur districts of Western Uttar Pradesh. A total of 160 progressive farmers were selected through purposive sampling and primary data were collected using a pre-tested structured interview schedule. Data were analysed using frequency, percentage, mean score, standard deviation, Pearson's product moment correlation and multiple linear regression. The overall awareness and utilization of ICT tools were 69.52 per cent and 62.60 per cent, respectively, with platforms embedded in routine KVK advisory work recording the highest recognition and use, while artificial-intelligence-based tools, Internet of Things-based sensors and Krishi Mapper recorded the lowest scores. Regression analysis showed that social participation, education, farm assets, annual income and land holding positively influenced ICT utilization, whereas age had a significant negative effect. The findings indicated that strengthening digital literacy and expanding KVK-led ICT extension activities could improve the effective adoption of digital technologies among farmers and support more responsive agricultural advisory services.

INTRODUCTION

Agriculture supports nearly 46 per cent of India's population and contributes about 16 per cent to the national Gross Domestic Product (Saidulu, 2025), yet the sector continues to face inadequate credit access, erratic weather, fragmented holdings and delayed flow of information. The conventional extension system, built around direct personal contact, has not been able to reach most farmers and about 60 per cent of them remain outside any organised extension coverage (Shashidhara, 2020). Information and Communication Technology (ICT), broadly defined as technologies for storing, processing and communicating data (Haqyar et al., 2025), offers a practical route to close this gap by placing crop-specific and location-specific advisories directly in farmers' hands through mobile phones, internet services and agricultural portals, without requiring an extension worker to be physically present (Mukherjee & Jha, 2024).

The Government of India has responded through platforms such as eNAM (Electronic National Agriculture Market), the mKisan Portal and Kisan Call Centres (Anand et al., 2022) and more recently

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through artificial intelligence (AI)-enabled advisory systems; the National Pest Surveillance System, for instance, has used AI-based diagnostics to issue pest-specific advisories to farmers across Odisha, although sustained compliance with these advisories remains uneven (Kumar et al., 2025). Krishi Vigyan Kendras (KVKs), functioning under the Indian Council of Agricultural Research, remain the principal ground-level institutions for delivering ICT-based extension. With 731 KVKs nationally, 89 of them in Uttar Pradesh alone (Saidulu, 2025) and only one extension worker for every 2,900 farmers, these centres increasingly rely on WhatsApp advisories, farmer portals and tele-extension services to widen their reach (Moulasab et al., 2025).

Despite this institutional push, actual ICT utilization presents a different scenario. Although most farmers own a mobile phone, between 48 and 88 per cent have never used email, internet portals or computers for farm-related work (Bansal et al., 2022) and ICT utilization among farmers has generally been reported at a low to medium level (Panda et al., 2019; Kumar et al., 2023). A multi-state study across the Indo-Gangetic plain similarly found that landholding size, ICT ownership and social media use raise awareness of digital advisory platforms while age and farming experience depress it and called for more location-specific evidence (Mukherjee et al., 2024). Systematic evidence on how AI-based and other emerging ICT tools are being received alongside conventional platforms among KVK-linked progressive farmers of Western Uttar Pradesh, however, remains limited and the socio-economic factors shaping this pattern are not well established for the region. The present study was therefore undertaken to assess the extent of awareness and utilization of ICT tools among progressive farmers associated with KVKs in Western Uttar Pradesh and to examine how their socio-economic characteristics relate to ICT utilization, with a view to informing more targeted digital extension strategies.

METHODOLOGY

The study was carried out during 2025 in the Meerut Division of Western Uttar Pradesh, with Ghaziabad and Hapur chosen purposively for the active role their Krishi Vigyan Kendras (KVKs) play in delivering ICT-based advisory services. Progressive farmers were those formally listed as such in KVK records based on consistent adoption of improved agricultural practices. A total of 160 progressive farmers, 80 from each KVK, were selected through purposive sampling, subject to two conditions: active linkage with the KVK and prior use of at least one ICT-based service, such as SMS crop advisories or WhatsApp-based inputs (Rashid et al., 2024); these 160 constituted the entire eligible list at the two KVKs, with no separate sampling frame drawn upon. Data were gathered through personal interviews using a structured schedule developed for the study (Chavan et al., 2019; Singh & Mathur, 2024), content-validated by subject-matter specialists, pilot-tested on non-sampled farmers for reliability and modified before the final survey.

Twelve socio-economic characteristics served as independent variables: age, gender, education, caste, occupation, land holding, annual income, social participation, farm assets, transportation facilities, irrigation facilities and housing pattern. Categorical variables were assigned ordinal scores, gender as male (1)/female (2) and caste as Scheduled Caste (1), Other Backward Class (2) and General (3). Awareness and utilization of ICT tools, the two dependent variables, were each rated on a three-point continuum, awareness as not aware (0), partially aware (1) and fully aware (2) and utilization as never (0), occasionally (1) and regularly (2). The coded data were analysed using frequency, percentage, mean score, standard deviation and rank to describe awareness and utilization, Pearson's Product Moment Correlation to examine their association with socio-economic variables and Multiple Linear Regression to identify factors influencing utilization. A mean awareness and utilization score was worked out for each of the 30 ICT tools; averaging these scores and expressing the result as a percentage of the maximum possible score of 2 gave the overall composite indices reported in Table 1. Prior to regression analysis, the assumptions of linearity, normality and homoscedasticity of residuals, independence of errors and absence of multicollinearity among predictors were examined and found satisfied.

RESULTS

Awareness of ICT tools among progressive farmers

Table 1 presents the awareness and utilization pattern of 30 ICT tools among the 160 progressive farmer respondents. On the awareness side, a clear pattern emerges: tools that KVKs have built into their routine advisory work, principally group messaging, weather and price applications and direct telephonic contact, dominate the top ranks, while emerging precision-agriculture technologies occupy the bottom. To ease interpretation, the 30 tools were grouped into highly, moderately and poorly aware or utilized categories based on their mean scores (1.50 and above, 1.00–1.49 and below 1.00, respectively, out of a maximum of 2.00).

WhatsApp groups managed by KVK scientists were the most widely known tool overall (mean 1.962), reaching near-universal familiarity among respondents. Together with weather forecast applications, the KVK YouTube channel, direct telephone contact with KVK scientists and government platforms such as the PMFBY App and SMS-based mKisan advisories, they made up a highly aware group of fourteen tools, all scoring 1.50 or above. A further nine tools, including the Kisan Suvidha App, KVK Facebook/social media groups and the e-NAM Portal, fell in the moderately aware band, familiar to a majority of respondents but without the near-universal reach of the top tier.

Awareness fell sharply for the seven most specialised digital tools, IoT-based farm sensors, AI-based advisory tools and Krishi Mapper among them, all of which scored below 1.00 and made up the poorly aware group. The overall composite awareness score across the 30 tools stood at 69.52 per cent, confirming a moderately high aggregate level that is concentrated heavily around KVK-promoted platforms rather than spread evenly across the full range of available technologies.

Utilization of ICT tools among progressive farmers

The utilization pattern mirrored the awareness gradient but at a consistently lower level throughout. WhatsApp groups run by KVK scientists again led all tools (mean 1.881) and direct telephonic contact with KVK scientists ranked a close second, confirming that voice-based contact has not been displaced by digital channels.

Table 1. Awareness and utilization of ICT tools among progressive farmers

S. No.	ICT Tool	Awareness Mean score	Awareness SD	Awareness Rank	Utilization Mean score	Utilization SD	Utilization Rank
1	SMS advisories from KVK/mKisan	1.638	0.588	11	1.619	0.613	7
2	WhatsApp groups operated by KVK scientists	1.962	0.191	1	1.881	0.425	1
3	Kisan Call Centre	1.700	0.512	8	1.662	0.560	6
4	Weather forecast mobile apps	1.838	0.418	2	1.738	0.577	3
5	Market price applications	1.538	0.662	13	1.500	0.691	8
6	Pest and disease diagnosis applications	1.500	0.614	14	1.462	0.653	12
7	Calling KVK scientists directly through mobile phone	1.762	0.564	6	1.762	0.649	2
8	Kisan Sarathi Portal	1.200	0.791	22	1.162	0.808	21
9	Krishi Mapper	0.800	0.867	30	0.438	0.766	30
10	Tele-agriculture services	1.262	0.781	18	1.238	0.789	19
11	KVK Portal	1.600	0.574	12	1.481	0.691	11
12	Farmers' Portal	1.681	0.587	9	1.300	0.875	17
13	e-NAM Portal	1.238	0.820	20	1.100	0.877	23
14	KVK YouTube channel	1.838	0.418	3	1.700	0.632	4
15	KVK Facebook/social media groups	1.362	0.756	16	1.319	0.788	15
16	mKisan Portal	1.200	0.845	23	1.200	0.845	20
17	Kisan Suvidha App	1.462	0.633	15	1.419	0.677	13
18	PMFBY App	1.719	0.563	7	1.500	0.785	9
19	Soil Health Card Portal/App	1.838	0.433	4	1.500	0.816	10
20	Pusa Krishi/ICAR mobile apps	1.238	0.813	21	1.138	0.835	22
21	Agriculture programmes on television	1.838	0.387	5	1.700	0.622	5
22	Agriculture programmes on radio	1.338	0.751	17	1.319	0.772	16
23	Online trainings/webinars of KVK	1.262	0.773	19	1.262	0.773	18
24	Email advisories/newsletters	0.881	0.879	26	0.762	0.865	24
25	Information kiosks/digital centres	0.862	0.872	27	0.762	0.865	25
26	Drone-based advisory/monitoring information services	0.838	0.875	28	0.600	0.826	26
27	AI-based advisory tools	0.819	0.903	29	0.600	0.848	27
28	IoT-based farm sensors	0.938	0.852	24	0.500	0.793	29
29	GIS/GPS-based agricultural tools	0.900	0.899	25	0.600	0.863	28
30	Digital land record-based services (Bhulekh)	1.662	0.571	10	1.338	0.831	14

Note: SMS = Short Message Service; KVK = Krishi Vigyan Kendra; PMFBY = Pradhan Mantri Fasal Bima Yojana; e-NAM = Electronic National Agriculture Market; mKisan = Mobile Kisan (SMS-based advisory portal, Government of India); ICAR = Indian Council of Agricultural Research; IoT = Internet of Things; AI = Artificial Intelligence; GIS = Geographic Information System; GPS = Global Positioning System.

Together with weather forecast applications, the KVK YouTube channel, televised programmes, the Kisan Call Centre and the PMFBY App, these formed a highly utilized group of ten tools, all with mean scores of 1.50 or above.

A further thirteen tools, including the KVK Portal, pest and disease diagnosis applications and the e-NAM Portal, fell in the moderately utilized band. Utilization of the more specialised technologies, IoT sensors, AI-based advisory tools and Krishi Mapper among them, was negligible by comparison, marking these seven tools as poorly utilized. The overall utilization score of 62.60 per cent stood 6.92 percentage points below the overall awareness score. This gap was narrow for KVK-embedded tools, only about 4 percentage points for the WhatsApp groups, but widened considerably for the specialised technologies, suggesting that the constraint on ICT adoption in the study area lies less in exposure to these tools than in the practical barriers, connectivity, cost and digital skill, that separate knowing a tool exists from actually using it.

Socio-economic determinants of ICT utilization

The correlation analysis (Table 2) identified four socio-economic characteristics with a significant bearing on ICT utilization. Social participation returned the strongest association ($r = 0.451$, $p < 0.001$), followed by age, which was negatively and significantly related to utilization ($r = -0.337$, $p < 0.001$). Education ($r = 0.201$, $p = 0.011$) and farm assets ($r = 0.189$, $p = 0.017$) were also positively significant. The remaining eight variables, gender, caste, occupation, land holding, annual income, transportation facilities, irrigation facilities and housing pattern, showed no significant bivariate relationship with utilization.

The regression model (Table 3) explained 33.03 per cent of the variance in ICT utilization ($R^2 = 0.3303$; Adjusted $R^2 = 0.2756$; $F(12,147) = 6.04$, $p < 0.001$). Social participation was again the leading predictor ($\beta = 0.418$, $p < 0.001$), followed by education ($\beta = 0.291$, $p < 0.001$) and farm assets ($\beta = 0.243$, $p = 0.001$). Age remained a significant negative predictor even after the other eleven variables were accounted for ($\beta = -0.152$, $p = 0.022$).

Annual income ($\beta = 0.182$, $p = 0.010$) and land holding ($\beta = 0.168$, $p = 0.026$) emerged as significant predictors in the regression despite showing no significant simple correlation, indicating that their influence on utilization operates jointly with, rather than independently of, the other variables in the model. Gender, caste, occupation, transportation facilities, irrigation facilities and housing

Table 2. Relationship between selected socio-economic characteristics and ICT utilization

Variable	Correlation coefficient (r)	p-value
Age	–0.337**	<0.001
Gender	–0.068NS	0.393
Education	0.201*	0.011
Caste	0.050NS	0.530
Occupation	0.059NS	0.459
Land holding	0.118NS	0.137
Annual income	0.090NS	0.258
Social participation	0.451**	<0.001
Farm assets	0.189*	0.017
Transportation facilities	–0.081NS	0.309
Irrigation facilities	–0.070NS	0.379
Housing pattern	0.012NS	0.880

Note: * Significant at 5 per cent level; ** Significant at 1 per cent level; NS = Non-significant. Exact p-values are reported in the adjoining column (two-tailed, df = 158).

pattern were non-significant, confirming that neither the bivariate nor the multivariate analysis found these structural attributes to have any independent bearing on ICT utilization.

DISCUSSION

An overall awareness level of 69.52 per cent points to a fairly digitally switched-on group, largely a function of how the sample was drawn. Kushwaha et al. (2025) found only 33.33 per cent of general farmers in Sagar district aware of KVK services, against which the higher awareness recorded here reflects every respondent's active KVK relationship. WhatsApp groups run by KVK scientists topped both awareness and utilization, largely because the platform asks nothing new of farmers, fits habits already built around the mobile phone and carries the credibility of being run by scientists farmers already trust, the relative advantage, compatibility and observability central to Rogers' (2003) diffusion of innovations framework. A similar pattern of smartphone- and WhatsApp-led engagement is reported in West Bengal and Bihar (Mukherjee & Jha, 2024; Anand et al., 2022).

Awareness dropped off sharply for the more advanced tools, AI-based advisory, IoT sensors, GIS/GPS applications and Krishi Mapper all fell below a mean score of 1.00, tools that demand steady connectivity, technical comfort and, in Rogers' (2003) terms, a chance to trial them before farmers can trust them, none of which is yet within easy reach here. Sharma et al. (2022) and Dashora and Henry (2022) both found KVK scientists in central and western India using smartphones daily while rarely touching specialised applications, so farmers can hardly know more than the scientists introducing them. Satapathy et al. (2024b) trace this gap to limited ICT knowledge, weak financial support and inadequate extension backing in Odisha and similar barriers likely operate in Western Uttar Pradesh too.

The gap between awareness and actual use, 6.92 percentage points overall and wider still for advanced tools, echoes a pattern reported widely elsewhere: Bansal et al. (2022) and Priyavadhana and Balakrishnan (2025) both found farmers aware of email, internet portals and government platforms without ever using them. Mishra et al. (2020), working in Lucknow district, rated television and mobile phones at a medium benefit level for about half the farmers and social media low for a similar share, a gradation close to the moderate-to-low utilization seen here, pointing to structural barriers across Uttar Pradesh rather than something unique to the western part of the state.

Social participation is the strongest correlate and predictor of ICT utilization, agreeing with Satapathy et al. (2024a) in Odisha; farmers embedded in cooperatives and farmer groups pick up new practices partly by watching and consulting peers, a peer-mediated learning process that KVK-run WhatsApp groups extend directly into the digital space (Nain et al., 2019). Age works the other way, a significant negative factor in both the correlation and regression results, most plausibly reflecting less lifetime exposure to digital interfaces and a shorter expected payback from learning them, a pattern also seen in Satapathy et al. (2024a) and Patra et al. (2020). Anand et al. (2022) found social participation non-significant in Bihar, likely because that sample lacked the uniform, active KVK linkage that defines respondents here.

Land holding and annual income were not significant on their own in the correlation analysis but became significant once other

Table 3. Multiple linear regression analysis of factors influencing ICT utilization

Variable	Unstandardized coeff. (B)	Standardized coeff. (β)	t-value	p-value
Constant	39.842	—	6.284**	<0.001
Age	–2.486	–0.152	–2.318*	0.022
Gender	–1.214	–0.041	–0.673NS	0.502
Education	2.184	0.291	3.954**	<0.001
Caste	0.491	0.043	0.692NS	0.490
Occupation	0.875	0.118	1.821NS	0.071
Land holding	1.968	0.168	2.247*	0.026
Annual income	2.754	0.182	2.596*	0.010
Social participation	4.623	0.418	5.446**	<0.001
Farm assets	2.386	0.243	3.365**	0.001
Transportation facilities	0.534	0.058	0.842NS	0.401
Irrigation facilities	1.106	0.086	1.296NS	0.197
Housing pattern	0.742	0.054	0.813NS	0.418

Note: * Significant at 5 per cent level; ** Significant at 1 per cent level; NS = Non-significant. Exact p-values are reported in the adjoining column (two-tailed, df = 147). $F(12,147) = 6.04$, $p < 0.001$; $R^2 = 0.3303$; Adjusted $R^2 = 0.2756$.

variables were controlled for in the regression, suggesting their effect works through, rather than around, social participation and education. Efforts to lift ICT use among less-resourced farmers may therefore work better through strengthening social participation and education than by targeting income or landholding directly. KVKs appear to have embedded a core set of ICT tools into farmers' routines successfully, but this has not extended to precision-agriculture technologies and closing that gap will likely take sustained, hands-on training delivered through channels farmers already trust.

For Krishi Vigyan Kendras and extension personnel, the findings point to anchoring new digital advisories on already-trusted, low-complexity platforms before introducing more technical tools and running peer-led demonstration sessions rather than one-time orientations to reach older farmers. Agricultural universities can support this by building digital-skill modules into their extension training curricula. State agriculture departments and policy makers may consider linking digital literacy drives to existing farmer group and cooperative networks, since social participation does more to drive adoption than income or landholding. ICT developers, for their part, would benefit from designing artificial-intelligence and sensor-based tools for offline or low-bandwidth use, given the connectivity constraints evident here, so that reach extends beyond the current base of digitally confident users.

CONCLUSION

The study confirms that progressive farmers linked to Krishi Vigyan Kendras are reasonably well informed about digital advisory tools, yet this awareness converts into regular use mainly for simple, socially embedded platforms actively promoted through institutional channels, while more advanced, data-driven technologies remain at an early stage of adoption. Social participation and education emerge as the resources that most consistently turn awareness into practice, while advancing age works against it, pointing to a generational as much as a technological divide. Digital extension therefore succeeds best when it builds on farmers' existing social networks rather than treating adoption as a matter of exposure alone. Krishi Vigyan Kendras and state agriculture departments should prioritise sustained, hands-on digital literacy support for older and less engaged farmers over simply expanding the range of tools on offer and extending this analysis to non-progressive farmer groups would strengthen the evidence base for such policy.

DECLARATIONS

Ethics approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Agricultural Extension, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250110, Uttar Pradesh, India waived the ethical approval. The purpose of the study was explained to every respondent, prior informed consent was obtained, participation was voluntary and the responses were kept anonymous and used solely for research purposes.

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Research Note

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Constraints Faced by Farm Women in Post-harvest Grain Management Practices in Rural Jharkhand, India

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HIGHLIGHTS

- Storage insect and pest management knowledge was the foremost constraint in household grain storage.
- Moisture-temperature knowledge gaps showed the need for practical pre-storage demonstrations for farm women.
- Limited scheme reach and low training participation indicated institutional gaps in women-focused extension delivery.
- User-friendly tools and low-cost storage improvements should be linked with hands-on training.

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ABSTRACT

The study was conducted during 2023 in Deoghar district of Jharkhand to identify and rank constraints faced by farm women in post-harvest grain management. A descriptive research design was used. Mohanpur and Madhupur blocks were selected randomly; two panchayats from each block and two villages from each panchayat were selected through the lottery method. Fifteen farm women directly involved in post-harvest grain handling were selected randomly from each village, making a sample of 120 respondents. Data were collected through personal interview using a pre-tested semi-structured schedule. Nine constraints were ranked by respondents and analysed through Garrett's ranking technique. Lack of knowledge about management of storage insects and pests ranked first with a Garrett mean score of 73.13. It was followed by lack of knowledge of moisture and temperature during storage (62.82), lack of post-harvest management knowledge among women (59.43) and limited reach to government schemes (55.93). The findings indicate that technical knowledge and institutional access were more serious constraints than time scarcity. Women-centred demonstrations on storage pest diagnosis, moisture control, safe stacking, storage sanitation and scheme linkage are needed to reduce grain losses.

INTRODUCTION

Post-harvest grain management is a critical stage in smallholder farming because harvested grain becomes food, seed or saleable produce only when it is dried, cleaned, protected and stored under safe conditions. Losses after harvest commonly arise from delayed threshing, poor drying, contamination, insect infestation, rodent damage, fungal growth and unsuitable storage structures. Evidence from grain storage studies indicates that moisture control, regular inspection, hygienic handling, hermetic storage and improved containers reduce deterioration and improve food safety (Bradford et al., 2018; Hubert et al., 2016; Kumar & Kalita, 2017; Mobolade

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et al., 2019). Studies on cereals and pulses also show that harvesting, threshing and storage losses remain substantial where technical guidance and storage facilities are inadequate (Dutta et al., 2018; Hengsdijk & de Boer, 2017; Vishwakarma et al., 2019). In this context, post-harvest management is not only a technical issue but also an extension issue. Farm women play a major role in household grain handling. They are generally involved in drying, cleaning, sorting, seed selection, storage preparation, processing and periodic supervision of stored grain. However, their contribution is often less visible in formal advisory systems, although women substantially participate in farm operations and decision making (Nain & Kumar, 2010; Saikia et al., 2020). Gender-sensitive post-harvest work further shows that reduction of losses requires attention to women's access to knowledge, resources, training and decision space (Nordhagen, 2021). In Deoghar district of Jharkhand, women's involvement in grain management activities has already been documented, especially in cleaning, drying, storage and processing operations (Gupta et al., 2024). Yet involvement alone does not ensure efficient management unless women have practical knowledge and access to suitable support. Several studies have reported that limited education, weak training exposure and restricted decision participation reduce adoption of improved agricultural and post-harvest practices among rural women (Kabir et al., 2023; Kumari, 2018). Recent extension research also stresses that diagnostic tools, knowledge tests, digital learning and data-driven advisory services can improve the targeting of agricultural extension programmes (Vijayan et al., 2022; Vijayan et al., 2023; Godara et al., 2024; Kumari et al., 2024; Singh et al., 2024). Good agricultural practice principles emphasise practical and locally feasible recommendations rather than general advice (Nain & Singh, 2015). Similarly, validated knowledge and attitude instruments can help locate precise capacity gaps before designing interventions (Singh et al., 2025; Singh et al., 2026a; Singh et al., 2026b). Bibliometric and programme-awareness studies also suggest that extension planning becomes stronger when it is evidence-based and problem-specific (Tiwari et al., 2023; Roy et al., 2024). Constraint ranking is useful for this purpose because it converts field-level perceptions into an order of priorities that extension agencies can act upon. It also helps distinguish knowledge gaps from infrastructure, training and time-related barriers, which may require different extension responses. Therefore, identifying constraints perceived by farm women is necessary for designing relevant training, demonstrations and scheme-linkage interventions. The study was conducted to prioritise the constraints faced by farm women in post-harvest grain management in Deoghar district of Jharkhand.

METHODOLOGY

The study was conducted during 2023 in Deoghar district of Jharkhand using a descriptive research design. Mohanpur and Madhupur blocks were selected randomly from the district. From each selected block, two village panchayats were selected, and from each panchayat two villages were chosen through the lottery method. Thus, eight villages were covered. Fifteen farm women who were directly involved in post-harvest grain management were randomly selected from each village, forming a sample of 120 respondents. Primary data were collected through personal interview with a pre-tested semi-structured schedule. The list of constraints was prepared after reviewing literature, field observations and consultation with extension personnel and subject-matter specialists. The schedule was checked with non-sample farm women for clarity and local understanding. Nine constraints were finally retained for ranking. Each respondent ranked the constraints from most severe to least severe according to her experience in post-harvest grain handling. Garrett's ranking technique was used to convert ordinal ranks into comparable scores (Garrett & Woodworth, 1969). Its application for prioritising perceived agricultural constraints has also been demonstrated in studies involving tribal farm women and makhana growers (Bahubalendra et al., 2025; Warshini et al., 2025). Percentage position was calculated as: $100(R_{ij} - 0.5)/N_j$, where R_{ij} is the rank assigned to the i-th constraint by the j-th respondent and N_j is the number of constraints ranked by the j-th respondent. The percentage positions were converted into Garrett scores. Scores for each constraint were summed and divided by the number of respondents to obtain the Garrett mean score. Constraints were arranged in descending order of mean score, and final ranks were assigned.

RESULTS

The ranking of constraints showed a clear order of severity in post-harvest grain management among farm women (Figure 1). Garrett mean scores ranged from 73.13 to 23.08; lack of knowledge about the management of storage insects and pests and time constraint due to household duties were the most and least severe constraints, respectively. Lack of knowledge about the management of storage insects and pests ranked first with a Garrett mean score of 73.13. This indicates a critical need for practical understanding of insect identification, early symptoms of infestation, cleaning and disinfection of storage structures, segregation of damaged grain, safe stacking and periodic inspection. In household storage, infestation may be recognised only after visible damage, powder formation, grain heating or adult insect emergence; therefore, preventive management and early detection should receive priority. Lack of knowledge of moisture and temperature during storage ranked second with a mean score of 62.82. Moisture and temperature directly influence mould growth, grain heating, seed viability and insect multiplication. Although farm women commonly assess dryness through experience-based methods, such judgement may be unreliable during humid, cloudy or interrupted drying periods. Simple demonstrations on safe drying, clean drying surfaces, repeated turning, protection from night moisture, raised storage and checking grain during humid periods are therefore required. Lack of overall post-harvest management knowledge among women ranked third with a mean score of 59.43, reflecting gaps across the complete sequence of harvesting, threshing, drying, cleaning, grading, storage preparation and inspection. Limited reach to government schemes ranked fourth with a mean score of 55.93, indicating inadequate direct access to information on training, tools, storage structures, processing support and other institutional provisions. Less participation of women in extension programmes or lack of training ranked fifth with a mean score of 46.73, revealing the need for locally delivered, women-centred and practice-oriented programmes. Lack

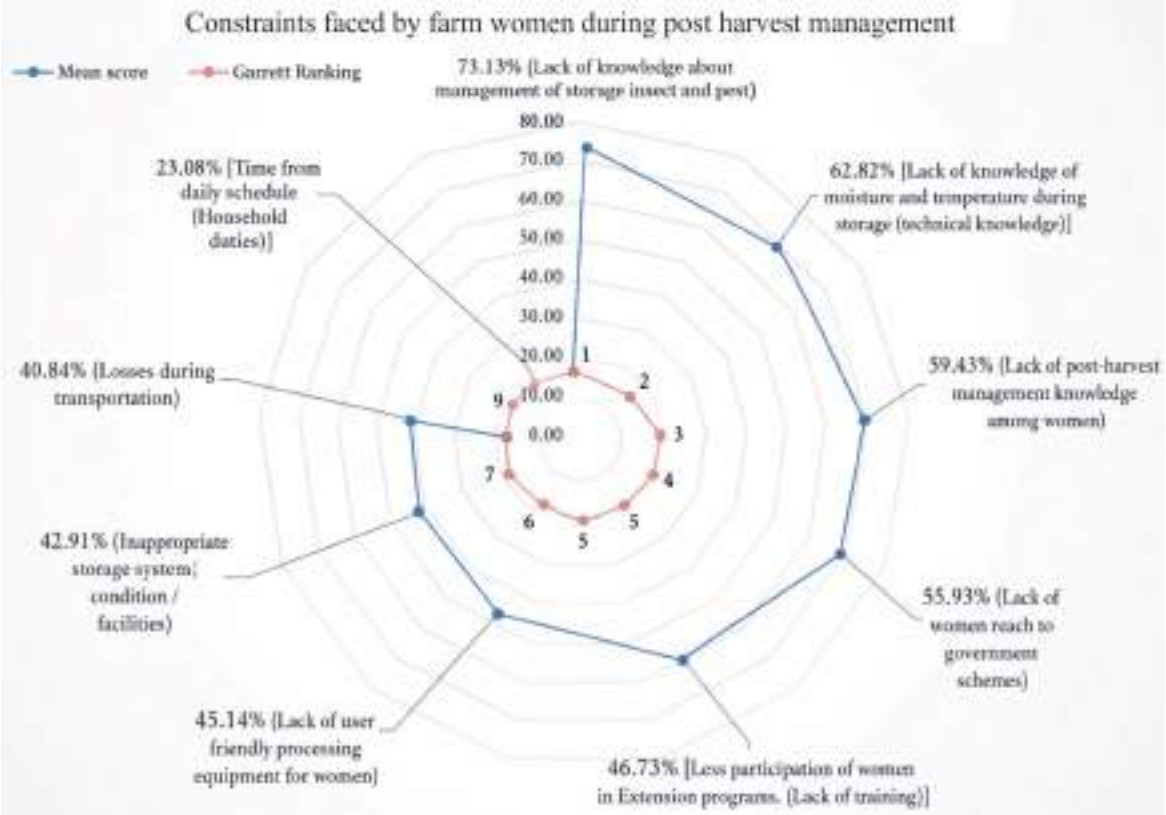


Figure 1. Garrett mean score-based ranking of constraints in post-harvest grain management

of user-friendly processing equipment ranked sixth with a mean score of 45.14; this may reflect limited local availability of affordable, lightweight and easily operable tools suited to women's work conditions. Inappropriate storage systems, conditions or facilities ranked seventh with a mean score of 42.91, pointing to limitations related to storage sanitation, elevation, ventilation, capacity and protection from insects, rodents and moisture. Losses during transportation ranked eighth with a mean score of 40.84, suggesting the need for improved handling, packaging and safe movement of grain from field to household storage or local markets. Time constraint due to household duties ranked ninth and was the least severe constraint, with a mean score of 23.08. Its lower rank should not be interpreted as an absence of household workload; rather, respondents considered technical knowledge, training, scheme access and institutional support to be more immediate and actionable barriers. Thus, the ranking does not imply that lower-ranked constraints are unimportant, but it provides a relative order for planning extension interventions.

DISCUSSION

The findings demonstrate that post-harvest grain management is a knowledge-intensive and gender-sensitive extension domain. The first three constraints concerned storage insects, moisture-temperature management and overall post-harvest knowledge. Bradford et al. (2018), Hengsdijk and de Boer (2017), Kumar and Kalita (2017), and Mobolade et al. (2019) similarly identified moisture, insects, fungal development and unsuitable storage conditions as major causes of grain deterioration. Dutta et al. (2018), Muthukumar et al. (2020) and Vishwakarma et al. (2019) also reported that harvesting, threshing, drying and storage losses persist when practical guidance and improved handling practices are inadequate. The highest rank assigned to storage insect and pest management indicates that extension messages must be specific, demonstrable and operational. Generic advice on safe storage is insufficient unless farm women can accurately identify infestation symptoms, thoroughly clean storage spaces, promptly segregate damaged grain and systematically inspect stored stocks at regular intervals. Hubert et al. (2016) showed that hermetic and improved storage technologies are effective only when users understand the conditions required for their correct use. Bradford et al. (2018) likewise emphasised moisture control as a central component of the dry-chain approach in humid climates. Accordingly, village-level demonstrations should use actual grain samples, damaged kernels, locally available containers and simple storage layouts rather than relying mainly on lecture-based communication. The middle-ranked institutional constraints also require focused attention. Limited reach to government schemes (55.93) and low participation in extension programmes or training (46.73) indicate that women are not always contacted directly by advisory systems. Godara et al. (2024), Kumari et al. (2024), Singh et al. (2024) and Tiwari et al. (2023) have highlighted the value of accessible advisory services, relevant training and effective programme communication. Knowledge-test research further shows that systematic diagnosis can identify precise capacity-building needs among extension personnel and

farmers (Singh et al., 2026a; Singh et al., 2026b; Vijayan et al., 2022; Vijayan et al., 2023). A similar diagnostic approach can be developed specifically for household grain management. The lower-middle ranks assigned to user-friendly processing equipment (45.14), inappropriate storage facilities (42.91) and transportation losses (40.84) show that physical and logistical barriers remain relevant, although respondents perceived them as less severe than knowledge and institutional deficiencies. These constraints can be addressed through group-based access to lightweight tools, low-cost storage improvements, safer packaging and locally coordinated transport support. The lowest rank assigned to time constraint (23.08) requires cautious interpretation. Farm women continue to carry substantial household responsibilities, but their responses indicate that information, skills and institutional access were perceived as more immediate barriers. This interpretation is consistent with the work of Kabir et al. (2023), Kumari (2018), Nain and Kumar (2010), Nordhagen (2021) and Saikia et al. (2020), who emphasised that women's agricultural contribution should be supported through decision space, appropriate training and access to resources. Nain and Singh (2015) also stressed that good agricultural practices should be practical and locally feasible. Roy et al. (2024) and Singh et al. (2025) further demonstrate the value of evidence-based measurement and problem-specific extension planning. Therefore, women-focused post-harvest extension should integrate pest and moisture demonstrations, direct scheme linkage, group access to suitable tools and affordable improvements in household storage.

CONCLUSION

The study identified technical knowledge and institutional access as the major constraints faced by farm women in post-harvest grain management. Storage insect and pest management was the top-ranked constraint, followed by moisture-temperature management, general post-harvest knowledge and limited reach to government schemes. Time constraint received the lowest rank, indicating that women considered knowledge, training and support services more critical than household duties alone. Extension agencies should organise village-level demonstrations on insect identification, safe drying, storage sanitation, raised stacking and periodic inspection. Scheme information should be communicated directly to women through self-help groups, women farmer groups and local institutions. User-friendly processing equipment and low-cost storage improvements should be promoted with training on proper use and maintenance. Such a focused approach can improve grain quality, seed safety and household food security while strengthening recognition of women's contribution in post-harvest management.

DECLARATIONS

Ethical approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Agricultural Extension, BHU, Varanasi, Uttar Pradesh, India waived the ethical approval. Informed consent was obtained from all respondents before data collection. The respondents were informed about the purpose of the study, and their participation was voluntary.

Data availability statement: Data is available upon reasonable request from the first author as well as corresponding author.

Consent for publication: Consent was obtained for using the collected information for academic analysis and publication. No personal or identifiable information of the respondents has been disclosed.

Competing interests: The authors declare that they have no competing interests.

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this manuscript. All authors have critically reviewed, revised and approved the final version of the manuscript and take full responsibility for its content.

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Research Note

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Prioritizing E-Learning Alternatives for University Students Through an Integrated AHP-TOPSIS Framework

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HIGHLIGHTS

- An integrated AHP-TOPSIS framework ranks five e-learning alternatives across accessibility, cost, interactivity, ICT availability, and academic quality.
- ICT availability and academic quality emerged as the most critical criteria for evaluating e-learning alternatives.
- Blended Learning ranked first for both undergraduate and postgraduate students at Banaras Hindu University.

ARTICLE INFO

Keywords: AHP, e-learning alternatives, Evaluation criteria, TOPSIS, University students.

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ABSTRACT

The growing reliance on e-learning in education and training has produced multiple instructional alternatives. This study aimed to prioritise five such e-learning alternatives, i.e., Blended Learning, Mobile Learning, Online Distance Learning, Flipped Learning, and Asynchronous Learning for university students using an integrated Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) framework. Data were collected from 132 undergraduate and postgraduate students across five constituent institutes of Banaras Hindu University, who rated each alternative on accessibility, cost, interactivity, ICT availability, and academic quality during 2024-25. AHP was used to derive criteria weights (based on experts' judgments), while TOPSIS ranked the alternatives using these weights from the actual users' (i.e., students) perspectives. Results showed that ICT availability (0.290) and academic quality (0.263) were the most influential criteria. Blended Learning ranked highest for both undergraduate and postgraduate students, while second-ranked preferences diverged, with undergraduates favouring Mobile Learning and postgraduates favouring Flipped Learning. These findings indicate that robust ICT infrastructure and academic quality are foundational to effective e-learning. The blended approaches, tailored with level-appropriate secondary delivery modes, offer the most learner-responsive strategy for institutions designing digital learning environments.

INTRODUCTION

The continuous growth of digital technologies has reshaped education systems which facilitated the increasing use of e-learning as a viable mode of education worldwide (Gupta & Sharma, 2020). According to the British Council (2025), "E-learning is the delivery of a learning programme by electronic means. It includes web-based learning, virtual classrooms, digital collaboration and delivery of content through the internet". The adaptable nature of e-learning permits students to get involved with educational content at their preferred time and place, thereby improving access to education and enhancing learning convenience (Balachandran & Mahalakshmi, 2023; Himmawan et al., 2025). The importance of e-learning became particularly evident during COVID-19 crisis, when schools and

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universities across the globe were compelled to suspend face-to-face instruction (Maatuk et al., 2022; Singh et al., 2024). This transition ensured the continuity of education during the global crisis and demonstrated the potential of ICT to support the educational process (Borah & Devarani, 2022).

Despite its widespread adoption, conventional online learning has several limitations. Limited interaction between instructors and learners, reduced student engagement, technological barriers, and inadequate opportunities for practical learning can negatively influence the learning experience (Guanzon & Kilag, 2024; Mishra & Kumari, 2024; Sanusi, 2025). Digital fatigue, which manifests as cognitive and emotional overload, often causes decreased focus and retention in online learning (Ritesh, 2024). It leads to reduced participation, which further increases learning challenges. These challenges highlight the requirement for more innovative and student-centred approaches that can retain the flexible nature of e-learning while overcoming its limitations. To address these challenges, several e-learning alternatives have gained considerable attention. These approaches offer different instructional strategies but share the common objective of improving accessibility, flexibility, interaction, content delivery and learner engagement. Blended learning combines classroom and online instruction; mobile learning supports learning through portable devices; flipped learning promotes active in-class engagement through pre-class study; and asynchronous learning enables learners to progress independently without real-time interaction.

But selecting the most appropriate pedagogical model among these diverse alternatives presents a multi-criteria decision-making problem, as institutions must navigate complex trade-offs between technical infrastructure, learner engagement, quality and outcomes (Adeniyi et al., 2024; Mizza et al., 2025). Also, the suitability of these alternatives may vary depending on learners' preferences and educational requirements, and the relative weight that students themselves attach to factors such as accessibility, cost, interactivity, infrastructural availability and academic quality. Most existing studies have examined individual e-learning modalities in isolation or relied on simple preference rankings. Thus, a gap existed in systematic, criteria-based comparisons that simultaneously account for multiple, often conflicting, decision points. Multi-Criteria Decision-Making (MCDM) techniques are well-suited to address this gap. Against this backdrop, this study aimed to evaluate and rank selected e-learning alternatives using AHP and TOPSIS frameworks in an integrated manner. This hybrid approach leverages the AHP's capability to calculate the relative weightage of diverse evaluation criteria while utilizing TOPSIS method to rank competing pedagogical models based on their proximity to an ideal solution (Mohammed et al., 2018). Combining SWOT with the analytical hierarchy process (AHP) was used by Afroz et al. (2021) to examine Agriclinics and Agribusiness Center (ACABC) Scheme.

METHODOLOGY

The study was conducted among students of five institutes of Banaras Hindu University, namely the Institute of Agricultural Sciences, Institute of Medical Sciences, Institute of Management Studies, Institute of Sciences, and the Institute of Environment and Sustainable Development during 2024-25. Students pursuing undergraduate and postgraduate programmes constituted the study population. An integrated AHP-TOPSIS framework was employed to evaluate and rank the e-learning alternatives, i.e., blended learning, mobile learning, online distance learning, flipped learning and Asynchronous learning.

In the first stage, the relative importance of the evaluation criteria was determined using the Analytic Hierarchy Process (AHP). A panel of 15 experts, comprising faculty from the Departments of Education, Extension Education and the Indian Institute of Technology (BHU), participated in the pairwise comparison exercise. Six experts were initially identified through institutional websites based on their reported use of e-learning alternatives for teaching, while the remaining nine were recruited using snowball sampling. All experts were experienced users of some of the selected e-learning alternatives. They compared the five evaluation criteria using a 9-point pairwise comparison scale (Saaty, 2008). The resulting criterion weights were subsequently used in the TOPSIS analysis.

In the second stage, the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) was applied using the responses collected from the 132 students selected using convenience sampling with voluntary participation. To ensure a common understanding of the selected e-learning alternatives, each alternative was introduced through handouts and specially designed video demonstrations during visits to the student hostels. Subsequently, a structured questionnaire was administered, yielding 132 valid responses from the participating students. The respondents were asked to evaluate each alternative against five criteria: accessibility, cost, interactivity, availability of ICT infrastructure, and academic quality. Responses were recorded on a 10-point rating scale, where higher scores indicated better performance. For the cost criterion, the rating scale was reversed, ensuring consistency with the remaining benefit criteria (Hwang & Yoon, 2012). The mean performance score of each e-learning alternative under each evaluation criterion was used to construct the decision matrix. The matrix was normalized and weighted using the criterion weights derived from AHP. Positive and negative ideal solutions were identified, Euclidean distances from these ideal solutions were calculated, and the relative closeness coefficient of each alternative was determined. The e-learning alternatives were finally ranked in order of their closeness coefficients.

RESULTS

Table 1 indicates the relative importance assigned by experts to each evaluation criterion. The results depicted that the Availability of ICT received the highest priority weight (0.290),

Table 1. The criteria weights produced by AHP methods [n1= 15]

Criteria	Priority Weights	Λ (MAX)	Consistency Index (CI)	Consistency Ratio (CR)	Rank
Accessibility	0.201	9.14	1.03	0.092	III
Cost	0.118				V
Interactivity	0.125				IV
Availability of ICT	0.290				I
Academic Quality	0.263				II

followed by Academic Quality (0.263), Accessibility (0.201), Interactivity (0.125), and Cost (0.118). The consistency of the judgments was assessed using the Consistency Ratio (CR). Only matrices with CR < 0.10 were accepted. These findings suggest that experts considered the availability of technological infrastructure and the quality of academic content as the most critical factors influencing the effectiveness of e-learning alternatives.

Table 2 revealed that Blended Learning emerged as the most preferred e-learning alternative among undergraduate students, followed by Mobile Learning, Flipped Learning, Online Distance Learning and Asynchronous Learning. The higher preference for blended learning may be attributed to its ability to combine the advantages of face-to-face instruction with the flexibility of online learning, thereby providing a more balanced and engaging learning experience.

Table 2. Best e-learning alternative for UG Students [n2= 69]

S.No.	Alternatives	S_i^+	S_i^-	P_i	Rank
1.	Blended Learning	0.003	0.033	0.915	1
2.	Mobile Learning	0.027	0.249	0.903	2
3.	Online Distance Learning	0.025	0.007	0.228	4
4.	Flipped Learning	0.020	0.013	0.403	3
5.	Asynchronous learning	0.031	0.003	0.100	5

Table 3 summarizes the preferences of postgraduate students regarding the selected e- learning alternatives. Similar to the undergraduate students, Blended Learning emerged as the most preferred alternative. However, the subsequent rankings differed slightly, with Flipped Learning occupying the second position, followed by Online Distance Learning, Mobile Learning and Asynchronous Learning. This preference may reflect the greater emphasis placed by postgraduate students on independent learning, critical thinking, and pre-class preparation, which are key characteristics of the flipped learning approach.

Table 3. Best e-learning alternative for PG Students [n3= 63]

S.No.	Alternatives	S_i^+	S_i^-	P_i	Rank
1.	Blended Learning	0.015	0.651	0.978	1
2.	Mobile Learning	0.379	0.374	0.497	4
3.	Online Distance Learning	0.134	0.134	0.499	3
4.	Flipped Learning	0.293	0.359	0.551	2
5.	Asynchronous learning	0.651	0.009	0.014	5

DISCUSSION

The AHP analysis revealed significant differences in the relative importance assigned to the evaluation criteria by experts. Among the identified criteria, the availability of ICT infrastructure emerged as the most important factor, as ICT infrastructure is consistently identified as a crucial component for the success of e-learning systems. Studies emphasize that robust technological infrastructure and reliable internet access significantly enhance the performance of online learning platforms (Mardiyati et al., 2026). Furthermore, the availability of ICT is not only about having the necessary hardware and software but also ensuring that these resources are accessible to all students, which is vital for equitable learning opportunities (Ramchandra & Goswami, 2024).

The TOPSIS analysis revealed distinct preferences for e-learning alternatives among university students. Among both undergraduate & postgraduate students, Blended Learning emerged as the most preferred alternative as it offers increased accessibility by combining online resources with traditional classroom settings, allowing students to access materials anytime and anywhere, thus accommodating diverse learning needs and schedules (Junior et al., 2024; Ahmed, 2025). Furthermore, it promotes greater interactivity through the integration of face-to-face discussions with online tools such as discussion forums, collaborative activities, and multimedia resources, which facilitate active learner engagement (Smith & Brown, 2023). The approach also improves the availability of educational content by providing multiple channels and formats through which students can access learning resources at their own pace (Bhadri & Patil, 2022). In addition, blended learning has been associated with enhanced academic outcomes, as it enables personalized learning experiences that address individual student requirements and learning preferences (Siddiqui et al., 2024; Ahmed, 2025). The effective integration of digital technologies within blended learning environments further supports diverse pedagogical approaches, thereby improving the overall quality and effectiveness of higher education (Alammary et al., 2016). The findings revealed that mobile learning emerged as the second most preferred e- learning alternative among undergraduate students. This preference can be explained by the convenience and flexibility offered by mobile learning, allowing students to access educational materials and participate in learning activities anytime and from any location. Such flexibility is particularly beneficial for undergraduate students who often balance academic responsibilities with various extracurricular and personal commitments (Cin et al., 2022). In contrast, flipped learning was identified as the second most preferred alternative among postgraduate students. This may be associated with its learner- centered approach, which promotes active learning and enables students to review instructional content before face-to-face class activities. This facilitates students to acquire foundational knowledge before class and utilise classroom sessions for discussions, problem-solving and collaborative learning activities (Gardner & Vessalas, 2016). Furthermore, the integration of flipped learning with mobile learning has been suggested as an effective strategy for enhancing the overall learning experience, as it enables educational content to be delivered in a manner that is adaptable to learners' contexts, preferences, and learning environments (Louhab et al., 2019).

CONCLUSION

The present study applied a sequential AHP-TOPSIS work model to systematically prioritize e-learning alternatives for university students, addressing the gap left by previous studies that evaluate digital learning modalities in isolation. The AHP results established that the success of any digital learning initiative depends first on a reliable technological foundation and credible academic content, rather than on convenience alone. Thus, Investment in robust and equitably distributed ICT infrastructure should be treated as a precondition for any institutional shift toward digital

or hybrid pedagogy. The subsequent TOPSIS analysis showed that combining the structure and accountability of traditional classroom instruction with the wide reach and of online delivery is most preferable. It also indicates that e-learning preferences are not uniform but shift with the level and nature of academic engagement. Thus, curriculum designers seeking to introduce or expand e-learning provision should be more inclined to blended models as a default framework, while tailoring the secondary mode of delivery, according to distinct learning orientations of different student cohorts.

DECLARATION

Ethics approval and informed consent: Ethical norms were strictly followed while conducting this research according to the principles of social science research. Ethical issues were considered and waived in Departmental Research Advisory Committee, Department of Extension Education, BHU, Varanasi. All participants provided their informed consent for collection of response.

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Research Note

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Assessment of Information Transfer and Farming Practices Constraints in Gajapati and Rayagada, Odisha

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HIGHLIGHT

- Insufficient knowledge of modern cultivation techniques was the most severe information transfer constraint (RBQ 85.62%).
- Non-availability of credit facilities ranked foremost among farming practices constraints (RBQ 85.26%).
- Limited literacy and high labour cost were perceived as least severe constraints.
- Cognitive and financial along, not educational or infrastructural deficits, principally restrict agricultural advancement.

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ABSTRACT

Timely transfer of agricultural information and alleviation of farm-level bottlenecks are vital for enhancing productivity in tribal rainfed regions; however, the comparative severity of these constraints remained inadequately quantified. The present study was undertaken in 2026 to assess and prioritise the constraints of information transfer and farming practices as perceived by farmers of Gajapati and Rayagada districts of Odisha. A total of 240 farmers were selected through multi-stage sampling covering eight blocks, and data were collected with a pre-tested structured interview schedule comprising eight statements under each constraint category. The responses were analysed using the Rank-Based Quotient technique. Insufficient knowledge about modern cultivation techniques (85.62%) and lack of conviction in new technology (78.49%) emerged as the most severe information transfer constraints, while non-availability of credit facilities (85.26%) and dependence on monsoon (80.31%) ranked foremost among farming practices constraints; limited literacy (28.28%) and high cost of labour (26.35%) were perceived as least severe. The study established that cognitive and financial bottlenecks principally restricted agricultural advancement and suggested skill-oriented extension approaches together with strengthened institutional credit and irrigation support as priority interventions for tribal farming communities.

INTRODUCTION

Agricultural extension has been identified as a key role player in closing the gap between research institutions and farming communities however, the mechanisms used to transfer knowledge have been found to be face with several constraints (Mishra et al., 2025). In India, where agriculture is the main occupation of more than half the population, the efficient dissemination of agricultural information is of great importance to increase productivity and food security. The tribal farmers, however, have many difficulties in accessing information and are faced with challenges such as limited literacy rate, lack of trained extension officers, poor infrastructure

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and technological gap (Raji et al., 2024; Sharma et al., 2025). To enhance the capabilities of extension support and technology adoption, it is crucial to understand these constraints as perceived by farmers. In rainfed areas, production is inherently challenged by climatic variability, resource limitations as well as socio-economic constraints (Yadav et al., 2026).

This concern is especially acute in tribal-dominated tracts, where geographical remoteness, low literacy and fragmented holdings restrict farmers contact with formal information sources (Saha et al., 2026). Odisha, which ranks second among Indian states in tribal population, illustrates this challenge sharply. Its interior districts of Gajapati and Rayagada are characterised by hilly terrain, rain-fed cultivation and predominantly Scheduled Tribe communities that depend on informal and interpersonal channels rather than institutional extension (Ghosh et al., 2024). Socio-economic status, ownership of communication tools and the reach of extension agencies all influence which information sources farmers actually use (Meena et al., 2022; Chandra et al., 2023; Singh et al., 2023; Niranjan et al., 2023). Recent Odisha-based investigations of occupational diversification and developmental programmes report that infrastructural, economic and socio-psychological barriers dominate, yet their relative intensity varies across settings (Jayasingh et al., 2024; Prajapati et al., 2025). Against this background, the present study assesses the pattern of information transfer and the constraints associated with farming practices among farmers of Gajapati and Rayagada districts of Odisha.

METHODOLOGY

Gajapati and Rayagada districts of southern Odisha were purposively selected in 2026 as predominantly tribal, rainfed tracts with low irrigation coverage. Gajapati lies between 18°50′–19°40′ N and 83°50′–84°30′E and Rayagada between 19°00′–19°58′N and 82°54′–84°02′E (Das et al., 2020; Pattanaik et al., 2006). Four blocks were selected per district (Gajapati: Rayagada, Gumma, Nuagada and Kashinagar; Rayagada: Kolnara, Rayagada, Gunupur and Ramanaguda) for their cropping diversity, tribal farm-household concentration and monsoon accessibility. Two villages per block (eight per district) were identified in consultation with block officials. To establish the sampling frame, total households in the selected blocks were divided by the total number of villages to obtain the average households per village; the eight villages accounted for 725 households in Gajapati and 791 in Rayagada. From each district, 120 households (15 per village) were selected, giving a total sample of 240 (Government of Odisha, Official portal; Ministry of Rural Development, Government of India). Each farmer was surveyed using a pre-tested structured schedule covering constraints in information transfer (8 statements) and farming practices (8 statements). As selection was purposive, the sample is not statistically representative; remote habitations facing the severest constraints may be under-represented, possibly understating constraint severity.

$$\overline{H}_d = \frac{H_d}{v_d} \quad \text{... (1)}$$

$$n = \sum_{d=1}^{D}(v_d \times h) = D \times v \times h \quad \text{... (2)}$$

Where, $\overline{H}d$ = average households per village in district d; Hd = total households in the selected villages; vd = villages per district (= 8); n = total sample size; D = districts (= 2); v = villages per district (= 8) and h = households per village (= 15).

The Rank Based Quotient (RBQ) approach was used by Sabarathnam (1988), which is widely used in agricultural research (Gowdhaman et al., 2024; Das et al., 2025) to analyse the ranked data. RBQ transforms the responses into weighted scores, giving higher-ranked constraints more weight, allowing systematic prioritization with less ranking bias. RBQ was calculated using the following formula:

$$RBQ_i = \frac{\sum_{j=1}^{N} f_{ij}(N - R_j + 1) \times 100}{nN} \quad \text{... (3)}$$

Where, RBQ_i = Rank Based Quotient for constraint i; f_{ij} = respondents assigning rank j to constraint i; N = total constraints (8); R_j = rank position (1–8); n = respondents (240); and Σ = summation over ranks. Data were analysed in Microsoft Excel and Google Colab.

RESULTS

The information transfer constraints, “insufficient knowledge about various aspects of modern techniques in cultivation” emerged as the most severe, securing the first rank with the highest Rank-Based Quotient of 85.62%, followed by “lack of conviction in the new technology” (78.49%) and “non-availability of desired technology” (68.80%). “Limited access to reliable and timely information” (61.09%) and “lack of awareness or knowledge about certain technologies” (50.73%) reflected moderate difficulty, whereas “not aware about an extension person” (40.47%), “lack of proper knowledge” (36.51%), and “limited literacy” (28.28%) were perceived as least serious.

Among the farming practices constraints, “non-availability of credit facilities” ranked first (85.26%), establishing access to finance as the predominant obstacle, followed by “dependence on monsoon”

Table 1. Statement-wise RBQ (%) and Ranking of Constraints

Statement	RBQ (%)	Rank
Information Transfer Constraints		
Insufficient knowledge about various aspects of modern techniques in cultivation	85.62	1
Lack of conviction in the new technology	78.49	2
Non-availability of desired technology	68.8	3
Limited access to reliable and timely information	61.09	4
Lack of awareness or knowledge of about certain technologies	50.73	5
Not aware about an extension person	40.47	6
Lack of proper knowledge	36.51	7
Limited Literacy	28.28	8
Farming Practices Constraints		
Non-availability of credit facilities	85.26	1
Dependence on monsoon	80.31	2
Small land	68.18	3
High cost of inputs	60.78	4
Land soil problem	52.08	5
Heavy pest and disease incidence	43.91	6
Lack of subsidy for inputs	33.12	7
High cost of labour	26.35	8

(80.31%) and "small land" holdings (68.18%), which highlight the vulnerability of rain-fed, fragmented cultivation. "High cost of inputs" (60.78%), "land soil problem" (52.08%), and "heavy pest and disease incidence" (43.91%) occupied intermediate positions, while "lack of subsidy for inputs" (33.12%) and "high cost of labour" (26.35%) were rated least severe. Overall, financial and natural-resource limitations constitute the principal barriers, pointing to the need for improved institutional credit, irrigation facilities, and resource-augmenting interventions.

Figure 1 depicts the rank-frequency distribution of the two constraint categories as paired heatmaps, with information transfer constraints presented in blue and farming practices constraints in green. In each matrix, the rows correspond to the eight constraint statements, arranged from top to bottom in descending order of severity based on their Rank-Based Quotient values, while the columns represent the rank positions from Rank 1 (most severe) to Rank 8 (least severe).

A pronounced diagonal gradient extending from the upper-left to the lower-right of both panels reveals a strong consensus among respondents on the relative severity of the constraints. In the information transfer category, the leading constraint, "insufficient knowledge about various aspects of modern techniques in cultivation," received Rank 1 from 107 respondents, whereas "limited literacy" was ranked at Rank 8 by 102 respondents. A corresponding pattern characterises the farming practices category, where "non-availability of credit facilities" attracted 99 first-rank responses and "high cost of labour" was assigned Rank 8 by 108 respondents. The intermediate constraints displayed comparatively dispersed shading around the middle positions, indicating mixed perceptions of their severity.

Figure 2 shows the Rank-Based Quotient (RBQ) values of the two categories of constraints using paired spider-net (radar) charts: info of info transfer constraints in blue, and farming of farming practices constraints in green. In each chart, the constraint statements of the chart are arranged around the circumference of the chart, the concentric rings indicating the RBQ scale from the centre (0) outwards to the periphery (100), with the greater the extension of a plotted point towards the periphery, the more severe the constraint perceived to be.

The polygon is the widest for the information transfer constraints item "insufficient knowledge about various aspects of modern techniques in cultivation" (RBQ 85.6) and the next widest for "non-availability of desired technology" (68.8) and "lack of conviction in the new technology" (78.5), while it is the most contracted for the two most severe constraints, "limited literacy" (28.3) and "lack of proper knowledge" (36.5). Similar patterns of constraint distribution are found for the farming practices constraints, with the distribution being concentrated at "non-availability of credit facilities" (85.3) and "dependence on monsoon" (80.3) and then shrinking to the "high cost of labour" (26.4) and "lack of subsidy for inputs" (33.1).

DISCUSSION

The constraints identified in this study follow a clear hierarchy rather than a flat distribution, a pattern effectively captured by the Rank-Based Quotient (RBQ) technique, which assigns differential weights to successive rank positions (Sabarathnam, 1988). This graded structure corroborates recent RBQ-based studies in Indian agriculture, where a few dominant constraints sharply contrast with the remainder (Kaleeswaran et al., 2024; Gowdhaman et al., 2024), reinforcing the need to prioritise constraints rather than merely enumerate them.

In the information transfer domain, insufficient knowledge of modern cultivation techniques (RBQ 85.62%) and lack of conviction in new technology (78.49%) emerged as the foremost constraints. The likely reason is that tribal farmers in Gajapati and Rayagada operate in geographically remote, hilly terrain with limited access

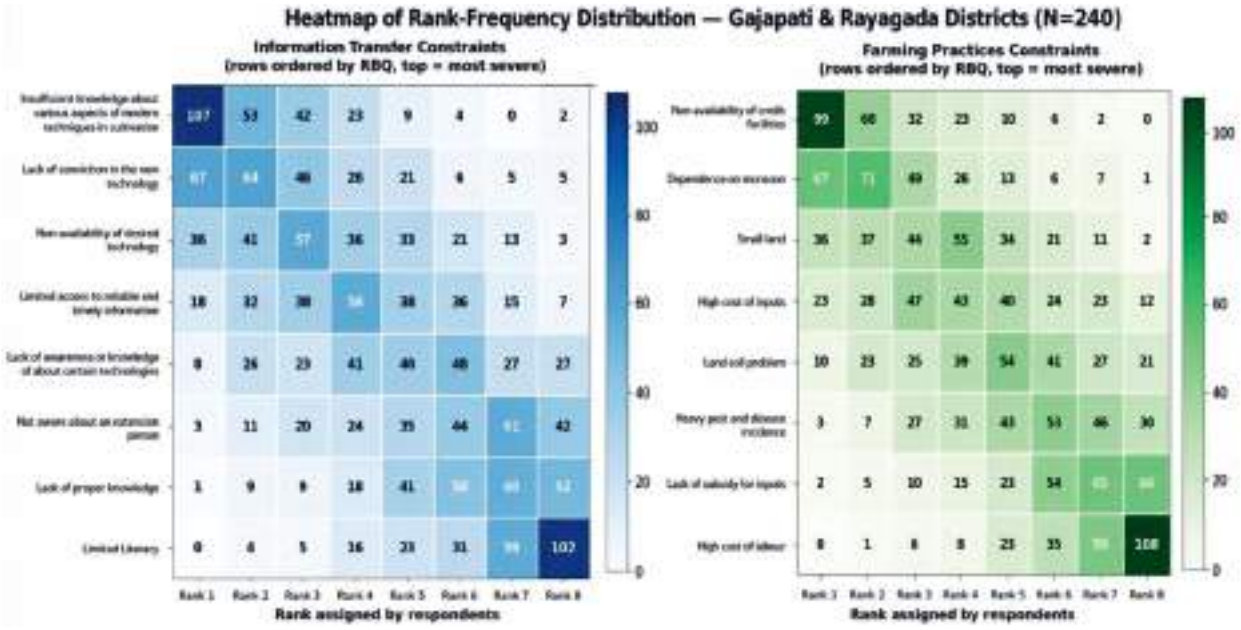


Figure 1. Rank Frequency Distribution Heatmap

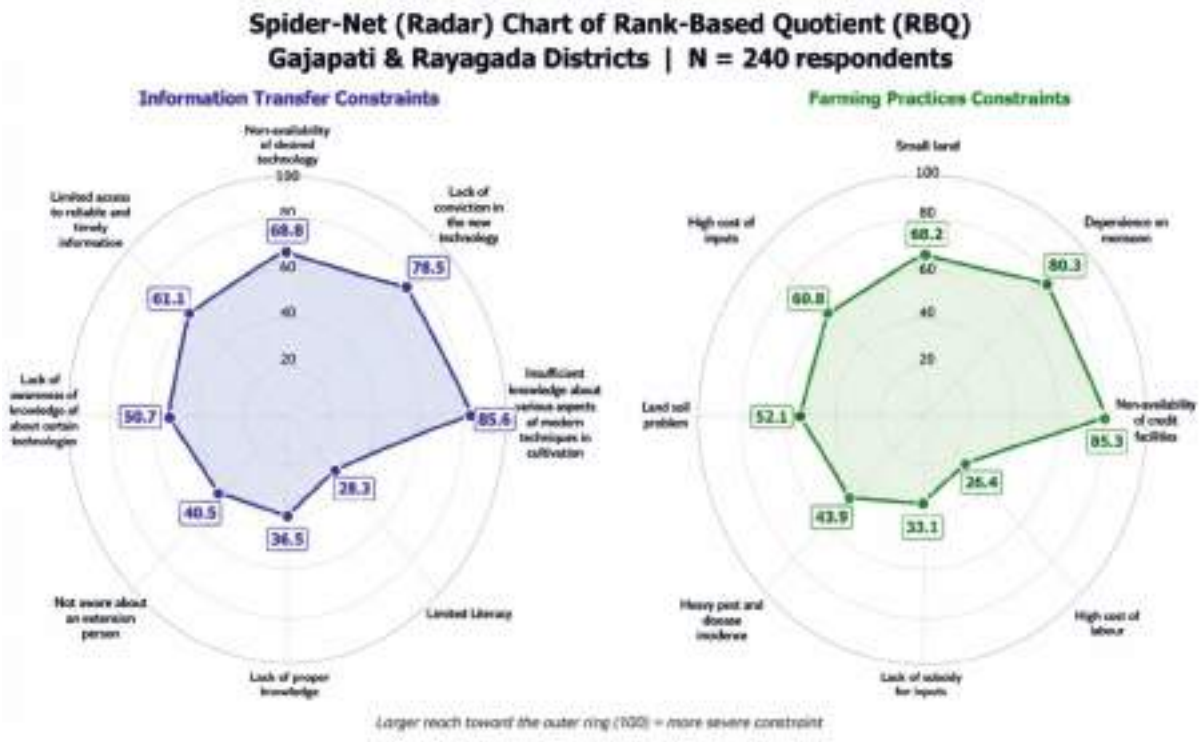


Figure 2. RBQ constraints analysis: Radar chart visualization

to formal extension infrastructure, leaving them exposed to new technologies only through fragmented, informal channels. Without adequate demonstration or repeated contact with extension agents, cognitive gaps persist and trust in unfamiliar practices remains low. For written material the content, format and illustrations were perceived as highly effective on journalistic parameters (Nain et al., 2019). The cognitive-attitudinal origin of constraints is consistent with Mittal and Mehar (2016), who established that information content, communication channel quality and farmers' personal attributes collectively determine what farmers trust and act upon. Notably, limited literacy ranked last among information transfer constraints (RBQ 28.28%), which appears counterintuitive in a tribal setting but is plausibly explained by the community's deep reliance on oral communication, peer learning and demonstration-based knowledge exchange. When information circulates through interpersonal channels rather than written material, literacy ceases to be a binding bottleneck, as Mittal and Mehar (2016) similarly observed.

Among farming practices constraints, non-availability of credit facilities (85.26%) and dependence on monsoon (80.31%) dominated. The predominance of credit constraint is attributable to structural exclusion: insecure podu land titles restrict collateral eligibility, thin banking networks limit outreach, and Business Correspondent presence is insufficient in scattered hill habitations. Without institutional credit, farmers cannot invest in inputs, equipment or risk-mitigation measures, making financial access the foundational bottleneck. This finding aligns with (Raina et al., 2011; Kaleeswaran et al., 2024; Gowdhaman et al., 2024), who similarly identified credit access as the primary constraint among Indian farm beneficiaries, and with (Jayasingh et al., 2024), who reported economic and infrastructural barriers as dominant in the Odisha farming context. Monsoon dependence ranking second (80.31%) reflects the near-total absence of irrigation infrastructure in these rainfed tracts, where undulating terrain precludes canal systems and community-managed water harvesting remains underdeveloped. Small landholdings (68.18%) compound this vulnerability, as fragmented plots reduce the viability of collective investment and mechanisation. The low severity assigned to high labour cost (RBQ 26.35%) is explained by the prevalence of family and community labour arrangements in tribal agriculture, which reduces dependence on hired labour and shifts cost concerns towards credit and inputs rather than wages. Similarly, the low ranking of input subsidy absence (33.12%) likely reflects limited awareness of subsidy schemes rather than their actual adequacy.

CONCLUSION

Constraints in Gajapati and Rayagada are hierarchical rather than uniform: insufficient knowledge of modern cultivation techniques and low conviction in new technology dominate information transfer, while credit non-availability and monsoon dependence dominate farming practices; limited literacy and labour cost are least restrictive. Advancement is thus constrained cognitively and financially, not educationally. A pilot extension package is proposed for two blocks per district: season long Farmer Field Schools on ragi and pulse agronomy, demonstration plots managed by trained lead farmers (one per 50 households) and vernacular audio-visual advisories routed through SHG and PRI networks. This should be paired with Joint Liability Group–based Kisan Credit Card saturation drives and MGNREGA-converged water harvesting. Feasibility is limited by scattered hill habitations

raising delivery costs, thin banking and Business Correspondent networks, insecure podu land titles restricting collateral, and undulating terrain precluding canal irrigation; FPO-mediated credit and community-managed lift irrigation are the realistic entry points.

DECLARATIONS

Ethics approval and informed consent: Ethical norms were strictly followed while conducting this research according to the principles of social science research. Ethical issues were considered and waived by Departmental Research Advisory Committee, Department of Agricultural Extension Education, M. S. Swaminathan School of Agriculture, Centurion University of Technology & Management, Odisha-761211, India. All participants provided their informed consent for collection of response.

Conflict of interest: The authors have declared that no conflict of interest exists in the conduct of the research.

Data availability statement: Data is available upon reasonable request from the first author.

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Perceived Nutritional Constraints and Preferred Interventions among Farm Women: Evidence from Mahbubnagar District, Telangana

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HIGHLIGHTS

- Low income was the most important factor that hindered the consumption of foods for good nutrition.
- Low levels of literacy and family priorities made a significant impact on dietary practices.
- Women's participation in household food decisions was the top suggested intervention.
- Strengthening nutrition-based education programs at the community level was recognised as the main intervention for improving nutritional status.

ARTICLE INFO

Keywords: Dietary diversity, Farm women, Nutritional constraints, Nutrition education, Women's empowerment.

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ABSTRACT

Adequate nutrition is essential for maintaining the health, productivity, and well-being of farm women; however, several socio-economic and behavioural factors limit their access to nutritious foods. The study undertaken during 2025, examined the constraints affecting nutritious food consumption and identified suitable interventions among 180 farm women in Mahbubnagar district, Telangana. A descriptive research design was adopted, and respondents were selected through a multistage random sampling technique. The identified constraints and suggestions were prioritised using the Rank-Based Quotient (RBQ) method. The findings revealed that low income was the most significant constraint, followed by family priority, low literacy, inadequate nutrition education, gender norms, traditional food habits, and limited availability of nutritious foods. Farm women identified greater participation in household food-related decision-making, community-based nutrition education, promotion of nutrient-rich kitchen gardens, and balanced dietary practices as the most effective strategies. These findings provide valuable insights for developing nutrition-sensitive interventions and policies to improve dietary diversity and nutritional well-being among rural farm women.

INTRODUCTION

Women are the most important target group when it comes to nutrition. Today's lifestyle and altered eating habits have resulted in nutritional deficiencies all over the world. Even in a rich population, micronutrient deficiencies are of concern (Rani, 2018). Nutritious food is essential for good health. One of the most important ways to be healthy is to eat the right foods. A well-balanced diet helps to maintain a healthy body and to prevent diseases (Kumbhare et al., 2023). Good nutrition is crucial to good health, better work productivity, and prevention of communicable and non-communicable diseases among rural people, especially the female farmers involved in agriculture (Wheeler & Nye, 2024).

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Although women play a vital role in food production, they are often disadvantaged in their nutritional status due to a lack of access to productive resources, low income and restricted participation in household decision-making (Gupta, 2024). Food affordability is a key driver of healthy food intake, with lower-income groups often choosing cheaper and higher-energy-density foods over those higher in nutrient content (Drewnowski et al., 2020). Women empowerment is the empowerment of women to participate in decision-making to function in poverty eradication, social integration and other areas in an integrated and sustainable way (Roy et al., 2024). In 2023, some 2.33 billion people were moderately or severely food insecure and 864 million were severely food insecure, reflecting the ongoing inequalities in access to sufficient food (FAO et al., 2024). Moreover, in 2022, approximately 2.8 billion people could not afford a healthy diet, and affordability continues to be a major challenge in low- and middle-income countries (LMICs) (FAO et al., 2024).

Food insecurity disproportionately affects women, with 26.1% of adult women facing moderate to severe food insecurity, versus 24.2% of men, and almost 1/3rd of women worldwide eating diets that are not diverse enough (UN Women, 2025). The statistics show that while the food production system is an important source of food, access to nutritious foods and socio-economic constraints limit farmers' nutritional outcomes, especially farm women, and highlight the need for context-specific solutions and nutrition-sensitive policies. (Kumbhare et al., 2023) noted that there are 17 Sustainable Development Goals (SDGs) set by the United Nations, where SDG 2 is for zero hunger, food security, improved nutrition, and sustainable agriculture. The nutritional status, dietary diversity and food consumption pattern of rural women have been studied in several studies, and the socio-economic and demographic determinants have been emphasized. But few studies have considered the limitations to the consumption of nutritious foods and the perceived interventions by the farm women using the Rank-Based Quotient (RBQ) approach. Although the role of the farm women is very significant in agriculture, studies on nutritional status, dietary diversity, access constraints etc. in Mahbubnagar district of Telangana is limited. Furthermore, information about the participation of women in agriculture is limited in Mahbubnagar district. This study thus addresses this gap by establishing and prioritising nutrition constraints and context-specific interventions while informing nutrition-sensitive policies and extension programmes.

METHODOLOGY

Mahbubnagar district of Telangana, India, was purposively selected because of the predominance of agriculture in the area, coupled with the active role of women in agriculture. The mandals were selected by purposive sampling to get maximum participation of women in agricultural activities in four mandals: Mahbubnagar, Bhoothpur, Devarakadra and Koilkonda. The four mandals were chosen for their representative nature of the various farming systems: Mahbubnagar (urban–rural transition), Bhoothpur (rainfed agriculture), Devarakadra (minor surface irrigation with intensive monoculture), Koilkonda (highly rain-dependent dryland agriculture). A total of 12 villages were selected (3 villages from each selected mandal). Random sampling was used to select 15 farm women from each of the villages, and a total of 180 women were sampled. A descriptive research design was employed to determine the main constraints for the consumption of nutritious food among the farm women and record their suggestions to improve their dietary practices and nutritional status.

The constraints and suggestions incorporated in the research were determined after an extensive literature review, Cronbach's Alpha for the identified scale items was 0.895, Interpretation was Good internal consistency. From this process, eight major constraints and five potential suggestions related to consuming nutritious food were finalised. Each constraint and suggestion was first ranked by the respondents in order of perceived importance, where Rank I was deemed to be of highest priority and the final rank was of lowest priority.

To prioritise the constraints and suggestions statistically, the Rank Based Quotient (RBQ) technique was used. Each rank given by the respondents was multiplied by the corresponding weight (n+1-i), where n is the number of ranks, and i is the rank given to the constraint or suggestion. The higher the rank, the more weight; the lower the rank, the less weight, and so on in this weighting procedure, which reflects more accurately what the respondents preferred. The weighted scores derived for each rank were aggregated over all the respondents and divided by the total number of respondents (N) and the total number of ranks (n). The value obtained was then multiplied by 100 to give a Rank-Based Quotient (0-100), with higher scores representing higher importance/priority. Last, the constraints and suggestions were ranked in order of their RBQ value to find their final rank.

$$RBQ = \frac{(\Sigma f_i\,(n + 1 - i)}{(N \times n)} \times 100$$

Where, f_i = Frequency of respondents assigning the ith rank, n = Total number of ranks, i = Rank assigned, N = Total number of respondents

RESULTS

Perceived constraints affecting nutritional security among farm women

Table 1 shows the factors that affect the consumption of nutritious food amongst the farm women. According to the RBQ analysis, low income was the most important nutritional constraint (RBQ = 74.5). The ranking is by the respondents' perception of

Table 1. Ranking of Perceived Constraints Affecting Nutritional Security among Farm Women Using Rank-Based Quotient (RBQ)

S.No.	Constraints	RBQ	Rank
1.	Low Income	74.5	I
2.	Family Priority	64.8	II
3.	Low Literacy	59.5	III
4.	Nutrition Education	55.6	IV
5.	Gender norms	54.2	V
6.	Traditional food habits	53.8	VI
7.	Limited availability of nutritious foods	49.3	VII
8.	Lack of access to kitchen garden inputs	37.9	VIII

the relative importance of income in affecting their ability to access nutritious foods, not an indication of a causal link. The second most important constraint was family priorities, indicating that women had other family members' nutrition needs preceding their own. Low literacy and poor nutrition education were also deemed significant barriers to awareness of balanced diets and food choices. Some other limitations the respondents perceived were gender norms, traditional food practices, lack of nutritional food items and lack of access to kitchen garden inputs.

Preferred interventions for overcoming nutritional constraints

Table 2 depicts the farm women's suggestions to address the identified nutritional challenges. The survey results showed that the most important focus was on women's participation in food-related decisions within the household, as 79.4% of respondents considered it to be the most important intervention (Rank Ist). It assumes that women's empowerment in decision-making processes allows them to shape food choices, food planning and resource distribution, all of which will eventually result in increased dietary diversity and nutrition outcomes. Strengthening community-based nutrition education programmes was the next most popular suggestion (78.5%), indicating the need to keep educating the community about balanced diets, nutrient needs, healthy preparation of food and proper feeding practices through continuous nutrition education. The third most commonly identified training priority was to train women to grow nutrient-rich kitchen gardens (61.1%), which highlights the importance of boosting household access to fresh vegetables and fruits and decreasing reliance on market availability. The fourth most important item was encouraging women to engage in 'balanced dietary habits' (53.4%), which indicates the importance of ongoing behaviour change communication for regular consumption of nutritious and diversified foods. Preference for frequent meetings by Anganwadi workers/nutrition experts (27.4%) was ranked at Vth, which is again important suggestion to improve the nutritional status of farm women. Overall, the results indicated that women believe empowerment, nutrition education, kitchen gardening, and nutrition-related practices are the most effective interventions for enhancing nutritional outcomes and the nutritional status of households.

DISCUSSION

The results indicate that factors impacting farm women's nutritional status do not stand alone, but rather are interlinked. Dietary behaviour is affected by all these economic restrictions, gender differences, knowledge deficits, and food access barriers. Thus, a comprehensive approach which involves livelihood strengthening, women empowerment, nutrition education, behavioural change communication, and nutrition-sensitive agriculture is needed to improve nutrition outcomes. Extension agencies can play a major role in improving dietary diversity and nutritional security among farm women if the role of extension agents is strengthened to provide the interventions in their immediate context. Households face financial constraints when purchasing healthy foods because of increasing food prices. Women's nutritional needs are often overlooked as priority is given to other family members. Limited literacy decreases the ability to understand nutrition related information, and lack of contact with extension decreases exposure to nutrition education. Women are less likely to be involved in food decision-making due to cultural beliefs and gender norms, and people are reluctant to change traditional food habits, which impacts dietary diversity. The lack of access to local markets, limited access to kitchen gardens and inputs, and seasonal shortages further constrain the uptake of nutritious and sustainable diets. The results of the present study are similar to the results of (Ravi et al., 2024; Kujur et al., 2026). The RBQ responses indicated that the issue of low income was considered as the most important perceived nutritional constraint, as it did not allow them to afford the purchase of rich nutrient foods and a balanced diet. Low income had the highest RBQ ranking because financial constraints were seen as the most proximal obstacle to purchasing healthy foods. Seasonal agricultural activities were the primary livelihood of most households, restricting food availability. In contrast, gender norms and nutrition education had an indirect impact on nutrition practices and were of less priority than economic constraints. The results of the present study corroborate findings of Chaturvedi et al. (2024), who found that women in rural households are largely engaged in domestic and care-related work activities, and during these activities, their capacity to ensure a well-balanced and nutritious diet is reduced. The research highlighted that the nutritional needs of women are often neglected in favour of their family's nutritional requirements, which contributes to poor nutritional status and dietary diversity in the household. The perceived constraint that stood out as the most important was low income, as many farm households relied on seasonal farm income, making it difficult to have access to a variety and adequate nutritional intake all year round. Moreover, low literacy rates and inadequate nutrition education limited awareness of balanced diets and healthy food choices, limiting the uptake of recommended nutrition. Limited decision-making power among female members of the household was another factor that slowed the use of better nutrition practices, since women's nutritional needs were not always prioritized. The results of these findings indicate that integrated interventions (combining income generation, nutrition education and women's empowerment) are needed to improve nutritional practices.

Table 2. Suggestions for overcoming the constraints faced by farm women in Mahbubnagar District, Telangana

S.No.	Suggestions	Percentage	Rank
1.	Ensure women's participation in household food-related decisions	79.4	I
2.	Strengthen nutrition-based education programs at the community level	78.5	II
3.	Farm women should be trained to adopt nutrient-rich kitchen gardens	61.1	III
4.	Motivate women to adopt balanced diets	53.4	IV
5.	Frequent meetings should be organised by the Anganwadi worker/nutrition expert to provide health and nutrition-related information	27.4	V

(Gokhale & Rao, 2022) also reported that educational level, income level and socio-economic status had significant impacts on dietary diversity among rural women. As food is available but not well utilised, the role of nutrition education is a constraint on how well food is used. While farm households may be able to grow a variety of agricultural products, low awareness of foods for dietary diversification, food combinations, availability of micronutrient-rich foods, and appropriate cooking methods may restrict the nutrition benefits. Nutrition education programmes can enhance knowledge, attitudes and practices about a healthy diet. The results of the present study were consistent with the results obtained by (Salam et al., 2023), who showed that structured nutrition education has a significant impact on increasing the knowledge of the participants about iron deficiency anaemia among the rural communities in Karnataka.

Salam et al. (2023) emphasized the importance of targeted educational approaches to increase awareness of nutrient needs, nutrient deficiency symptoms, nutrient prevention strategies, and proper nutrition practices. The authors stressed that poor nutritional knowledge and inadequate educational opportunities limit access to food resources within the household and often make individuals unable to make sound food choices. This was also observed in the current study, where low literacy was one of the key factors affecting diet patterns and nutrition status of the farm women. Low levels of education can limit access to reliable nutrition information, impact understanding of healthy eating, and limit the use of new food preparation and consumption practices. In addition, the results suggest that just providing food is not enough to improve nutrition outcomes if knowledge sharing and behavioural change strategies are not effective. The results of the present study corroborate the results of Islam et al. (2024), which indicated that women continue to be constrained in access to productive resources, decision-making, nutrition information, and health services in South Asia, primarily due to entrenched gender norms and unequal power relationships.

The traditional roles of women, which are often given priority over the nutritional needs of women, were highlighted as hurting the nutritional intake of women, because the nutritional needs of other members of the family are often given priority. These findings corroborate the findings of the current study, which found that gender norms were one of the dominant constraints affecting the dietary habits and dietary situation of farm women. Even though food availability has improved, food habits are very strong and resistant to change, as highlighted by Masters et al. (2022). Owoputi et al. (2022), However, determined that enhanced crop diversity and nutrition-sensitive farming increased food security and women's dietary diversity through increased availability of nutritious foods. The priority given to nutrition education, kitchen gardens and food balancing demonstrates that the respondents were aware of the importance of having agricultural production and nutrition improvement together. Likewise, the Women's Empowerment Framework points out that women's involvement in household decision-making is crucial in enhancing the dietary diversity and the nutritional status of the household. The importance of women's participation in food-related decisions in the present study reinforces this approach and showed that women's empowerment is an important factor for food security of farm households.

CONCLUSION

Food choices are influenced by socio-economic, educational and cultural constraints, which need to be taken into account when improving the dietary pattern and nutritional status of farm women. Improving women's decision-making, nutrition education, kitchen gardens and nutritional practices can increase dietary diversity, food security and sustainable nutrition for rural women. The study offers significant policy implications from Department of Agriculture, Department of Women and Child Development, ICDS, Anganwadi Centres, KVKs, State Agricultural Universities, Panchayati Raj Institutions, and NGOs for agricultural extension and rural development, nutrition organisations, and local food production to develop nutrition-sensitive programmes that can incorporate nutrition education and women's empowerment. The results can support the design, implementation, and evaluation of nutrition and kitchen garden promotion and women's decision-making activities for agricultural extensionists to improve the nutrition dimension of agricultural activities.

DECLARATIONS

Ethical approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Agricultural Extension Education, M. S. Swaminathan School of Agriculture, Centurion University of Technology & Management, Odisha waived the ethical approval. Informed consent was obtained from all respondents before data collection. The respondents were informed about the purpose of the study, and their participation was voluntary.

Data availability statement: Data is available upon reasonable request from the first author as well as corresponding author.

Competing interests: The authors declare that they have no competing interests.

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From Hearth to Wellbeing: Clean Cooking, Women's Welfare and Socioeconomic Development in Agricultural Households

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HIGHLIGHTS

- Economic independence was the strongest determinant of improved living standards.
- Social participation and LPG refill affordability enhanced rural household well-being.
- PMUY supports agricultural livelihoods through women's socio-economic empowerment.

ARTICLE INFO

Keywords: Clean energy transition, Women's empowerment, Social participation, Energy poverty, LPG adoption, Rural extension, Energy access.

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ABSTRACT

Clean cooking is an important rural development issue for agricultural households because it can reduce women's domestic drudgery and promote their participation in household and community activities. Although the Pradhan Mantri Ujjwala Yojana (PMUY) has expanded LPG access among economically disadvantaged rural households, its welfare outcomes remain underexplored. This cross-sectional study examined the socioeconomic determinants of perceived living standards among 279 women PMUY beneficiaries in rural Madhya Pradesh, selected through multistage stratified random sampling during 2025. An Ordered Logit Model and Average Marginal Effects were used for analysis. The model was statistically significant (LR $\chi^2 = 130.92$, $p < 0.001$). Education, perceived health improvement, refill affordability, social participation, perceived LPG safety, decision-making respect, and economic independence were positively associated with higher perceived living standards, whereas income increase, reported by only 3% of respondents, showed a potentially fragile negative association. Refill affordability, social participation, and economic independence had the largest marginal effects. The findings highlight the importance of sustained refill affordability, women's agency, and social participation in improving perceived welfare and underscore the role of extension institutions in promoting awareness, refill support, and women-centred livelihood interventions.

INTRODUCTION

Rural development in agricultural communities depends not only on farm production and household income, but also on the health, time use, social participation, and decision-making capacity of rural households. Access to clean cooking energy is therefore relevant to agricultural and rural development, particularly in low- and middle-income countries (Mounika et al., 2026). Energy poverty limits access to modern fuels and reinforces multidimensional deprivation through reduced health, educational opportunities, economic participation, and community engagement. Rural women and children bear a disproportionate burden because they are often responsible for biomass collection and cooking, leading to prolonged smoke exposure and time-intensive domestic

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work (International Energy Agency, 2020). Affordable, reliable, and sustainable modern energy is consequently linked with SDG 7, gender equality, and improved well-being (Rao & Pachauri, 2017; Elavarasan et al., 2021).

Many rural households continue to depend on firewood, crop residues, and animal dung for cooking. This dependence contributes to household air pollution, environmental degradation, health risks, and social inequality (Guta et al., 2024; Byaro et al., 2024). For women in agricultural households, the labour involved in fuel collection and cooking may reduce the time available for farm activities, income-generating work, skill development, and participation in local institutions. Clean cooking is therefore not only an energy-access concern; it is also associated with women's welfare, social inclusion, and inclusive rural development. The transition to cleaner fuel may create conditions that enable women to participate more effectively in household, social, and livelihood activities.

The PMUY, launched in 2016, provides subsidised LPG connections to women from economically disadvantaged households in India (NITI Aayog, 2020). In agricultural households, access to LPG may reduce cooking-related drudgery and support improvements in health, safety, social participation, and women's agency. Previous studies have examined PMUY mainly in relation to LPG adoption, affordability, usage, and household energy transitions (Dash et al., 2018; Gould & Urpelainen, 2018; Swain & Mishra, 2020). However, limited attention has been given to perceived living standards as a broader welfare outcome and to how PMUY-related factors such as affordability, health, social participation, safety, decision-making, and economic independence are associated with women's perceived welfare. This study addresses this gap by examining the socioeconomic determinants of perceived living standards among women PMUY beneficiaries in rural agricultural households, providing a broader assessment of PMUY outcomes beyond LPG adoption and use.

This study addresses that gap by examining the socioeconomic determinants of perceived living standards among 279 women PMUY beneficiaries in rural agricultural households in Madhya Pradesh. By integrating affordability, health, social participation, perceived safety, respect for decision-making, and economic independence within a single empirical framework, the study provides evidence for rural development and women's welfare. The findings can help extension agencies, self-help groups, Gram Sabha platforms, and local institutions design targeted awareness, refill support, and women-centred livelihood interventions.

METHODOLOGY

The study was conducted in 2025 in rural Madhya Pradesh, India, selected for its large rural and agricultural population and continued need for clean cooking among economically disadvantaged households. The study sample was drawn from 8 districts and 16 villages, with 16 respondents selected from each village, yielding a total of 279 women participants. Eight districts, Vidisha, Raisen, Rajgarh, Sehore, Dewas, Ujjain, Hoshangabad, and Damoh, were purposively selected to capture socioeconomic, agricultural, and PMUY coverage variations. The study included women PMUY beneficiaries from agricultural households. Agricultural status was verified based on the household's primary livelihood, while village-level PMUY beneficiary lists served as the sampling frame. Eligible women were randomly selected. Informed consent was obtained from all respondents, and the study followed the ethical principles of the Declaration of Helsinki.

A multistage stratified random sampling technique was employed. Districts were selected in the first stage, followed by the selection of villages and eligible women beneficiaries through random sampling. Data were collected through personal interviews using a pre-tested structured interview schedule. The sampling approach was based on previous studies of clean cooking adoption and women's decision-making in rural households (Swain & Mishra, 2020).

The required sample size was estimated at a 95% confidence level and a 5% margin of error using the formula:

$$n = \frac{[Z^2 \times p \times (1 - p)]}{E^2}$$

where, $Z = 1.96$, $p = 0.24$, and $E = 0.05$. Based on an estimated PMUY beneficiary population of 1,484,028 households, the required sample size was 280 (Ministry of Petroleum and Natural Gas, n.d.; Ranjan et al., 2025). After data screening, 279 complete and valid responses were retained for analysis. Primary data were complemented with official PMUY and government records.

The dependent variable was women's perceived standard of living after PMUY benefits, measured using the question, "How would you rate your household's standard of living after receiving PMUY benefits?" Responses were coded 1 = poor, 2 = good, and 3 = very good. The questionnaire was pre-tested for clarity and suitability before the survey. Education was coded as an ordered score according to the highest educational attainment; LPG refill affordability and social participation were similarly measured using ordered categories. Health improvement, income increase, LPG safety, decision-making respect, and economic independence were coded 0 = no and 1 = yes. An Ordered Logit Model was used because the dependent variable was ordinal, and Average Marginal Effects were estimated to facilitate interpretation (Asiama & Ankrah, 2026). The model was specified as:

$$Logit\,[P\,(Y_i \leq j)] = \alpha_j - (\beta_1\,Education + \beta_2\,Health\ improvements + \beta_3\,Affordability + \beta_4\,Social\ gatherings + \beta_5\,Income\ increase + \beta_6\,Safe\ gas + \beta_7\,Decision\ respect + \beta_8\,Economic\ independence)$$

where (Y_i) denotes the living-standard category, (j) the threshold, (αj) the threshold parameters, and (β) the estimated coefficients. Results were reported as odds ratios, p-values, and Average Marginal Effects, with significance assessed at 5%.

RESULTS

Factors associated with perceived living standards

The results of the Ordered Logit Model are detailed in Table 1. The model demonstrated statistical significance (LR $\chi^2 = 130.92$, $p < 0.001$), with a pseudo-R^2 of 0.267. Factors such as education, perceived health improvement, refill affordability, social participation, LPG safety, respect in decision-making, and economic

Table 1. Ordered logit result

Variable	Coefficient	Odds Ratio	Std. Error	z-value	p-value	AME (%)	95% CI (Lower)	95% CI (Upper)
Education	0.013	1.013	0.005	2.88	0.004	+1.8%	0.004	0.022
Health improvements	0.278	1.320	0.090	3.09	0.002	+4.3%	0.102	0.454
Affordability	0.967	2.632	0.192	5.03	0.000	+15.1%	0.590	1.345
Social gatherings	1.176	3.244	0.226	5.21	0.000	+18.3%	0.733	1.619
Income increases	-1.743	0.175	0.749	-2.32	0.020	-27.2%	-3.212	-0.274
Safe gas	0.157	1.170	0.063	2.48	0.013	+2.4%	0.033	0.281
Decision respect	0.252	1.287	0.118	2.15	0.032	+3.9%	0.022	0.482
Economic independence	1.259	3.522	0.316	3.98	0.000	+19.6%	0.639	1.878
Cut 1	2.271		0.860				0.584	3.958
Cut 2	6.531		0.948				4.671	8.390
No. of Obser	279							
LR chi^2	130.92							
Prob>chi^2	0.000							
Pseudo R^2	0.267							
Log likelihood	-179.511							

independence were positively correlated with higher perceived living standards. Notably, economic independence, social participation, and refill affordability exhibited the strongest associations. Conversely, an increase in income was found to be negatively related to perceived living standards. Concerns regarding multicollinearity were minimal (mean VIF = 1.26). To ensure robustness, a Generalized Ordered Logit model was also estimated, yielding consistent findings; the Wald test results were not significant (χ^2 (7) = 8.09, p = 0.324). All analyses were carried out using Stata.

Average marginal effects (AME)

The AME presented in Table 1 indicated the magnitude of association between the explanatory variables and the probability of reporting a higher perceived living standard. Education increased this probability by 1.8 percentage points, while perceived health improvement increased it by 4.3 percentage points. Refill affordability increased the probability of reporting a higher perceived living standard by 15.1 percentage points. Participation in social gatherings increased this probability by 18.3 percentage points. Perceived LPG safety and decision-making respect increased the probability by 2.4 and 3.9 percentage points, respectively. Economic independence had the largest positive marginal effect, increasing the probability of reporting a higher perceived living standard by 19.6 percentage. In contrast, income increase reduced this probability by 27.2 percentage points.

Goodness-of-fit of the model

The goodness of fit tests (Table 2) indicated no significant difference between observed and model predicted frequencies (Pearson χ^2 = 0.073, df = 2, p = 0.964; Deviance χ^2 = 0.057, df = 2, p = 0.972). With both p values well above 0.05, the ordered logit model demonstrates an acceptable fit. The low degrees of freedom reflect the limited number of distinct covariate patterns/ groups used in the test, rather than the number of predictors, and therefore should be interpreted as a property of the grouping structure.

Table 2. Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	0.073	2	0.964
Deviance	0.057	2	0.972

DISCUSSION

The findings suggest that PMUY's rural development contribution extends beyond LPG access to broader dimensions of women's well-being, including health, safety, social participation, decision-making, and economic agency. This indicates that rural extension interventions should view clean cooking as part of an integrated livelihood and women's empowerment strategy. Sustained benefits, however, depend on affordable and regular LPG refills. When refill costs compete with food, health, education, and agricultural expenditures, households may continue using biomass alongside LPG. Thus, PMUY's effectiveness depends not only on providing connections but also on enabling sustained use, consistent with evidence identifying refill affordability as a key constraint among economically vulnerable households (Guta et al., 2024).

Social participation is also positively associated with perceived living standards. Women who participate in social gatherings may have greater access to self-help groups, community meetings, informal support networks, and local information channels. These platforms can strengthen social inclusion and facilitate awareness of livelihood, welfare, and energy-related opportunities (Rathour et al., 2022). The finding aligns with studies linking cleaner cooking practices to reduced domestic drudgery, increased social participation, and community-level benefits (Behera et al., 2015; Gould & Urpelainen, 2018). Although the present study does not measure time saved from fuel collection or cooking, the association indicates that women's participation is an important dimension of rural development.

Economic independence has the largest positive marginal effect among the significant positive variables, indicating that greater

economic independence is associated with higher perceived living standards. This may reflect women's greater participation in household decisions, livelihood activities, and community institutions, consistent with research highlighting women's agency in cleaner-fuel adoption and rural welfare (Swain & Mishra, 2020). Education, perceived health improvement from reduced smoke exposure, LPG safety, and decision-making respect further indicate that perceived welfare extends beyond material conditions and includes social, health, and agency-related dimensions (Rao & Pachauri, 2017; Melin et al., 2021). The negative association for income increase requires particular caution because only 3.0% of respondents reported an increase, raising the possibility of estimation instability or quasi-complete separation. A sensitivity analysis excluding this variable showed that the principal effects of affordability, social participation, and economic independence remained positive and statistically significant, with similar odds ratios to the full model. Thus, the negative income-increase coefficient should not be interpreted as evidence that higher income reduces perceived welfare.

The findings suggest that maximising the welfare benefits of PMUY requires policy interventions beyond LPG connection provision. Improving refill affordability through targeted support, adapting implementation to local socioeconomic conditions, strengthening awareness through PAHAL and Gram Sabha platforms, and promoting women's livelihood opportunities and community participation can support sustained clean cooking adoption and inclusive rural development. Extension agencies, self-help groups, Gram Sabha platforms, and local institutions can further assist vulnerable households through awareness, refill-related support, and livelihood linkages (World Health Organization, 2016; Sharma & Dash, 2022). However, this study has several limitations. The cross-sectional design permits identification of associations rather than causal relationships, while the single-state setting may limit generalisability to all PMUY beneficiaries. In addition, both the explanatory and outcome measures are based on self-reported perceptions and may therefore be subject to recall and social-desirability bias. This possibility is particularly relevant because PMUY is a government welfare programme, which may have encouraged some respondents to report more favourable perceptions of its benefits. Future research should use longitudinal designs, broader geographical coverage, objective measures of LPG use and expenditure, and validated measures of extension exposure to strengthen causal inference and reduce potential reporting bias.

CONCLUSION

The study highlights that the welfare potential of PMUY depends not only on LPG connections but also on sustained affordability, women's agency, and social participation. Policy efforts should therefore move beyond connection coverage towards measures supporting regular refill use and women-centred livelihood and community engagement. Rural extension agencies, self-help groups, Gram Sabha platforms, and local institutions can contribute through targeted awareness, information on refill support, and livelihood linkages. However, the findings have important limitations. The cross-sectional design prevents causal inference, while the single-state setting limits generalisability. Further, reliance on self-reported explanatory and outcome measures may introduce recall and social-desirability bias, particularly because PMUY is a government welfare programme. Future research should employ longitudinal designs, broader geographical coverage, objective measures of LPG use and expenditure, and validated measures of extension exposure. Such evidence can strengthen understanding of PMUY's sustained welfare effects and support more equitable clean-cooking interventions.

DECLARATIONS

Ethical approval and consent to participate: The study involved no invasive procedure on human participants as such the committee of Department of Humanities and Social Sciences, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India waived the ethical approval. Informed consent was obtained from all respondents before data collection. The respondents were informed about the purpose of the study, and their participation was voluntary.

Data availability statement: Data is available upon reasonable request from the first author as well as corresponding author.

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this manuscript. All authors have critically reviewed, revised and approved the final version of the manuscript and take full responsibility for its content.

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Multidimensional Constraints to Native Fish Biodiversity Management: Perceptions of Fishers in North-East India

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HIGHLIGHTS

- Constraint severity differed significantly across states, water bodies and villages.
- Findings highlight the need for context-specific interventions for sustainable biodiversity management.

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ABSTRACT

Native fish biodiversity in North-East India is increasingly threatened due to environmental degradation, livelihood pressures, inadequate infrastructure, and weak institutional support. This study assessed the multidimensional constraints fishers perceive in managing native fish biodiversity in selected freshwater ecosystems in Manipur and Tripura. A cross-sectional study was conducted during 2023–2025 among 240 fishers from 12 villages across the Loktak, Pumlen, Rudrasagar, and Dumboor water bodies of Northeast India. Primary data were collected through personal interviews, focus group discussions, and field observations. Constraints were assessed using a five-point severity scale and analysed through Weighted Mean Scores, Kruskal–Wallis H tests and eta-squared (η^2H) for assessing effect size. Significant village-level differences were observed for all constraint dimensions ($p<0.001$), with large effect sizes for physical, environmental, marketing, infrastructural, institutional and overall constraints ($\eta^2H=0.495–0.914$). In contrast, technology-transfer constraints showed a moderate effect ($\eta^2H = 0.120$). Among the lakes, Pumlen recorded particularly high physical, marketing and infrastructural constraints, whereas Rudrasagar showed comparatively lower constraint levels. The findings highlight a clear gap between biodiversity knowledge and its translation into conservation action. Sustainable management therefore requires location-specific, participatory fisheries extension interventions that integrate capacity building, market support, improved infrastructure, information access, and community participation.

INTRODUCTION

Fish biodiversity, a fundamental component of freshwater ecosystems, contributes to ecological stability, ecosystem functioning, food security, and community livelihoods (Reid et al., 2019). However, freshwater ecosystems are increasingly exposed to habitat degradation, pollution, wetland encroachment, hydrological alterations, overexploitation, invasive species, and climate change, threatening native fish populations and ecosystem integrity (Dudgeon et al., 2006; Tickner et al., 2020; Sreeraman et al., 2023; Koreti et al., 2025). The northeastern region of India, with its abundant freshwater ecosystems, is no exception.

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The northeastern region of India is a major centre of freshwater fish biodiversity, hosting diverse aquatic ecosystems and forming part of the Indo-Burma Biodiversity Hotspot (Vishwanath, 2017). It has many fish species, including endemic, threatened, and economically important species, and rivers, wetlands, lakes, and reservoirs serve as habitats for indigenous and ethnic fishing communities, who benefit from them through their livelihoods (Sarma et al., 2018). Traditional fishing practices and indigenous ecological knowledge (IEK) support biodiversity conservation and sustainable fisheries management (Jones et al., 2024). These socio-ecological systems, however, face ever-changing threats from habitat modification, pollution, hydrologic modifications, and overexploitation (Vishwanath, 2017; Sreeraman et al., 2023). The water resources of Manipur and Tripura, i.e. the Loktak and Rudrasagar Ramsar wetlands (Ramsar Sites), and Pumlen Lake and Dumboor Reservoir, are valuable inland fisheries resources and livelihoods for the local fishing communities. Different threats to these ecosystems impact fish habitats, species diversity, recruitment, and fisheries productivity (Dutta et al., 2018; Meinam et al., 2025).

Socio-economic, infrastructural, institutional, and technological conditions also affect biodiversity management, alongside ecological pressures. However, constraints such as limited livelihood opportunities, poor infrastructure, marketing problems, limited access to credit and technology, and weak institutional support and extension services hamper fishers' ability to implement conservation-oriented practices (Allison & Ellis, 2001; Béné et al., 2016; Bayala, 2023). Likewise, poor coordination, minimal stakeholder involvement, and weak co-management reduce the success of conservation programmes (Ostrom, 2009; Masud et al., 2022). Contextually, several studies have focused on fish species diversity and wetland degradation in the wetlands of North-East India, where the multidimensional constraints faced by fishers and their spatial variations due to agroecological specificity remain relatively under-researched (Barman, 2004; Bhattacharjee, 2013; Mandal, 2015; Dauruhi et al., 2025). Thus, an assessment can identify deficiencies that hinder effective biodiversity management and may provide a basis for appropriate community-level interventions.

Against this background, this study assessed the constraints of native fish biodiversity management as perceived by fishers in selected freshwater ecosystems of Northeast India. The study examined physical, environmental, marketing, infrastructural, institutional, and technology-transfer constraints and their spatial variations to provide a comprehensive understanding of the challenges confronting community-linked biodiversity management and to support location-specific extension, participatory management, and policy interventions.

METHODOLOGY

The study was conducted during 2023–2025 in Manipur and Tripura, which were purposively selected for their rich freshwater fish biodiversity and local communities' dependence on them. In Manipur, Loktak Lake (Ramsar site) and Pumlen Lake were selected, whereas in Tripura, Rudrasagar Lake (Ramsar site) and Dumboor Reservoir were selected. Three villages from each selected water body were purposively selected based on the presence of active fishing communities and their relevance to the study, resulting in 12 villages, i.e. Thanga, Karang and Laphupatvillages of the Loktak Lake; Yangbi, Komnao and Tokpa Ching villages of the Pumlen Lake; Rangamura, Kemtali and Chandanmuravillages of the Rudrasagar Lake; and Chaplin Sora, Mandir Ghat and Indrajit Para villages of the Dumboor Reservoir.

A quota sampling approach was used to select respondents, with 20 active fishers selected from each selected village, resulting in a total sample of 240 fisher respondents. Quota sampling was used to select fishers because each lake required adequate representation from specific population subgroups. It also helped select respondents without requiring a complete understanding of population size in the sampling frame. Primary data were collected through personal interviews using a pre-tested, semi-structured interview schedule. A pilot study was conducted with 40 non-sampled respondents to pre-test and modify the interview schedule. The final interview schedule covered six constraint categories: physical, environmental/ anthropogenic, marketing and financial, infrastructural, extension/ institutional, and transfer of technology. Each constraint was measured using a five-point severity scale: Most Severe (MS) = 5, Severe (S) = 4, Moderate (M) = 3, Less Severe (LS) = 2 and Least Severe (L) = 1. The collected data were coded, tabulated, and analysed using appropriate descriptive and inferential statistical techniques. The Weighted Mean Score (WMS) was used to assess the perceived severity of individual constraints and rank them within each constraint category using the following formula:

$$WMS = \frac{\Sigma f_i S_i}{N}$$

where, f_i represents the frequency of respondents selecting the ith response category, S_i represents the score assigned to the corresponding response category, and N represents the total number of respondents. The Kruskal-Wallis 1-way ANOVA (k samples) test was used to assess differences in constraint perceptions and their spatial variations among the selected water bodies and villages. Statistical significance was tested at the 5% level ($p< 0.05$). Further, the strength of associations was assessed using bias-corrected eta-squared for Kruskal–Wallis (η^2H) to measure the effect size.

$$\eta^2H = \frac{H - k + 1}{N - k}$$

Where, H = Kruskal-Wallis H, k = No. of Lakes / Villages, N = No. of respondents

The bias-corrected eta-squared (η^2H) value was interpreted using the conventional benchmarks of <.01 = negligible, .01–<.06 = small, .06–<.14 = moderate, and ≥.14 = large (Tomczak & Tomczak, 2014).

RESULTS

Constraints of native fish biodiversity management perceived by the fishers of Manipur and Tripura

The nature and severity of these constraints vary with ecological and socio-economic conditions. Physical constraints,

particularly water scarcity (WMS = 4.492), were the most severe problem in Manipur. Fishers of Tripura identified unfavourable climatic factors (WMS = 4.275) as the major constraint. Regarding environmental and anthropogenic constraints, deforestation and overexploitation ranked first in Manipur (WMS = 4.533), followed by weed domination (WMS = 4.517). whereas flooding (WMS = 4.050) and overexploitation (WMS = 3.733) were the major environmental constraints in Tripura. For marketing and financial constraints, intermediaries' domination (WMS = 4.500) emerged as the most serious problem in Manipur, whereas fluctuation in market prices (WMS = 3.992) ranked first in Tripura. For infrastructural constraints, poor landing and marketing infrastructure ranked first in both Manipur (WMS = 4.500) and Tripura (WMS = 2.667). Among extension and institutional constraints, fishers in Manipur identified a lack of training and awareness programmes (WMS = 4.442) as the most critical issue. In contrast, weak extension services ranked first in Tripura (WMS = 4.250). Among technology transfer constraints, lack of awareness of government fisheries schemes ranked first in both Manipur (WMS = 4.567) and Tripura (WMS = 4.408), as shown in Table 1.

Comparative analysis of spatial variations of perceived constraints among the fishers

Table 2 revealed significant differences in perceived constraints among fishers in Loktak, Pumlen, Rudrasagar, and Dumboor lakes. Fishers around Pumlen Lake experienced the highest levels of physical, marketing and infrastructural constraints. Similarly, fishers in Loktak Lake also reported high environmental and institutional constraints. In contrast, Rudrasagar Lake consistently recorded the lowest mean ranks for most constraint categories, while fishers of Dumboor Reservoir exhibited moderate levels of constraints. Thus, fishers in Manipur, particularly at Pumlen Lake, experienced substantially greater constraints than fishers in Tripura.

Table 1. Constraints of native fish biodiversity management as perceived by the fishers of Manipur and Tripura

Constraints	Manipur (n=120)		Tripura (n=120)	
	Weighted Mean Score	Rank	Weighted Mean Score	Rank
Physical Constraints				
Unfavourable climatic factors	4.550	I	4.275	I
Water scarcity	4.492	II	2.750	IV
Skilled labour scarcity	3.975	IV	4.050	II
Non-availability of fish seed material	3.700	V	2.083	V
Inadequate storage facilities	4.392	III	3.933	III
Environment/ Anthropogenic Constraints				
Pollution	4.483	III	3.533	III
Deforestation and Urbanisation	4.533	I	1.917	VI
Drought problem	3.950	IV	3.050	IV
Flood problem	3.516	V	4.050	I
Overexploitation	4.533	I	3.733	II
Under exploitation	2.750	VI	2.633	V
Weeds Domination	4.517	II	1.842	VII
Marketing and Financial Constraints				
Less demand for fish	3.350	VI	2.200	VI
Competition from larger units	3.450	V	3.475	II
Fluctuation in market price	3.958	IV	3.992	I
Intermediaries' domination	4.500	I	3.050	IV
Lack of access to credit facilities and subsidies	4.200	III	3.000	V
Lack of alternate income sources during lean seasons	4.275	II	3.100	III
Infrastructural Constraints				
Community/personal ownership	4.242	II	2.000	III
Inadequate storage and preservation facilities	3.950	III	2.550	II
Poor landing and marketing infrastructure	4.500	I	2.667	I
Extension/ Institutional Constraints				
Weak extension services	4.008	IV	4.250	I
Lack of training /awareness programme	4.442	I	3.867	II
Inadequate technical knowledge in identifying proper solutions	4.233	III	3.600	IV
Weak coordination between agencies/stakeholders	4.425	II	3.775	III
Transfer of Technology Constraints				
Lack of location-specific fishing advisories	3.492	IV	3.425	III
Difficulty in using improved fishing gears and implements	3.508	III	2.483	IV
Limited access to information through mass media platforms	3.725	II	4.400	II
Lack of awareness about government schemes related to fisheries	4.567	I	4.408	I

Table 2. Analysis of fisheries constraints across the lakes

Variable	Lakes Mean Rank (N=240)				H-value	df	η^2H	Effect size*	P-value	Significance
	Pumlen	Loktak	Rudrasagar	Dumboor						
Physical	202.35	153.83	37.51	88.32	197.915	3	0.826	Large	0.000	Significant
Environmental	188.67	172.22	48.33	72.78	185.881	3	0.775	Large	0.000	Significant
Marketing	202.08	148.65	30.87	100.41	200.472	3	0.837	Large	0.000	Significant
Infrastructural	202.78	158.15	30.50	90.58	219.308	3	0.917	Large	0.000	Significant
Institutional	164.10	166.00	88.14	63.76	106.755	3	0.440	Large	0.000	Significant
Transfer of Technology	148.56	121.90	92.06	119.48	21.223	3	0.077	Moderate	0.000	Significant

*<.01 = negligible, .01–<.06 = small, .06–<.14 = moderate, and ≥.14 = large (Tomczak & Tomczak, 2014)

The Kruskal–Wallis test revealed statistically significant differences across the four lakes for all categories of fisheries constraints (H=21.223–219.308, df=3, p<0.001). The effect sizes indicated large differences for physical (η^2H=0.826), environmental (η^2H=0.775), marketing (η^2H=0.837), infrastructural (η^2H=0.917), and institutional constraints (η^2H=0.440). Among these, infrastructural constraints showed the largest effect, showing the greatest variation in perceived constraints across the lakes. Transfer of technology constraints showed a moderate effect (η^2H=0.077), indicating comparatively lower spatial variation among the lakes. This shows Pumlen generally recording the highest levels of perceived constraints and Rudrasagar the lowest.

The village-level analysis in Table 3 further demonstrates variation in the perceived severity of fisheries constraints across the selected 12 fishing villages. The H-values ranged from 38.352 for transfer of technology constraints to 219.472 for infrastructural constraints, while η^2H values ranged from 0.120 to 0.914, indicating considerable differences among villages. Infrastructural constraints recorded the highest effect size (η^2H=0.914), followed by physical (0.837), marketing (0.834), environmental (0.773), and institutional constraints (0.526), all representing large effects. Transfer of technology showed a moderate effect (η^2H=0.120), suggesting less spatial variation across villages than other factors. The overall constraint score also showed a large effect (η^2H=0.495), indicating substantial differences in overall perceived constraints among villages.

The mean ranks also showed clear spatial differences, where villages surrounding the Pumlen Lake, namely Topa Ching, Yangbi and Komnao, reported the highest physical, environmental and infrastructural constraints, indicating greater challenges. Similarly, villages around Loktak Lake, particularly Karang, Thanga, and Laphupat Tera, recorded the highest marketing constraints. In contrast, villages around Rudrasagar Lake, i.e., Rangamura, Kemtali, and Chandanmura, experienced the lowest levels of constraints across most dimensions. However, institutional and technology-transfer constraints remained comparatively evident in some villages. Villages around the Dumboor Lake showed moderate levels of constraints, with Chaplin Sora recording comparatively higher technology-transfer constraints.

The overall village-level pattern in Table 3 highlights considerable spatial heterogeneity in the constraints fishers face. These findings emphasise the need for lake- and village-specific

Table 3. Analysis of fisheries constraints across the fishing villages

Villages	Mean Rank						
	Physical	Environmental	Marketing	Infrastructural	Institutional	Transfer of Technology	Overall
Topa Ching	211.74	185.10	145.62	203.05	166.10	157.50	178.19
Yangbi	192.36	190.09	152.95	202.50	158.86	130.07	171.14
Komnao	207.30	189.80	144.13	202.27	167.07	163.23	178.97
Thanga	150.53	171.33	202.93	156.40	165.50	124.90	161.93
Karang	155.83	174.74	208.02	157.36	170.24	122.17	164.73
Laphupat Tera	157.12	173.38	191.98	165.24	163.43	121.26	162.07
Rangamura	38.10	56.70	21.10	30.50	81.18	80.60	51.36
Kemtali	44.20	34.53	36.95	30.50	76.53	88.15	51.81
Chandannura	30.23	53.78	34.55	30.50	106.73	107.43	60.54
Indrajit Para	70.73	71.53	106.68	78.63	13.25	84.03	70.81
Mandir Ghat	89.08	79.38	93.20	95.53	64.63	114.45	89.38
Chaplin Sora	105.15	67.45	101.35	97.58	50.63	159.98	97.02
H-value	201.916	187.143	201.112	219.472	131.019	38.352	123.879
η^2H	0.837	0.773	0.834	0.914	0.526	0.120	0.495
df	11	11	11	11	11	11	11
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Effect size*	Large	Large	Large	Large	Large	Moderate	Large
Significance	Significant	Significant	Significant	Significant	Significant	Significant	Significant

*<.01 = negligible, .01–<.06 = small, .06–<.14 = moderate, and ≥.14 = large (Tomczak & Tomczak, 2014)

interventions focusing on habitat restoration, infrastructure, market linkages, extension services, and community-based resource management to conserve native fish biodiversity.

DISCUSSION

The study suggested that conservation and management of native fish biodiversity were influenced not only by fishers' knowledge but also by multidimensional constraints, including physical, environmental, marketing, infrastructural, institutional, and technological factors (Roche et al., 2022). Conservation outcomes are shaped by interactions among ecological conditions, livelihood requirements, institutions, information, and community capacities (Ostrom, 2009). Hamelin et al. (2024) and Sharma et al. (2025) identified a persistent knowledge-action gap. They indicated that knowledge does not necessarily translate into management action because of contextual, institutional, and resource-related barriers.

The higher severity of constraints in Manipur suggested strong links between biodiversity conservation, ecological degradation, and livelihood dependence on wetlands. Pumlen and Loktak reflected multiple pressures experienced by fishing communities. Recent evidence reported *phumdi* proliferation, water pollution, and declining fish species and production as major perceived risks (Singh & Mistri, 2025). Moreover, climatic variability, anthropogenic pressures, and hydrological changeshave been associated with livelihood vulnerability among fishers (Imdad et al., 2025). De and Dwivedi (2024) emphasised environmental management, stakeholder participation, alternative livelihoods, inter-sectoral coordination, and freshwater biodiversity monitoring.

The comparatively lower constraint scores in Tripura, particularly from Rudrasagar Lake's fishers, did not indicate an absence of management concerns. Saha (2018) identified alternative income generation, appropriate land-use practices, and conservation management as important extension needs. He also reported inconsistent attitudes toward consultation with fisheries officials and applying government regulations. In Dumboor Reservoir, moderate constraint levels across most dimensions suggest fishers faced persistent challenges. De and Dwivedi (2024) highlighted similar concerns about stakeholder participation, institutional coordination, and freshwater biodiversity management. Institutional communication, community participation, market access, and fisheries infrastructure remain important for converting awareness into effective management practices (Pomeroy and Rivera-Guieb 2006).

Village-level variation indicated that constraint severity was shaped by local ecological, livelihood, and service-access conditions. Large effect sizes for infrastructural, physical, marketing, and environmental constraints suggested substantial differences in facilities, market access, and local resource conditions. Fishers and fish farmers in Manipur have also reported similar constraints, including poor transportation, inadequate marketing facilities, limited training, and limited financial support (Salam et al., 2020).

In Tripura, inadequate training, extension services, and awareness of government schemes indicated information gaps. Singh et al. (2023) emphasised need-based training, frequent farmer visits, and training evaluation. Niangti et al. (2025) reported similar training gaps among fish farmers, while Periginji et al. (2026) highlighted the need for local-language content, usability, and social and institutional support for digital extension. Extension interventions should therefore combine locally relevant information, digital and interpersonal communication, scheme facilitation, and institutional contact (Reed et al., 2009). Integrating indigenous ecological knowledge with scientific fisheries knowledge is desirable, as fishing communities possess locally developed knowledge of fish species, seasonal changes, fishing grounds, and aquatic environments. Linking these can improve the relevance and acceptability of conservation interventions (Gomes et al., 2025).

CONCLUSION

Barriers included ecological pressures, inadequate infrastructure and market facilities, limited training and awareness, weak extension support, and poor awareness of government schemes. These suggested a gap between biodiversity knowledge and its translation into conservation action, indicating that knowledge alone did not ensure conservation action. Therefore, conservation measures needed to be location-specific and participatory, integrating ecological management, infrastructure, market linkages, extension support and stakeholder coordination. These will enable fishers' conservation knowledge to translate into effective action, supporting sustainable fisheries and livelihood resilience in North-East India. Fisheries extension for native fish biodiversity conservation should move beyond awareness to an integrated approach that combines biodiversity education, capacity building, need-based information, community networks, institutional cooperation, market and livelihood support, and habitat management. Manipur requires greater emphasis on habitat restoration, infrastructure, livelihood diversification, market linkages, and institutional support, whereas Tripura requires stronger fisheries services, flood management, extension support, and institutional communication.

DECLARATIONS

Ethical approval and consent to participate: To protect participant welfare and scientific integrity, we confirm that we conducted this study in accordance with ethical guidelines and with approval from the PME Cell of Central Agricultural University, Imphal, India (Ref. No. 8451 CF/CAU, Date 09/02/2024). To protect individuals' privacy, all data collection and processing procedures adhered to applicable regional laws. We also confirm that all participants consented to participate in the project and to the publication of the manuscript, and that all participants were above 18 years of age during the project period.

The authors confirm that the submitted work has not been published previously (except in the form of an abstract, a published lecture, or an academic thesis, that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or any other language, including electronically, without the written consent of the copyright holder.

We also confirm that we did not use generative AI or AI-assisted technologies in the writing process.

Author contributions: Martina Meinam, Biswajit Lahiri, and SoibamKhogen Singh contributed to the study's conception and design. The supervision and project administration were handled by Biswajit Lahiri. Material preparation, data collection and analysis were performed by Martina Meinam, Biswajit Lahiri, and Prasenjit Pal. Martina Meinam, Biswajit Lahiri, SoibamKhogen Singh, and Amitava Ghosh wrote the first draft of the manuscript. Anil Datt Upadhyay and Y Jackie Singh reviewed and edited the manuscript and supported graphical mapping and the incorporation of relevant visualisation to improve clarity. All authors read and approved the final manuscript.

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Research Note

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Barriers Hindering Tribal Women's Participation in Agriculture in Angul District, Odisha

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HIGHLIGHTS

- Poor market access and limited value-addition opportunities restricted tribal women's economic participation in farming.
- Environmental and infrastructural constraints were perceived as comparatively less severe than social and economic barriers.

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ABSTRACT

Tribal women contributed extensively to agricultural labour in India's tribal belts, yet their participation remained constrained by social, economic, technological, environmental, and institutional barriers that were rarely studied systematically at the district level. The present study was conducted in Angul district of Odisha during 2024-25 to identify and rank the constraints faced by tribal women in agricultural participation. Four blocks (Chhendipada, Athamalik, Pallahada and Kaniha) were purposively selected, and sixteen villages were chosen at random, from which 160 tribal women respondents were drawn. Data were collected through a pre-tested structured interview schedule covering ten constraints under five broad dimensions and were analysed using the Garrett Ranking Technique. The results showed that lack of awareness about agriculture's importance (mean score 87.76) ranked as the most severe constraint, followed by inadequate training on modern farming practices and market trends (83.32). Economic and market constraints, patriarchal social structures, and unclear government policies followed in order of severity, while environmental and infrastructural constraints were rated comparatively less severe. The findings offered extension functionaries and policymakers an evidence-based basis for designing targeted interventions for tribal women in agriculture.

INTRODUCTION

Despite the rapid growth of industry and services, close to 60 per cent of the population still depends on agriculture, directly or indirectly, for food, work, income, and foreign exchange. Within this broad agricultural setting, tribal communities hold a unique position. Living mostly in isolated, ecologically sensitive, and resource-rich areas, tribal populations share a deep bond with land

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and forest. Farming for them extends beyond mere survival; it is woven into their identity, culture, and everyday existence, guided by inherited knowledge and an understanding of seasonal cycles (Gulati et al., 2025).

Women in these communities perform a central but often overlooked role in sustaining agriculture. Their work extends beyond fieldwork to include seed storage, collection of forest produce, livestock management, and sustainable land management. Tribal women engage in nearly every phase of cultivation, including land preparation, sowing, weeding, harvesting, and post-harvest handling, along with allied activities such as animal husbandry, fishing, and participation in Self Help Groups. In many families, women shoulder most of the agricultural burden while men migrate temporarily for wage labour. Yet their deep involvement is frequently constrained by an interconnected web of social, economic, institutional, and personal barriers that limit how fully and effectively they can engage in and benefit from farming (Nain & Kumar, 2010; Chandravadia & Bariya, 2018). Their contribution rarely earns them recognition as farmers, leaving them largely overlooked in policy and public perception (Mishra et al., 2024).

These barriers are seldom uniform or isolated. They range from limited access to land ownership, credit, and modern inputs, to social restrictions on mobility and decision-making, inadequate extension contacts, lack of training opportunities, and the added burden of domestic responsibilities alongside farm work (Singh et al., 2017; Das et al., 2018; Kumari et.al., 2020). Odisha is home to the largest number of tribal groups among Indian states, with 62 recognised communities, 13 of which are classified as particularly vulnerable. Its Scheduled Tribe population exceeds 9.5 million, making up roughly 23% of the state's population. Agriculture contributes about 26 per cent of the state's economic output and sustains nearly 65 per cent of workers, with rice as the primary crop. However, the sector struggles with declining soil quality, waterlogged fields, and frequent droughts, floods, and cyclones. Against this backdrop, tribal women continue to face poverty, limited land rights, and inadequate access to modern inputs, finance, and markets, all of which restrict their capacity to participate in and benefit from agricultural activity (Slathia et al., 2015; Bhilavekar et al., 2025). These barriers intersect with socio-economic, technical, and psychological constraints that further limit tribal women's agency in farming decisions (Kujur et al., 2026).

Angul district, known for its industrial activity centred on the Talcher coalfield, is also home to a considerable tribal population dependent on farming. While tribal women here contribute substantially to agricultural labour, the constraints they face have not been systematically identified or ranked at the district level, leaving extension efforts at risk of addressing symptoms rather than priority barriers (Naveen et al., 2023).

METHODOLOGY

This study was conducted in Odisha, an eastern state of India, selected for its substantial tribal population and the researcher's familiarity with the regional language and customs, which facilitated data collection and helped build trust with participants during 2024-25. Angul district was chosen within Odisha for its notable tribal presence, largely farming-based rural economy, and industrial profile. Of the district's eight blocks, four, namely Chhendipada, Athamalik, Pallahada, and Kaniha, were purposively selected for their contrasting population sizes. From the complete list of villages in each selected block, four villages were then randomly chosen using the lottery method, yielding sixteen villages in total. Similarly, from the list of tribal women households maintained in each selected village, ten respondents were randomly drawn using the simple random sampling method, producing a total sample of 160 respondents across the four blocks. Data were gathered using a structured interview schedule that was pre-tested and prepared in consultation with the research advisor, the Student Advisory Committee, and faculty from the Department of Extension Education. The schedule listed constraints commonly associated with tribal women's participation in agriculture, drawn from a review of prior literature and refined through discussion with subject matter experts and pilot interviews in the study area. Respondents were asked to rank ten identified constraints, grouped under five broad dimensions, namely knowledge and awareness, economic and market, technological and infrastructure, natural resource and environmental, and social and institutional constraints, according to the severity with which each affected their agricultural participation (Chandravadia & Bariya, 2018; Dagar & Upadhyay, 2022; Meena et al., 2026). Responses were recorded directly on the schedule and later compiled onto a master sheet capturing the rankings provided by all 160 respondents (Dagar & Upadhyay, 2022). The ranks assigned by respondents were analysed using the Garrett Ranking Technique. Under this method, the ranks given by each respondent were converted into percentage position scores using the formula.

$$\text{Percent position} = \frac{R_{ij} - 0.5}{N_j} \times 100$$

Where, R_{ij} was the rank given to the ith constraint by the jth respondent and N_j was the number of constraints ranked by that respondent. Percentage positions were converted into Garrett scores using Garrett's conversion table, summed, and averaged for each constraint. Constraints were then arranged in descending order of mean score, with the highest score treated as the most significant barrier to participation (Dagar & Upadhyay, 2022; Gupta et al., 2020).

RESULTS

The constraints faced by tribal women in agricultural participation, analysed through the Garrett Ranking Technique, are presented in Table 1. Ten identified constraints, grouped under five broad dimensions, namely knowledge and awareness, economic and market, technological and infrastructure, natural resource and environmental, and social and institutional constraints.

Under the knowledge and awareness dimension, lack of awareness about agriculture and its importance emerged as the foremost constraint, with a mean Garrett score of 87.76 (Rank I), followed by lack of awareness and training on modern farming practices and market trends, with a mean score of 83.32 (Rank II). These two constraints occupied the top positions among all ten identified barriers, indicating that gaps in basic understanding, rather than resource scarcity alone, formed the primary hurdle to fuller participation among tribal women.

Table 1. Garrett ranking of constraints faced by respondents

S.No.	Constraints faced by the respondents	Mean Garrett Score	Total Garrett Score	Rank
Knowledge and Awareness Constraints				
1.	Lack of awareness about agriculture and its importance leading to less involvement.	87.76	10531.20	I
2.	Lack of awareness and training on modern farming practices and market trends.	83.32	9999.20	II
Economic and Market Constraints				
3.	Low market access and low selling price of products.	81.25	9780.00	III
4.	Limited opportunities for value-addition and agri-entrepreneurship in the region.	79.83	9570.60	IV
Technological and Infrastructure Constraints				
5.	Limited access to modern agricultural technologies and equipment.	75.17	9015.40	V
6.	Lack of proper infrastructure.	63.15	7575.40	X
Natural Resource and Environmental Constraints				
7.	Inadequate irrigation facilities and dependence on monsoon rains.	65.75	7890.50	IX
8.	Climate change and environmental challenges such as soil degradation and water scarcity.	69.60	8350.40	VIII
Social and Institutional Constraints				
9.	Patriarchal society.	73.50	8820.00	VI
10.	Unclear government policies.	71.55	5882.00	VII

Within the economic and market dimension, low market access and low selling price of products ranked third with a mean score of 81.25, while limited opportunities for value addition and agri-entrepreneurship ranked fourth with a mean score of 79.83. Both constraints reflected the difficulties respondents faced in translating agricultural effort into remunerative returns. Among technological and infrastructure constraints, limited access to modern agricultural technologies and equipment ranked fifth with a mean score of 75.17, whereas lack of proper infrastructure was ranked tenth, the lowest among all constraints, with a mean score of 63.15, indicating that respondents distinguished between the availability of specific technologies and the broader state of rural infrastructure.

Social and institutional constraints included patriarchal society, ranked sixth with a mean score of 73.50, and unclear government policies, ranked seventh with a mean score of 71.55, indicating that gender-based restrictions and weak policy communication both weighed appreciably on respondents' participation, though less severely than knowledge and market barriers. Natural resource and environmental constraints comprised climate change and environmental challenges such as soil degradation and water scarcity, ranked eighth with a mean score of 69.60, and inadequate irrigation facilities and dependence on monsoon rains, ranked ninth with a mean score of 65.75. These two constraints, together with the infrastructural deficit ranked tenth, occupied the bottom of the priority order, indicating that respondents perceived environmental and infrastructural factors as comparatively less severe than knowledge, economic, and social barriers.

DISCUSSION

The findings of the present study indicated that limited awareness of agriculture's importance and inadequate training on modern farming practices constituted the most severe constraints for tribal women in Angul district. This pattern aligned with earlier work showing that limited knowledge, skill deficits, and inadequate exposure to developmental programmes formed leading obstacles for tribal women engaged in farming and allied sectors (Chandravadia & Bariya, 2018; Shamna et al., 2018; Dhruw et al., 2020). The dominance of knowledge-related constraints over resource-based ones suggested that even where inputs or infrastructure existed, tribal women were often unable to use them effectively due to inadequate information, extension contact, or training exposure. This observation was consistent with findings from Odisha, where tribal farm women reported that domestic responsibilities and inadequate extension activities, largely led by male functionaries, formed major barriers to accessing agri-allied information (Bahubalendra et al., 2025), reinforcing that informational gaps recurred as a dominant constraint across tribal contexts in India.

Economic and market-related constraints occupied the next tier of severity, with poor market access and unfavourable selling prices ranked third and limited scope for value addition or agri-entrepreneurship ranked fourth. These results reflected the structural disadvantages tribal women faced in reaching remunerative markets, consistent with evidence that weak market intelligence, poor access to regulated markets, and limited scope for agro-based value addition restricted the income tribal households could generate from farming and allied livelihoods (Bhilavekar et al., 2025), and that strengthening women's role in farm-level decision-making was central to improving household economic and food security outcomes (Shah et al., 2022). The relatively high severity attached to market-related barriers, despite their ranking below knowledge constraints, indicated that even when tribal women were willing and informed, structural limitations in market access continued to erode potential gains from their agricultural labour.

Among the remaining dimensions, restricted access to modern technology and equipment ranked fifth, while patriarchal social structures ranked sixth, underscoring that gender-based restrictions on decision-making authority and control over customary economic resources, compounded by limited access to education, continued to constrain women's agricultural roles even where infrastructure existed (Paray, 2019). Unclear government policies followed at seventh, suggesting that despite the presence of welfare and extension schemes, poor communication and weak last-mile delivery

kept many entitlements out of reach for tribal women. This corroborated evidence that stronger institutional support, including access to self-help group platforms and extension services, meaningfully improved women's agricultural decision-making and practice adoption (Raghunathan et al., 2019). The comparatively moderate severity of institutional and social constraints, relative to knowledge and market barriers, indicated that while patriarchal norms and policy gaps mattered, they were perceived as somewhat less immediately limiting than the absence of basic awareness and remunerative market access.

Natural resource and environmental constraints, comprising climate-related challenges and irrigation dependency, along with general infrastructural deficits, were perceived as comparatively less severe than knowledge, market, and social barriers. This suggested that while environmental unpredictability affected farming outcomes, respondents regarded it as a background condition rather than the most pressing obstacle to their participation, a distinction consistent with findings that livelihood security among tribal women was shaped more strongly by informational and institutional gaps than by environmental variability alone (Dagar & Upadhyay, 2022). The lower ranking of infrastructural constraints did not imply their absence but rather reflected respondents' relative prioritisation when weighed against more immediate knowledge and market-related barriers.

Taken together, the overall pattern of constraints reflected a hierarchy in which cognitive and informational barriers outweighed economic ones, which in turn outweighed social, institutional, and environmental barriers. This gradient suggested that interventions addressing awareness and skill gaps, such as targeted training and extension contact, were likely to yield more immediate improvements in tribal women's agricultural participation than infrastructure-focused interventions alone. This finding echoed multi-criteria evidence from other tribal contexts, where capacity-building and informational interventions were identified as priority strategies for empowering tribal women in agriculture (Kujur et al., 2026).

CONCLUSION

The study established that knowledge and awareness gaps, rather than resource scarcity, formed the most severe barriers to tribal women's participation in agriculture in Angul district, with limited awareness of agriculture's importance and inadequate training on modern practices ranked as the top two constraints. Economic and market-related limitations followed closely, reflecting structural disadvantages in reaching remunerative markets. Social constraints rooted in patriarchal norms and unclear government policies further compounded these difficulties, while environmental and infrastructural factors, though present, were perceived as comparatively less pressing. The clear hierarchy identified through the Garrett Ranking Technique suggests that extension interventions prioritising awareness-building and skill training are likely to yield faster gains in tribal women's agricultural participation than infrastructure-led approaches alone, supporting more targeted and inclusive policy design for tribal regions of Odisha.

DECLARATIONS

Ethical approval and consent to participate: The study was conducted in accordance with principles laid out in the Declaration of Helsinki (1964) and its subsequent modifications. Ethical approval was waived by the departmental Review Board of the Department of Agricultural Extension Education, ANDUA&T Kumarganj, Ayodhya, UP. Informed consent was sought from all the participants.

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