ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Indian Journal of Extension Education

Volume 62, No. 2
April-June 2026

THE INDIAN SOCIETY OF EXTENSION EDUCATION
Division of Agricultural Extension, ICAR-Indian Agricultural Research Institute
New Delhi 110 012, Website : www.iseeiari.org

Peer Reviewed Open Access UGC CARE Listed, Scopus indexed Journal

INDIAN JOURNAL OF EXTENSION EDUCATION
(ISSN 0537-1996, eISSN 2454-552X)

The Indian Journal of Extension Education is an open access peer reviewed quarterly publication of the Indian Society of Extension Education, Division of Agricultural Extension, ICAR-IARI, New Delhi-110012, registered under Societies Registration Act XXI of 1860 (Punjab Amendment) Act 1957 extended to Union Territory of Delhi with registration no S-2504 of 1964-65 dated June 22,1964.

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Indexing

SCOPUS, CABI, AGRIS, Index Copernicus International, BASE, EBSCO, WorldCat, PlumX, Mendley, Scilit, Semantic Scholar, Google Scholar, Crossref etc.

EDITORIAL

Declared by the United Nations, the year 2026 underscores the need for policy reforms, resource mobilisation, and strengthened global cooperation to support women in agriculture. The Global Conference on Women in Agri-Food Systems, held during March 12–14, 2026, in New Delhi, emphasised technology-driven, climate-smart, and gender-responsive agricultural policies.

The Indian Union Budget projects agricultural expenditure at Rs. 1.5 lakh crore (a 5.4% increase), with a strong emphasis on technological advancement, including initiatives such as *Bharat VISTAAR*. Concurrently, geopolitical tensions in the Middle East have escalated fuel and fertiliser prices, threatening 38% of global nitrate-based fertiliser supplies and 20% of phosphate fertilisers. This poses risks for India's agri-food exports–valued at over $11 billion to the region–particularly tea, tobacco, and dairy fats, while also raising concerns about fertiliser availability for the upcoming monsoon planting season.

The agricultural outlook for 2026 indicates persistently high input costs and subdued demand, likely accelerating the adoption of automation and cost-efficient technologies. Greater emphasis is also expected on regional food security, climate resilience, and biologically based solutions for sustainable pest and soil management.

The Indian Society of Extension Education, New Delhi, organised its National Seminar 2026 in Goa (January 29–31) on "*Digital Technologies for Sustainable Food Systems and Atmanirbhar Bharat,*" bringing together over 350 professionals to deliberate on digital integration in extension systems and scalable livelihood models.

During the quarter, Dr. Gopal Ji Trivedi, a veteran agricultural extensionist, was conferred the Padma Shri Award (2026) for his distinguished contributions to agriculture.

This issue (April–June 2026) features 30 manuscripts, including six research tools, three research notes, and twenty-one full-length papers, with international contributions from Indonesia, Bangladesh, the Philippines, and Nigeria. The papers cover a wide spectrum of themes, including food security, digital agriculture, social and behavioural dimensions, climate adaptation, agricultural diversification, extension innovations, and farmer-centric institutions such as FPOs.

The journal's Scopus CiteScore *(https://www.scopus.com/sourceid/21100846015)*has improved from 2.1 to 2.2 during the quarter.

On behalf of the editorial board, I extend sincere thanks to all reviewers, contributors, and members of the editorial and executive bodies for their continued support. We also acknowledge the publisher for maintaining timelines. 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.

(Manjeet Singh Nain)
Chief Editor

INDIAN JOURNAL OF EXTENSION EDUCATION

Volume 62 **April-June, 2026** **No. 2**

CONTENTS

Research Articles

Research Tool

Research Note

Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (1-9)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Exploring Global Research Trends on Extension Advisory Services in Climate-Smart Agriculture

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HIGHLIGHTS

- Scientific publications on EAS and CSA have increased sharply since 2015, reflecting the global momentum in climate policy.
- Thematic evolution shows a shift from conceptual frameworks to applied studies on innovation, capacity building, and policy integration.
- EAS are pivotal in translating CSA knowledge into field-level climate resilience and sustainable farming practices.

ARTICLE INFO

Keywords: Bibliometric analysis, Climate-smart agriculture, Extension advisory services, Knowledge dissemination, Research collaborations, Sustainable agriculture.

https://doi.org/10.48165/IJEE.2026.62201

Citation: Anuranj, P. R., & Vishnu, S. (2026). Exploring Global Research Trends on Extension Advisory Services in Climate-Smart Agriculture. *Indian Journal of Extension Education*, *62*(2), 1-9. https://doi.org/10.48165/IJEE.2026.62201

ABSTRACT

The study examines global research trends on the role of Extension Advisory Services (EAS) in advancing Climate-Smart Agriculture (CSA) from 1984 to 2024. Data retrieved from the Scopus database were analysed using VOS viewer and the R-based Bibliometrix package to map publication trends, citation influence, collaboration networks, and thematic evolution. The results show a sharp rise in research output after 2015, coinciding with global policy momentum following the FAO's CSA framework and the Paris Agreement. Collaboration networks reveal strong linkages between African and European institutions, reflecting an emphasis on participatory and farmer-oriented approaches. Keyword and thematic analyses indicate a transition from conceptual discussions on extension and adaptation toward applied research focused on capacity building, innovation systems, and behavioural change. The findings highlight the critical role of EAS in enabling sustainable agricultural transformation. Strengthening institutional capacity, digital integration, and regional collaboration remains essential for enhancing the effectiveness of EAS in building climate resilience. Overall, EAS functions as the operational backbone of CSA by translating knowledge into adaptive, farm-level actions.

INTRODUCTION

Climate change, alongside food and nutrition insecurity, continues to be among the most urgent global issues, demanding immediate and innovative solutions (Brooks & Loevinsohn, 2011; Kabato et al., 2025). With the world population expected to reach 9.7 billion by around 2050, increasing food demand will put significant pressure on already-strained agricultural systems. (UN, 2019). Without sustainable management, this expansion in food production will further intensify environmental degradation and resource depletion (Anuranj et al., 2024; McLaughlin & Kinzelbach, 2015). Current food systems are also the largest source of methane emissions (Kabato et al., 2025), underscoring the unsustainable nature of prevailing agricultural practices. These trends highlight the urgent need for transformative change in how food is produced, distributed, and consumed (IPBES, 2019). If unaddressed, emissions from food systems will continue to rise, threatening ecosystem stability and global food security (Abbasi & Zhang, 2024; Bajzelj et al., 2014). In this context, the adoption of climate-smart technologies and practices emerges as an essential strategy.

Received 27-11-2025; Accepted 19-02-2026

Climate-Smart Agriculture (CSA) offers a holistic framework aimed at sustainably increasing productivity and income, enhancing resilience to climate change, and reducing GHG emissions (Barman & Neog, 2024; Bai et al., 2019). It has emerged as an effective strategy for restructuring and guiding agricultural development in response to the challenges posed by climate change (Yadav et al., 2025). Beyond technological interventions, CSA depends on the diffusion of knowledge, supportive policies, and targeted investments in agricultural research and innovation (Das et al., 2022; Prajapati et al., 2025). Empowering farmers with timely, relevant information remain central to the implementation of CSA, underscoring the indispensable role of Extension Advisory Services (EAS).

EAS connect research with field work, offering farmers tailored advice and support to boost productivity and sustainability (Kumar et al., 2022; Singh & Kaunert, 2023). These services aid technology transfer and decision-making on crops and resources (Kumar et al., 2021; Sharma et al., 2024) and bolster capacity to tackle cross-cutting issues such as climate adaptation, nutrition, and disaster response (Kingiri, 2020; Silici et al., 2021). Through participatory methods and farmer training, EAS build adaptive capacity and promotes resilient agriculture aligned with CSA (Mishra et al., 2025; Jellason et al., 2020). By encouraging sustainable practices, EAS reduces agriculture's environmental impact and supports food security and rural resilience (Rajesh et al., 2024; Gugissa et al., 2022). Initially focused on technology dissemination, EAS now also addresses climate change adaptation and mitigation (Ghosh, 2019), serving as key enablers for operationalising CSA and translating research into farm-level innovations (Raj & Garlapati, 2020).

Despite growing recognition of EAS within CSA, existing research remains fragmented and largely context-specific, with limited understanding of global trends, thematic evolution, and collaboration patterns. Bibliometric analysis serves this purpose effectively by mapping scholarly patterns, identifying collaboration networks, and revealing intellectual structures across domains (Akhtar et al., 2023; Phoong et al., 2022; Donthu et al., 2021). Therefore, this study conducts a bibliometric analysis to systematically map global research trends, thematic structures, and knowledge gaps concerning the role of EAS in advancing CSA.

METHODOLOGY

A bibliometric analysis was performed to explore the role of EAS in CSA. This bibliometric analysis aimed to evaluate the scientific literature on the role of extension in CSA using the Elsevier Scopus database, given its broad multidisciplinary coverage, strong representation of agricultural and social science journals, and compatibility with bibliometric analysis tools. The study was conducted by retrieving all relevant research articles published between 1984 and 2024. The search was executed using a comprehensive set of keywords related to the role of extension services, advisory services, and CSA, ensuring the inclusion of all relevant studies within this domain.

The initial search involved the use of keywords such as 'extension services,' 'advisory services,' 'climate-smart agriculture,' 'CSA,' and related terms. This search expression was developed to cover the broad, related areas linking EAS to CSA. The Scopus search string used included the terms related to extension systems ("Extension Advisory Services," "Agricultural Extension," "Extension Services," "Advisory Services," "Extension Education," "Extension Programs"), climate-smart agriculture ("Climate-Smart Agriculture," "CSA," "Climate-Smart Practices," "Sustainable Agriculture," "Climate-Smart Agriculture Practices," "Climate Adaptation in Agriculture"), and their perceived role ("Role," "Impact," "Effect," "Contribution," "Importance").

Using the AND and OR operators helped link the concepts and narrow the results to studies examining the relationship between extension and CSA. This approach ensured that the literature retrieved was comprehensive, relevant, and aligned to analyse how extension systems contribute to the development and adoption of CSA practices. The search strategy was carefully refined to include only peer-reviewed research articles, reviews, and conference papers, resulting in a preliminary set of articles. Duplicate records were manually identified and removed during data cleaning, and the data were subsequently screened for relevance and language. The final dataset comprised 230 research articles.

The dataset comprising the selected scholarly publications was analysed using VOSviewer and the Bibliometrix package integrated within the R environment, as commonly adopted in previous bibliometric studies (Roy et al., 2024; Bretas & Alon, 2021). These tools enabled both quantitative analysis and visual representation of research patterns, facilitating the examination of publication trends, thematic structures, and collaboration networks in the field of extension in CSA. This combination ensured a methodologically robust and visually supported understanding of the research landscape.

RESULTS

Trends in scientific production

The annual distribution of publications related to the role of EAS in CSA from 1984 to 2024 is presented in Figure 1. The temporal evolution of the scientific output reveals three distinct phases. The initial phase, extending from 1984 to 2005, was characterised by sporadic and low publication activity, indicating that research attention toward the nexus between EAS and CSA was minimal during this period. Only isolated studies appeared, often within broader discourses on agricultural development or rural communication, with limited integration of climate adaptation perspectives. The period from 2006 to 2016 shows a gradual increase in publications, reflecting growing global awareness of climate change impacts on agriculture and climate adaptation as a policy focus. The FAO's CSA Framework (2010) and global climate initiatives likely spurred research growth, with scholars viewing EAS as institutional mechanisms for resilience and sustainability.

A marked acceleration occurred in the third phase, beginning in 2017, with the publication rate rising sharply and peaking in 2022 at more than 30 publications per year. This pronounced surge indicates a maturing research domain driven by international policy commitments, such as the Paris Agreement (2015), and increased funding for climate-adaptive agriculture. It also reflects a growing awareness of the indispensable role that EAS play in scaling climate-smart technologies, farmer capacity building, and

participatory adaptation. Despite minor fluctuations across individual years, the upward trend is sustained, confirming the establishment of this topic as a consolidated field of inquiry. Overall, the increasing volume of literature signifies both scholarly engagement and institutional endorsement of EAS as pivotal actors in facilitating climate-resilient agricultural transitions.

Citation impact

The citation trend across the analysed period, as illustrated in Figure 2, reveals the maturation and intellectual influence of the field. Prior to 2005, the number of citations per publication was negligible, reflecting the absence of foundational literature that explicitly linked extension systems to climate resilience. From 2010 onwards, the average number of citations per year began to rise markedly, aligning with the period when seminal conceptual and empirical works started to emerge. These influential papers provided the theoretical grounding and methodological frameworks that connected advisory systems with the CSA paradigm.

Two notable peaks are observed around 2016 and 2018. These coincide with the publication of high-impact studies that introduced integrative approaches, combining technical innovation, institutional strengthening, and participatory communication, to promote CSA adoption. Such works were frequently cited in policy documents and global assessments, suggesting their influence beyond academia. A moderate decline in average citations is noted after 2020. This trend can largely be attributed to citation lag, where recently published papers have not yet accumulated substantial citations. Another plausible factor is the diversification of publication outlets, as the field expanded into interdisciplinary domains, diluting citation concentrations. Nevertheless, the general trajectory of increasing citation frequency signifies the growing scholarly and practical influence of research in this area.

Geographical distribution and international collaboration

The global distribution of research and collaboration networks, as depicted in Figure 3, highlights the international dimension of EAS-CSA. Research activity is widely dispersed, with significant contributions from both developed and developing countries. The United States, the United Kingdom, and select European nations emerge as central hubs of collaboration, maintaining strong linkages with African and Asian counterparts. This North-South collaborative pattern reflects the global research agenda's emphasis on supporting smallholder adaptation and the role of advisory services in low-income, climate-vulnerable regions.

In Africa, countries such as Kenya, Ethiopia, Malawi, and Tanzania stand out for their consistent research contributions. These nations have benefited from sustained international funding and capacity-building initiatives focusing on EAS and CSA. Their

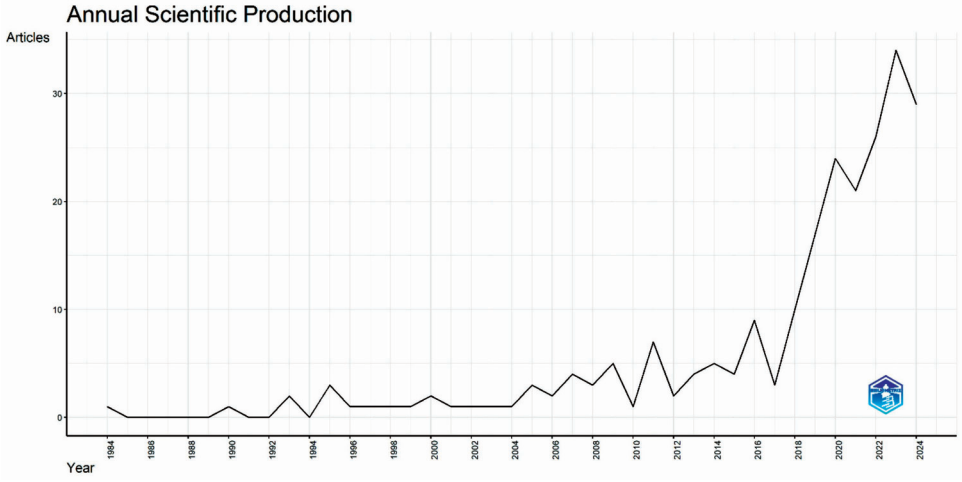

Figure 1. Annual scientific production on EAS in CSA (1984 to 2024).

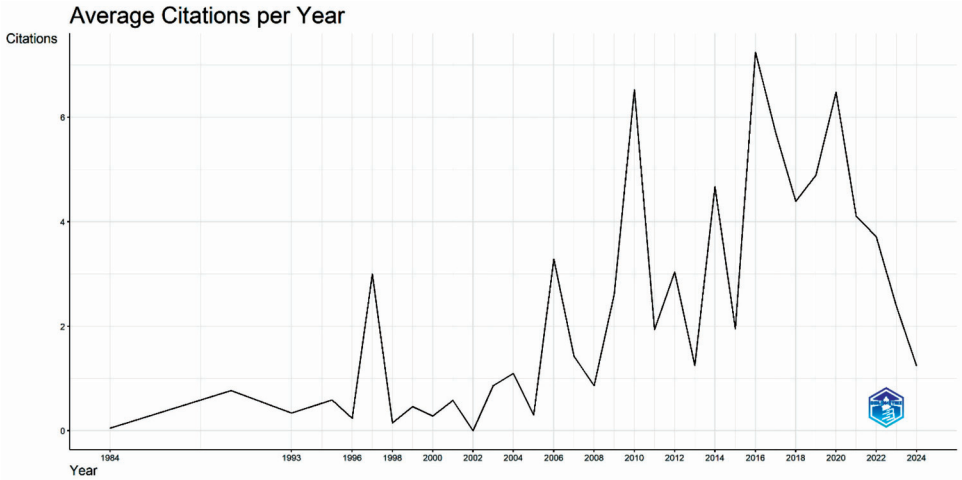

Figure 2. Average article citation per year on EAS in CSA (1984 to 2024).

prominence suggests that empirical work on extension-driven adaptation is disproportionately concentrated in contexts where smallholder farming is predominant. Additionally, collaborations between African and European institutions, often supported by multilateral programs, have facilitated the co-production of knowledge and context-specific extension models. South Asian countries, including India, Bangladesh, and Nepal, also appear as emerging contributors, though with comparatively weaker collaborative linkages. Conversely, regions such as Latin America and Southeast Asia are underrepresented, suggesting geographic imbalances in the research landscape. Overall, the international collaboration network underscores the field's global relevance while highlighting the importance of continued investment in transnational research partnerships to enhance knowledge sharing and policy translation.

The co-authorship network in Figure 4 highlights author collaborations within the field, showing distinct yet connected research communities. The red cluster, led by Susannah M. Dougil and Andrew J. Whitfield, centres on climate adaptation, institutional learning, and advisory reform. The blue cluster, led by John Recha and Krista Heiner, focuses on climate information, participatory methods, and farmer advisory systems in East Africa. The orange and green clusters, involving Christian Thierfelder, Innocent Pangapanga-Phiri, and Daniel Adu-Ankrah, relate to conservation agriculture, sustainable intensification, and participatory extension studies. The clusters show moderate network density, with some authors bridging clusters for cross-disciplinary collaboration in CSA. This highlights opportunities for greater consolidation via research groups, journal issues, or global networks.

Keyword co-occurrence and thematic structure

The keyword co-occurrence network shown in Figure 5 captures the conceptual and thematic architecture of research on EAS in CSA. The clustering structure reveals four dominant thematic groups. The first cluster (red) is dominated by keywords such as *role*, *research*, *agricultural extension*, *sustainable agriculture*, *challenge*, *program*, and *problem*. This cluster represents the conceptual and evaluative core of the literature, focusing on understanding the role of extension systems, sustainability challenges, and research-based assessments of extension programmes within the broader climate change context. The second cluster (green) centres on terms including *access*,

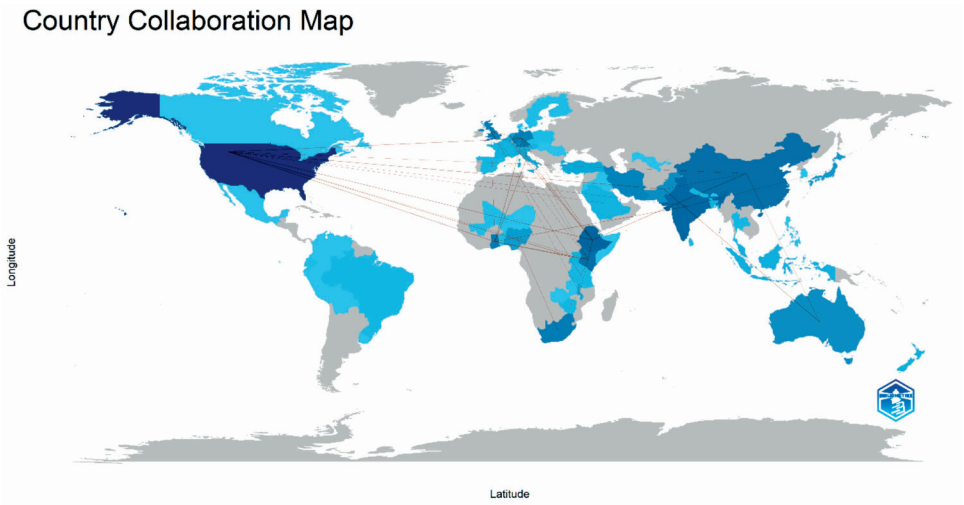

Figure 3. Country collaboration map depicting international research networks in EAS and CSA.

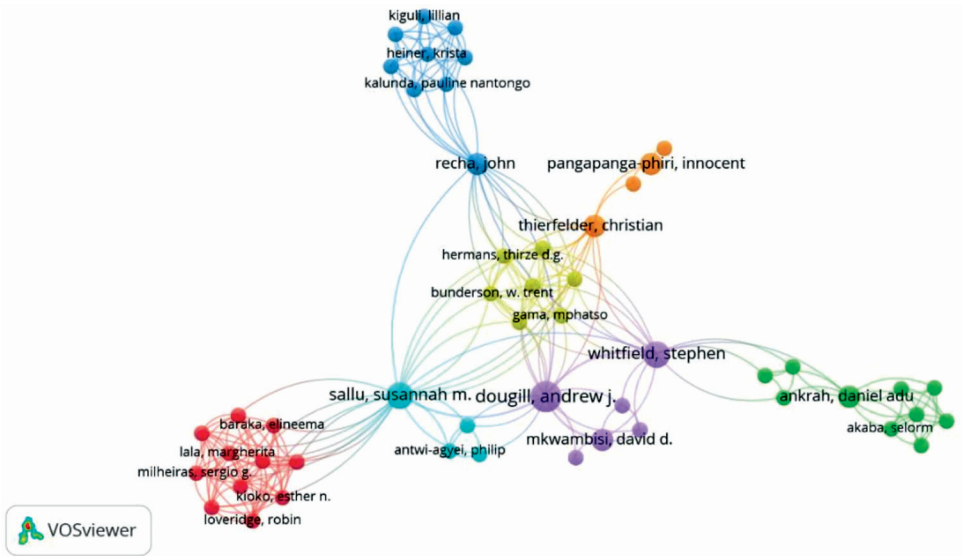

Figure 4. Co-authorship network among authors publishing on EAS in CSA.

climate-smart agriculture, *CSA*, *smallholder farmer*, *household*, *income*, *livelihood*, *credit*, and *crop*. This cluster reflects a farmer-centric and livelihood-oriented strand of research, emphasising access to CSA practices, household-level outcomes, and the socio-economic dimensions of extension and advisory interventions. The third cluster (blue) includes keywords such as *innovation*, *case study*, *uptake*, *community*, *process*, and *context*. This cluster encompasses implementation-oriented and learning-based studies that examine how CSA innovations are introduced, adapted, and adopted through community engagement, participatory processes, and context-specific extension approaches.

Together, these three clusters illustrate the multidimensional nature of EAS-CSA research, linking conceptual inquiry into extension roles, practical concerns regarding farmer access and livelihoods, and process-oriented studies of innovation uptake and community engagement. The central positioning of terms such as *role*, *access*, and *CSA* indicates their bridging function across the thematic structure.

The temporal evolution of research themes shown in Figure 6 illustrates how EAS-CSA research has developed from 1984 to 2024. During the early phase, studies largely focused on broad and foundational themes such as agricultural extension, sustainable agriculture, and regional contexts. This period was characterised by exploratory research examining the general role of extension systems in agricultural development and early climate adaptation efforts, with limited emphasis on adoption or livelihood outcomes. From around 2017 onwards, the thematic focus shifted toward more applied and farmer-centric concerns. Keywords related to access, smallholder farmers, households, income, and climate-smart agriculture gained prominence, indicating increased attention to adoption processes and socio-economic dimensions of CSA. This shift reflects a growing recognition of the importance of advisory services in enabling farmers to access resources, make informed decisions, and improve livelihood resilience under changing climatic conditions.

In later years, themes such as innovation, uptake, capacity building, and CSA practices became more visible, indicating a shift

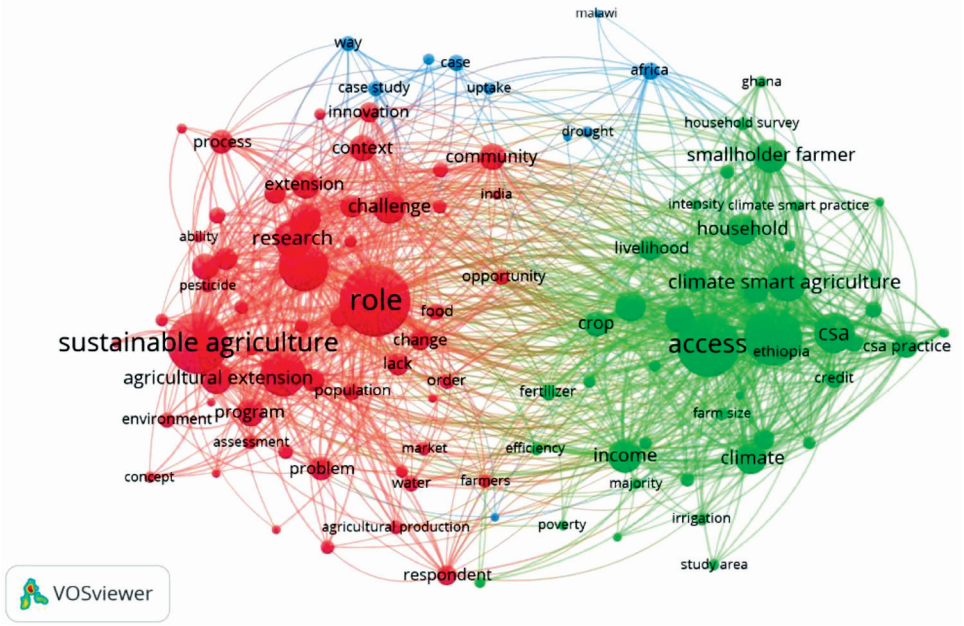

Figure 5. Keyword co-occurrence network showing thematic clusters in EAS-CSA research.

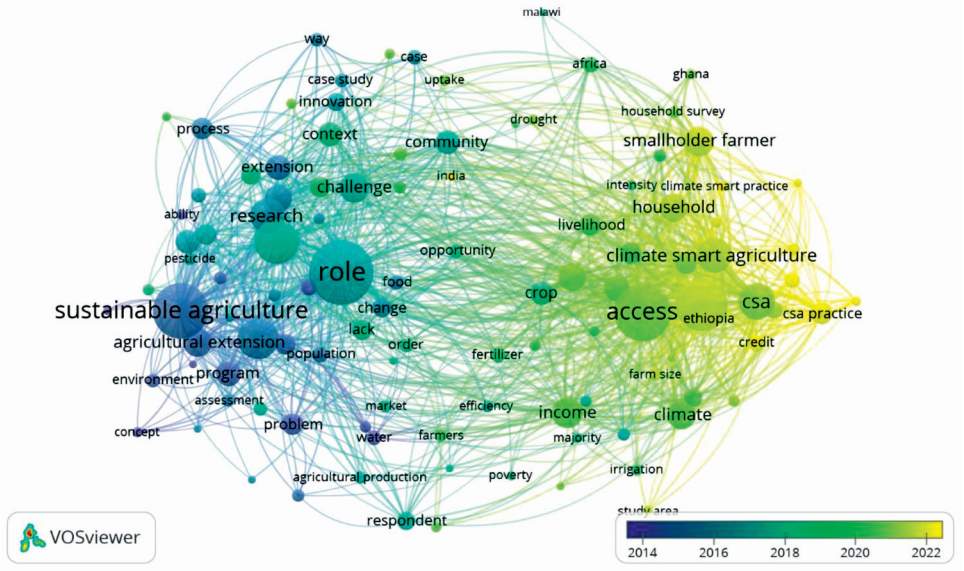

Figure 6. Temporal evolution of major research themes in EAS-CSA literature (2014 to 2022).

Table 1. Evolution of Extension Advisory Focus in Climate-Smart Agriculture Research

Period	Extension Advisory Focus	Evidence from Bibliometric Results
Before 2016	Conceptual extension and sustainability focus	Frequent use of agricultural extension and sustainable agriculture.
2017-2019	Participatory approaches and CSA access	Rising prominence of access, smallholder farmers, household, livelihood, and adoption-related terms
Beyond 2020	Advisory-led CSA implementation	Strong visibility of CSA, CSA practices, income, credit, innovation, and capacity building

Table 2. Notable insights from the study

Figure No.	Title/content	Notable insight
Figure 1	Annual scientific production	Rapid growth after 2015 indicates an increasing research focus on the EAS-CSA linkage
Figure 2	Average citations per year	Peaks from 2016 to 2018 indicate influential conceptual papers
Figure 3	Country collaboration map	Strong collaborations between Africa, Europe, and the U.S.
Figure 4	Co-authorship network	Moderate author connectivity with a few leading researchers
Figure 5	Keyword co-occurrence clusters	Four thematic areas: adaptation, participation, sustainability, and adoption
Figure 6	Evolution of keywords over time	Shift from conceptual to applied, policy-oriented research

toward implementation-oriented research. The close spatial positioning of clusters suggests strengthening linkages between extension systems, socio-economic factors, and climate outcomes. Overall, the temporal pattern demonstrates a progression from conceptual discussions of extension roles to applied, policy-relevant research focused on supporting farmer-level adaptation and sustainable agricultural transitions.

The comprehensive bibliometric analysis reveals that research on the role of EAS in CSA has expanded substantially over the past four decades (Table 1). The acceleration in publication output after 2015, accompanied by a rise in global collaborations, reflects the integration of extension discourse into mainstream climate and agricultural development research.

In summary, the results affirm that EAS serve as pivotal intermediaries in the operationalisation of CSA principles, bridging scientific innovation with local adaptation practices. The steady increase in research activity and the diversification of themes indicate a vibrant and expanding scholarly community committed to understanding and strengthening the role of advisory systems in climate-resilient agriculture (Table 2).

DISCUSSION

This bibliometric analysis shows that research on Extension and Advisory Services (EAS) and Climate-Smart Agriculture (CSA) has become increasingly important for policy beyond academia. The sharp rise in studies after 2015 reflects how global policy milestones, such as the FAO's CSA framework and the Paris Agreement, have pushed extension research to focus more on climate-resilient farming and knowledge systems (Lipper & Zilberman, 2017). At the same time, this raises a practical concern: global priorities may not always translate easily into locally relevant extension support.

The increase in publications after 2017 suggests that EAS is now widely seen as a key link between climate science and farmers' actions. While many studies highlight the role of institutional innovation in shaping farmers' adaptive behaviour (Chander & Rathod, 2020; Ranjan et al., 2025), they also reveal a gap between ambitious climate goals and the actual capacity of extension systems on the ground. Recent conceptual work (Dougill et al., 2021; Prajapati et al., 2025) therefore points to the need for extension services to move beyond information delivery and take on stronger facilitation and coordination roles.

Collaboration patterns show both progress and imbalance. Much of the research focuses on Africa and South Asia, where climate risks are high, but is often led by institutions from Europe and North America. While such partnerships support shared learning and innovation (Bhatta et al., 2015; Nkiaka et al., 2019; Pathak et al., 2024), they also underline the need for greater leadership from local institutions to ensure solutions are context-specific and practically useful.

The co-authorship networks highlight the increasingly interdisciplinary nature of this field, bringing together agricultural science, climate policy, and social sciences. This shift signifies a move toward systems thinking in extension research, emphasising technological, behavioural, and institutional change (Dangles et al., 2016; Dougill et al., 2021). This systems-based approach is promising, but it also reveals ongoing challenges in coordination across sectors and governance levels, which extension research has not yet fully addressed.

Changes in key research themes further confirm a clear shift away from traditional, top-down extension models. Earlier emphasis on awareness and technology transfer has given way to stronger attention on farmer empowerment, sustainability, and innovation systems (Waters-Bayer et al., 2015; Tambo & Wünscher, 2017; Arowosegbe et al., 2024; Prajapati et al., 2025; Barman et al., 2026). Alignment with Agricultural Innovation Systems and pluralistic extension approaches (Klerkx et al., 2012; Paschen et al., 2017; Panja et al., 2022) suggests that extension policies now need to rethink mandates, skills, and incentives to support collaboration and learning. Despite this progress, important gaps remain. Evidence is still heavily concentrated in sub-Saharan Africa, with far fewer studies from Southeast Asia and Latin America. This underscores the need for more comparative, long-term, and mixed-methods research to better understand how extension systems perform under sustained climate stress (Autio et al., 2021; Prajapati et al., 2025).

In summary, the results of this bibliometric synthesis suggest that EAS is no longer viewed simply as a channel for advice, but as a key institutional driver of climate adaptation and innovation. To fully realise its role in improving productivity, adaptation, and mitigation, policies must focus on strengthening extension capacities, ensuring inclusiveness, and supporting the scaling of climate-smart practices based on strong evidence.

CONCLUSION

The study affirms that extension advisory services are a fundamental driver of climate-smart agricultural transformation, serving as the vital link between scientific knowledge, policy frameworks, and on-ground practices. The analysis reveals a global transition from traditional dissemination models to participatory, adaptive, and farmer-centred systems that enhance innovation, behavioural change, and resilience. Strengthening institutional capacity, investing in inclusive digital tools, and fostering multi-stakeholder collaboration emerge as key priorities for scaling sustainable adaptation and productivity. The findings highlight that well-integrated advisory systems enable effective adoption of climate-resilient practices and improve farmers' ability to manage risks and uncertainties. Future research can explore region-specific models, digital integration strategies, and impact assessments of advisory innovations. Expanding cross-regional comparative studies will further enrich our understanding and guide policy frameworks that ensure agricultural sustainability and resilience in the face of changing climatic conditions.

DECLARATIONS

Ethics approval and informed consent: As the research was carried out with bibliometric analysis, the Scopus database from KAU, Thrissur, was used for the study, with inclusion and exclusion criteria.

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 author declares that they have 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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (10-14)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Understanding Entrepreneurial Behaviour of Rural Youth in Agriculture and Allied Sectors

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HIGHLIGHTS

- Rural youth prioritise the adoption of new agricultural ideas over profit maximization, indicating intrinsic motivation for farm modernisation.
- Youth exhibit 73.12% (medium-level) entrepreneurship, indicating broad but underdeveloped capacity requiring activation through appropriate support mechanisms.
- Agricultural-intensive occupations (r = 0.353) and larger landholdings (r = 0.310) positively correlate with entrepreneurship, indicating enterprise capacity increases with agricultural engagement depth.

ARTICLE INFO

Keywords: Rural youth, Entrepreneurship, Agriculture, Multiple regression, Ghazipur.

https://doi.org/10.48165/IJEE.2026.62201

Citation: Singh, S., Kumar, S., Doharey, R. K., Singh, S., & Sahoo, S. (2026). Understanding Entrepreneurial Behaviour of Rural Youth in Agriculture and Allied Sectors. *Indian Journal of Extension Education*, *62*(2), 10-14. https://doi.org/10.48165/IJEE.2026.62201

ABSTRACT

The study examined the entrepreneurial behaviour of 160 rural youth during 2024-25, through a cross-sectional survey design. Using Ordinary Least Squares (OLS) multiple regression analysis, assessed the influence of socioeconomic, informational, and behavioural factors on entrepreneurial tendencies. Entrepreneurial behaviour was conceptualized as a composite of innovativeness (mean = 26.87), achievement motivation (mean = 20.53), and risk orientation (mean = 21.49). The regression model explained 36.14% of the variance in entrepreneurial behavior. Age emerged as a significant negative predictor ($\beta = -0.32$, $p = 0.001$), indicating that younger youth were more entrepreneurial. Annual income was the strongest positive predictor ($\beta = 1.7 \times 10^{-5}$, $p < 0.001$), highlighting the critical role of economic capacity. Knowledge level showed a marginally positive association ($p = 0.055$), while education and mass media exposure were non-significant. Notably, 73.12% of respondents exhibited medium-level entrepreneurship, suggesting substantial untapped potential. The findings underscore that rural youth entrepreneurship is fundamentally conditioned by economic resources and age-cohort effects, with implications for extension programmes and policy targeting resource constraints rather than motivation alone. Tailored interventions addressing capital access, practical skill development, and risk-reduction mechanisms are essential for converting latent entrepreneurial potential into active enterprise creation among rural youth.

INTRODUCTION

Rural India stands at a critical juncture where traditional agricultural practices must respond to the pressures of a rapidly modernizing and market-driven economy. With nearly 65% of India's population residing in rural areas and about 86% of farmers categorized as small and marginal landholders, agriculture continues to shoulder the dual responsibility of ensuring food security and

Received 15-12-2025; Accepted 18-02-2026

sustaining rural livelihoods (Verma et al., 2024). Despite employing close to half of the national workforce, the sector contributes only about 18–20% to India's gross domestic product, highlighting structural inefficiencies and limited value addition within rural economies (George, 2023).

One of the most pressing challenges confronting rural India is the declining engagement of youth in agriculture. Rural youth (18–35 years) constitute nearly 40% of the rural population, representing a significant demographic dividend (Bharti et al., 2022). However, agriculture is increasingly perceived as economically unviable, socially unrewarding, and risk-prone. Inadequate access to quality education, skill development, institutional credit, and entrepreneurial support systems has resulted in large-scale rural-urban migration (Prasad & Chandrasekhar, 2018). This migration drains rural areas of energetic and innovative human capital, adversely affecting agricultural productivity, rural entrepreneurship, and social cohesion (Raina et al., 2016).

In this context, entrepreneurship in agriculture and allied sectors has emerged as a strategic pathway for revitalizing rural economies. Agripreneurship involves the application of entrepreneurial principles innovation, opportunity recognition, and risk-taking to agricultural and allied activities such as precision farming, organic agriculture, value addition, agro-processing, and digital agricultural services (Bhati et al., 2014). These ventures contribute not only to employment generation but also to income diversification, resilience building, and inclusive rural growth.

Entrepreneurial behaviour is conceptually defined in this study as the composite expression of innovativeness, achievement motivation, and risk orientation demonstrated by individuals in identifying opportunities, mobilizing resources, and managing enterprises under conditions of uncertainty. Research shows that in the farm sector, entrepreneurial success was determined by family size, land size, turnover and annual income whereas in the non-farm sectors, five determinants of entrepreneurial success were long-term involvement, initiative, number of employees, entrepreneurial experience and annual income (Kobba et al., 2021). Innovativeness reflects the ability to generate and adopt new ideas or practices; achievement motivation denotes the inner drive to excel and attain set goals; and risk orientation represents the readiness to take calculated risks inherent in entrepreneurial ventures (Rai et al., 2020). Recognizing the role of entrepreneurship in rural transformation, the Government of India has introduced several initiatives such as the Pradhan Mantri Kaushal Vikas Yojana (PMKVY), Agricultural Technology Management Agency (ATMA), and Rashtriya Krishi Vikas Yojana (RKVY) to promote skill development, technology dissemination, and enterprise creation (Samrit et al., 2023).

Ghazipur district of eastern Uttar Pradesh presents a representative agrarian setting to address this gap. Situated in the Varanasi division, the district is characterized by traditional farming systems alongside emerging opportunities in allied sectors such as animal husbandry, fisheries, and agro-processing. Its favorable agro-climatic conditions, proximity to major markets, and rich socio-cultural base make it an appropriate location for examining entrepreneurial behavior among rural youth (Amaran & Krishnamoorthy, 2023). The findings are expected to contribute to the broader discourse on rural development and youth empowerment while offering practical recommendations for fostering an entrepreneurial ecosystem in rural India.

METHODOLOGY

The study was carried out in Ghazipur district of Uttar Pradesh during 2024–25, an agriculturally intensive region where farming and allied enterprises constitute the primary livelihood of rural households. A descriptive research design was adopted to examine the socio-economic, informational, and psychological determinants of entrepreneurial behaviour among rural youth engaged in agriculture and allied sector. A multi-stage sampling technique ensured comprehensive demographic representation. In the first stage, four blocks were randomly selected from the district. Subsequently, four villages were randomly chosen from each block. From every selected village, 10 rural youth involved in agriculture and allied activities were identified through simple random sampling, yielding a final sample size of 160 respondents.

Primary data were collected using a structured interview schedule administered face-to-face by trained investigators. This method minimised bias and enhanced the accuracy of responses. The instrument captured socio-personal variables (age, education), economic attributes (landholding, annual income), informational variables (knowledge), and a standardised measure of entrepreneurial behaviour. Entrepreneurial behaviour was conceptualised as a multidimensional construct comprising innovativeness, achievement motivation, and risk orientation. Three dimensions widely recognised in extension and behavioural research. Each dimension was measured through validated Likert-type items that were pretested for clarity and reliability with the Content Validity Method. Content validity was ensured through expert review from subject specialists, while internal consistency measures during pilot testing exceeded recommended thresholds, ensuring dependable scale scores for analysis.

Before statistical analysis, data were screened for completeness, coding accuracy, and outliers. Descriptive statistics were used to summarize respondent characteristics and variable distributions. Bivariate assessments were conducted to understand zero-order relationships and to inform model specification. The dependent variable, entrepreneurial behaviour, was computed as a composite score formed by aggregating and standardizing the three-dimensional scores so that higher values represented stronger entrepreneurial tendencies.

To examine the determinants of entrepreneurial behaviour, an Ordinary Least Squares (OLS) multiple regression model was employed because it determinants of entrepreneurial behaviour, while acknowledging the ordinal origin of individual items as a methodological consideration.

$$Y_i = \beta_0 + \beta_1 (\text{Age}i) + \beta_2 (\text{Education } i) + \beta_3 (\text{Income } i) + \beta_4 (\text{Media } i) + \beta_5 (\text{Knowledge } i) + \varepsilon_i$$

Where, Y_i is the entrepreneurship score for farmer i, β_0 is the intercept, $\beta_{1\text{-}5}$ are the partial regression coefficients, and ε_i is the error term.

Statistical significance was set at $\alpha = 0.05$, and all analyses were conducted using Python (version 3.12) with the *stats models*

and *scipy* libraries. This comprehensive and statistically grounded methodology facilitated the identification of distinct factors affecting rural youth, thereby enabling targeted policy formulation and effective intervention strategies.

RESULTS

The data presented in Table 1 revealed that the entrepreneurial profiling of rural youth revealed notable variation across four key attributes. Among these, Innovativeness received the highest average score (22.86), securing the top rank, indicating that youth had a strong focus on increasing yield and optimising cultivation practices. Risk orientation (22.16) and Achievement (21.83) followed as the second and third highest-ranked attributes, respectively. These results suggest that rural youths are relatively proactive in facing risk and driven by personal accomplishment with performance goals. On the other hand, attributes such as Economic motivation (17.80) were ranked lower, implying comparatively weaker financial or profit-driven impulses relative to other behavioural traits

Table 1. Entrepreneurial attribute scores and rankings across the rural youth

S.No.	Entrepreneurial attribute	Mean Score	Rank
1	Innovativeness	26.86	I
2	Risk Orientation	21.49	II
3	Achievement	20.52	III
4	Economic motivation	18.46	IV

Table 2 showed the overall level of entrepreneurial behaviour among rural youth engaged in agriculture. The majority of respondents fell into the medium entrepreneurship behaviour category, representing 73.12%. A smaller proportion exhibited low levels of entrepreneurship (16.25%) while only 10.63% demonstrated high entrepreneurial behaviour.

Table 2. Overall entrepreneurship level in rural youth regarding agriculture

Categories	Frequency	Percentage
Low <81	26	16.25
Medium 81-93	117	73.12
High >93	17	10.63
Total	160	100

Mean=87.44 S.D. 5.73

Table 3 presented the bivariate correlations between the independent variables and entrepreneurial behaviour among rural youth. Age showed a significant negative association with entrepreneurial behaviour ($r = –0.323$, $p < 0.001$), indicating that entrepreneurial behaviour as age increases within the youth category, potentially due to increased risk aversion, family responsibilities, or preference for income stability among relatively older youth. In contrast, occupation ($r = 0.353$, $p < 0.001$), landholding size ($r = 0.310$, $p < 0.001$), and annual income ($r = 0.425$, $p < 0.001$) each displayed significant positive correlations, suggesting that youths engaged in more agriculture-related occupations, possessing greater land resources, or having higher income were more likely to demonstrate elevated entrepreneurial behaviour. Media exposure exhibited a small but significant negative correlation with entrepreneurship ($r = –0.169$, $p = 0.033$), implying that higher exposure did not necessarily translate into stronger entrepreneurial engagement. Knowledge level showed a significant positive relationship ($r = 0.241$, $p = 0.002$), indicating that better-informed respondents displayed higher entrepreneurial behaviour. Education and caste did not show statistically significant associations with entrepreneurial behaviour ($p > 0.05$), and family size also exhibited no meaningful correlation. Collectively, these results indicated that economic and occupational factors were more strongly related to entrepreneurship than demographic variables among rural youth.

Table 3. Relationship between independent variables with entrepreneurship in rural youth

Variables (Unit)	Entrepreneurship level 'r'	P-Value
Age (Years)	-0.323**	<0.001
Education	-0.140	0.078
Size of family (Numbers)	0.039	0.620
Caste	-0.071	0.374
Occupation	0.353**	<0.001
Land holding (ha)	0.310**	<0.001
Annual Income (Rs.)	0.425**	<0.001
Media Exposure	-0.169*	0.033
Knowledge Level	0.241**	0.002

The overall regression model demonstrated moderate explanatory power for entrepreneurial behaviour among rural youth, as shown in Table 4. The model accounted for 36.14% of the total variance ($R^2 = 0.3614$), while the adjusted R^2 of 0.3256 indicated a stable level of explanatory power after accounting for the number of predictors. The F-statistic confirmed that the model was statistically significant ($F = 10.08$, $p = 1.15 \times 10^{-7}$), demonstrating that the set of predictors collectively explained entrepreneurial behaviour better than a null model. The residual standard error (RSE = 4.65) suggested a reasonable degree of dispersion of observed values around the predicted scores.

Table 4. Model fit statistics

Statistic	Value	F-statistic	Residual Std. Error	Prob (F-statistic)
R^2	0.3614	10.075	4.6496	1.15×10^{-7}
Adjusted R^2	0.3256			

Table 5 revealed significant variation in entrepreneurial behaviour among rural youth in Ghazipur. The model intercept was positive and statistically significant ($\beta = 82.28$, SE = 9.76, $t = 8.43$, $p < 0.001$), indicating a high baseline entrepreneurial behaviour score when all predictors were held constant. Age exhibited a negative and significant association with entrepreneurial behaviour ($\beta = –0.32$, SE = 0.10, $t = –3.30$, $p = 0.001$), suggesting that entrepreneurial tendencies declined slightly with increasing age. Annual income showed a positive and highly significant effect ($\beta = 1.7 \times 10^{-5}$, SE = 4.0×10^{-5} , $t = 4.68$, $p < 0.001$), indicating that financially better-off youth demonstrated stronger entrepreneurial behaviour. Education did not significantly predict

Table 5. Regression Coefficients (OLS Estimates) of entrepreneurship behaviour in rural youth

Predictor	β (Coefficient)	Std. Error	t- value	p-value	95% CI
Intercept	82.2786	9.7612	8.43	<0.001	[62.88, 101.67]
Age	-0.3225	0.0976	-3.30	0.001	[-0.516, -0.129]
Education	0.4297	0.4258	1.01	0.316	[-0.416, 1.276]
Annual Income	1.7×10^{-5}	4.0×10^{-6}	4.68	<0.001	[1.0×10^{-5}, 2.4×10^{-5}]
Mass Media Exposure	-0.1856	0.2287	-0.81	0.419	[-0.640, 0.269]
Knowledge	0.1128	0.0581	1.94	0.055	[-0.003, 0.228]

entrepreneurial behaviour ($\beta = 0.43$, SE = 0.43, t = 1.01, p = 0.316), and mass media exposure also showed no meaningful effect ($\beta = -0.19$, SE = 0.23, t = –0.81, p = 0.419). Knowledge exhibited a marginally positive influence ($\beta = 0.11$, SE = 0.06, t = 1.94, p = 0.055), with its confidence interval narrowly crossing zero, indicating a trend-level association.

DISCUSSION

The present study delineates the entrepreneurial behaviour of rural youth engaged in agriculture in Ghazipur district, highlighting a distinct pattern of behavioural attributes and determinants. The finding that innovativeness emerged as the most prominent attribute suggests a growing inclination among rural youth towards adopting novel agricultural technologies and practices. This aligns youth are increasingly seen as agents of technological change. This result resonates with the findings of Sonu and Jha (2025), who also identified innovativeness as a critical component of entrepreneurial behaviour in rural settings, though our study places it at the very forefront of behavioural traits. The moderate scores for risk orientation and achievement motivation indicate a cautious ambition; while youth are willing to innovate, their capacity to absorb risk remains tempered, likely due to the inherent uncertainties of the agricultural sector in eastern Uttar Pradesh.

The distribution of overall entrepreneurial behaviour, with the majority falling into the medium category, reflects a typical bell-curve distribution often observed in developmental studies. This finding is consistent with Shivacharan (2014); Gupta et al. (2014); Mukharjee and Ghosh (2025) and Kademini et al. (2026) similarly reported a predominance of medium-level entrepreneurial behaviour among rural youth in their respective studies on agri-entrepreneurship and secondary agriculture.

The correlation and regression analyses provide deeper insights into the drivers of this entrepreneurial behaviour of youth. A striking finding is the significant negative association between age and entrepreneurial behaviour. This indicates that younger respondents are more entrepreneurially inclined than their slightly older counterparts. This inverse relationship challenges some traditional views where experience is seen as a prerequisite for business acumen. However, in the context of modernising agriculture, younger individuals are often more adaptable, tech-savvy, and open to risk, which are key entrepreneurial traits. This result corroborates the findings of Okello (2020) and Gowda et al. (2023), who also observed that younger agripreneurs tended to display stronger behavioural characteristics, likely due to their greater openness to new ideas and less entrenchment in traditional, risk-averse farming methods.

Economic factors, specifically annual income and landholding size, emerged as powerful positive correlates. The regression model further solidified annual income as a highly significant predictor. This highlights the resource-dependence of entrepreneurship; financial security provides a safety net that allows youth to take the risks associated with entrepreneurial ventures, which consistently identify economic status as a foundational driver for entrepreneurial capacity in rural India (Tariq et al., 2022). Without a baseline of economic stability, the cognitive bandwidth for innovation and risk-taking is severely constrained. The major contributors of behavioural dimensions to entrepreneurial climate, such as work commitment, social norms, social capital, contact with extension cosmopolite channels, achievement motivation, risk-taking, and innovativeness, have contributed significantly to the prediction of the creation of a favourable entrepreneurial climate Gupta et al. (2023).

Conversely, the role of education and mass media appeared less influential in this specific context. The non-significant relationship with education suggests that formal schooling levels may not directly translate into agricultural business acumen, perhaps due to a disconnect between general academic curricula and practical vocational skills needed for agri-business. Similarly, the non-significant and even negatively trending coefficient for mass media exposure is intriguing. It implies that mere exposure to media does not guarantee entrepreneurial conversion. Mukharjee and Ghosh (2025) found the quality and relevance of information matter more than just the frequency of contact. It is possible that the media consumed was entertainment-oriented rather than educational, or that generic agricultural broadcasts failed to address the specific, localized needs of these youth. The marginal positive influence of knowledge reinforces the idea that specific, actionable technical knowledge is more valuable than general media exposure. Informed youth are better positioned to recognise opportunities and mitigate risks. This nuance suggests that extension efforts should focus less on broad media campaigns and more on targeted knowledge transfer and capacity building.

CONCLUSION

The entrepreneurial landscape of rural youth in Ghazipur district is characterised by substantial but latent potential, with 73.12% of respondents exhibiting medium-level entrepreneurial behaviour. This widespread yet moderate capacity suggests that current policy frameworks have successfully ignited interest but failed to fully activate high-level enterprise creation. The study identifies a distinct entrepreneurial behaviour of youth. The significant negative association with age confirms that younger cohorts possess greater adaptability and risk tolerance, highlighting a critical window for intervention in early adulthood before migration or alternative livelihoods take precedence. Concurrently, the

dominant positive influence of annual income underscores that economic security is a foundational prerequisite for entrepreneurship; motivation alone cannot overcome financial resource constraints. Policy interventions must therefore move beyond a "one-size-fits-all" approach toward stratified support. Ultimately, enabling rural youth entrepreneurship requires shifting focus from purely motivational campaigns to structural reforms that address capital access and specific skill gaps, thereby leveraging India's demographic dividend for sustainable agricultural growth.

DECLARATION

Ethical approval and consent to participate: Our study did not require ethical approval, and all the authors agree. However, the informed consent was sought from the respondents

Consent of publication: Participants provided consent for publication.

Availability of supporting data: Supporting data are available upon request.

Competing interests/Author contributions: No competing interests were declared. Conceptualization of research (SS, RKD); Designing of the experiments (SS, RRD, SS); Contribution of experimental materials (SS, RKD, SS); Execution of field survey and data collection (SS, SS); Analysis of data and interpretation (KS); Preparation of manuscript (KS).

Conflict of interest: No conflicts of interest among the authors.

The authors declare that during the preparation of this work, 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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (15-19)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Assessment of Wheat Farmers' Knowledge through Kisan Call Centre Advisory Services in Prayagraj, India

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HIGHLIGHTS

- Younger and middle-aged farmers demonstrated significantly higher knowledge levels (χ^2 = 166.66, p<0.01) and better adaptation to ICT-based extension services
- Limited digital literacy, poor connectivity, and inadequate awareness campaigns restrict KCC's full potential in agricultural knowledge transfer
- Findings emphasise the need for targeted digital literacy programs, strengthened awareness campaigns, and farmer-centric service delivery improvements

ARTICLE INFO

Keywords: Kisan Call Centre, ICT extension, Knowledge level, Wheat cultivation, Advisory services.

https://doi.org/10.48165/IJEE.2026.62203

Citation: Kumar, R., Sonu, K., Mazhar, S. H., Verma, A., & Singh, V. (2026). Assessment of Wheat Farmers' Knowledge through Kisan Call Centre Advisory Services in Prayagraj, India. *Indian Journal of Extension Education*, *62*(2), 15-19. https://doi.org/10.48165/IJEE.2026.62203

ABSTRACT

The study examined the effectiveness of Kisan Call Centre (KCC) as an ICT-enabled extension tool in disseminating improved wheat cultivation knowledge among Prayagraj district's farmers, during 2023-24. A purposive sampling design was employed to select 120 wheat farmers from Chaka block who had utilized KCC services. Data were collected through structured interviews and analysed using descriptive statistics, Chi-square test, and correlation analysis. Results revealed that while 93.49% of farmers were aware of KCC's existence, their knowledge of advanced extension services remained limited. Only 17.88% had a complete understanding of KCC objectives, and awareness about weather advisories (9.94%), conference call facilities (8.13%), and governing agencies (8.13%) was poor. Knowledge distribution showed 50.83% farmers in the medium category, 41.67% in the high category, and 7.50% in the low knowledge category. Chi-square analysis indicated a significant association between age and knowledge levels (χ^2 = 166.66, p<0.01), with younger farmers demonstrating better ICT adoption. Education and occupation showed no significant association with knowledge levels. Correlation analysis revealed strong positive relationships between knowledge and social participation (r=0.827), mass media exposure (r=0.735), and information source diversity (r=0.749). These findings provide crucial insights for extension administrators to develop farmer-centric ICT strategies for effective agricultural extension.

INTRODUCTION

Information and Communication Technology (ICT) has emerged as a revolutionary force in transforming agricultural extension systems globally. Agriculture, the backbone of India's economy employing 62% of the population, faces significant challenges in knowledge dissemination and technology transfer. With

Received 17-12-2025; Accepted 18-02-2026

72.2% of India's population residing in rural areas, effective agricultural extension becomes crucial for sustainable development and food security.

Wheat (*Triticum aestivum*), India's second most important food crop after rice, plays an essential role in ensuring food and nutritional security. Cultivated predominantly during the Rabi season, wheat productivity has improved globally through high-yielding varieties, advanced agronomic practices, and mechanization. However, effective knowledge dissemination remains key to successful adoption, making ICT indispensable in modern agricultural extension.

Uttar Pradesh leads India's wheat production with 9.65 million hectares under cultivation and 26.87 million tonnes output. Despite its dominance in area and production, the state lags behind Punjab and Haryana in productivity due to limited access to technical information, inadequate awareness of modern practices, pest infestations, nutrient deficiencies, and climatic irregularities (Government of Uttar Pradesh, 2023). Prayagraj district faces additional challenges, including *Phalaris minor* infestation, yellow rust disease, and irregular rainfall, which further constrain productivity and reduce profitability for small and marginal farmers.

To bridge this information gap, the Government of India launched the Kisan Call Centre (KCC) scheme on January 21, 2004, under the Ministry of Agriculture and Farmers' Welfare. Operating through a toll-free number (1800-180-1551), KCC functions as an ICT-based extension platform providing timely, accurate, and location-specific agricultural advice from 6:00 AM to 10:00 PM daily (DAC & FW, 2022).

The KCC operates on a three-tier system: Level I queries are handled by Farm Tele-Advisors (FTAs) - agricultural graduates fluent in local languages; unresolved queries escalate to Level II, managed by Subject Matter Specialists (SMSs) from agricultural universities; and complex issues reach Level III, where senior experts provide specialized guidance. The system is supported by the Kisan Knowledge Management System (KKMS), ensuring consistency in advisory services. The Kanpur-based centre serves Uttar Pradesh farmers, including Prayagraj district, offering advice on varietal selection, nutrient management, pest control, irrigation scheduling, and government schemes in Hindi, reducing language barriers.

Despite its potential, awareness and adoption remain limited due to poor connectivity, digital illiteracy, and farmers' reliance on informal information sources (Raina et al., 2011; Nain et al., 2015; Rathore & Sharma, 2020). While studies confirm KCC's effectiveness in knowledge dissemination, underutilization prevents realization of full potential. Query pattern analysis suggests that optimizing handling and categorization could enhance efficiency, enabling extension agencies to address seasonal and crop-specific needs more effectively (Sharma et al., 2021; Godara et al., 2024).

Against this backdrop, the present research paper aimed to evaluate wheat farmers' knowledge levels regarding improved cultivation practices through KCC services in Prayagraj district. The study focused on identifying knowledge gaps, assessing awareness levels, and exploring opportunities for strengthening ICT-enabled agricultural extension. Findings are expected to provide valuable insights for policymakers and extension agencies in improving service delivery and bridging the knowledge divide in rural India.

METHODOLOGY

The present study adopted an ex-post-facto research design to evaluate the knowledge level of wheat farmers regarding the Kisan Call Centre (KCC) services in Prayagraj district, Uttar Pradesh. This design was deemed appropriate as the events and conditions under investigation had already taken place and could not be influenced or altered experimentally. The research was carried out during 2023–24 in Prayagraj district, which was purposively selected owing to its extensive wheat cultivation area covering approximately 2.85 lakh hectares, better accessibility for fieldwork, diversity in farming communities, and the researcher's familiarity with the local socio-cultural setting. A multi-stage sampling approach was utilized for the study. At the first stage, Chaka block was chosen purposively from a total of 23 blocks based on its relatively higher concentration of KCC users and improved adoption of information and communication technologies. In the second stage, eight villages were selected randomly using random number tables. At the final stage, 120 wheat farmers were selected through proportional allocation. To be included, farmers were required to have been cultivating wheat for at least three years, to have availed KCC services a minimum of two times in the past two years, and to express willingness to participate. A pre-tested structured interview schedule was employed for data collection. It consisted of three sections: (i) personal and socio-economic characteristics, including age, education, occupation, landholding, income, social participation, and media exposure; (ii) a 15-item knowledge scale with three response categories (fully correct = 3, partially correct = 2, incorrect = 1); and (iii) information on KCC utilization patterns such as frequency of use, types of queries raised, and satisfaction level. The data were collected through face-to-face interviews conducted in the local Hindi dialect at the farmers' residences. Each interview lasted between 45 and 60 minutes, and the researcher personally administered all interviews to ensure accuracy and uniformity in data collection. A knowledge index was calculated as.

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

Data analysis was performed using SPSS V.27. Descriptive statistical tools such as frequency, percentage, mean, and standard deviation were used to summarize the findings, while inferential statistics including chi-square tests were applied to examine associations, and Pearson's correlation coefficient was used to assess relationships between variables. Statistical significance was considered at both 0.01 and 0.05 levels of probability.

RESULTS

The Table 1 revealed that an overwhelming majority of respondents (93.49%) possessed awareness about KCC existence, indicating high levels of basic recognition. However, specific knowledge aspects exhibited significant variations. While 52.84% of farmers demonstrated correct knowledge about KCC's contact number, a substantial proportion (43.91%) remained unaware, and a small percentage (3.25%) provided incorrect information. Regarding service offerings, 47.15% of respondents understood the multiple communication modes available through telephone/mobile

Table 1. Distribution of respondents based on knowledge about Kisan Call Centre

Statements	Fully Correct (%)	Partially Correct (%)	Not Correct (%)	KI
Awareness about KCC existence	93.49	6.51	0.00	96.74
KCC contact number	52.84	43.91	3.25	74.79
Multiple communication modes	47.15	48.78	4.07	71.54
KCC objectives	17.88	73.17	8.95	54.46
Operating hours (6 AM-10 PM)	34.96	57.72	7.32	63.82
Holiday services	45.53	47.97	6.50	69.51
Regional language support	95.90	4.06	0.00	97.93
SMS services	69.10	20.33	10.57	79.79
Conference call facility	8.13	67.48	24.39	41.87
Governing agency awareness	8.13	26.83	65.04	21.545
Weather information services	9.94	39.01	51.05	29.44
Special facilities	8.95	17.07	73.98	17.485
Service utilization	89.43	10.57	0.00	94.71
Service charges	83.73	13.00	3.25	90.23
Problem-solving capability	10.57	17.07	72.36	19.10

devices, while 48.78% lacked this knowledge. When examining KCC objectives, only 17.88% demonstrated complete understanding, whereas the majority (73.17%) possessed partial knowledge. Awareness about operating hours (6:00 AM to 10:00 PM) was moderate, with 34.96% of respondents being fully aware. Table 1 showed that 45.53% of farmers knew about holiday services, though 47.97% were partially aware. An impressive 95.90% were aware of regional language support, demonstrating effective localisation. However, awareness about advanced features remained limited: SMS services (69.10%), conference calls (8.13% fully correct), and weather information services (9.94% fully correct). Awareness of governing agencies was particularly poor, with only 8.13% correctly identifying the agency and 65.04% being completely unaware. Knowledge about special facilities remained limited (73.98% unaware). Despite knowledge gaps, service utilization was high (89.43%), and 83.73% were aware of service charges. Only 10.57% believed KCC solved all agricultural problems, while 72.36% felt it did not address all issues comprehensively.

Table 2 demonstrated varying degrees of association between selected socio-personal variables and farmers' knowledge levels. The association between education and knowledge was statistically non-significant ($\chi^2 = 10.07$, $p = 0.259$), indicating that formal education did not significantly influence KCC knowledge among farmers. This suggested that awareness depended more on extension exposure than formal schooling. A highly significant association was found between age and knowledge ($\chi^2 = 166.66$, $p < 0.01$), implying that age considerably influenced farmers' knowledge levels. Younger and middle-aged farmers possessed higher knowledge compared to older farmers, attributed to their greater adaptability and better access to communication technologies. The association between occupation and knowledge was statistically non-significant ($\chi^2 = 6.72$, $p = 0.151$), showing that occupation did not determine knowledge levels. Farmers engaged in cultivation and those involved in allied occupations had similar knowledge levels regarding KCC services.

Table 2. Association analysis between socio-personal variables and knowledge levels

Variables	Chi-square Value	p-value	df	Significance
Education	10.073	0.260	8	Non-significant
Age	166.669	<0.001	6	Highly significant
Occupation	6.723	0.151	4	Non-significant

The correlation analysis revealed significant relationships between respondents' profiles and their KCC knowledge in Table 3. Strong positive correlations emerged between knowledge and social participation (r=0.827), mass media exposure (r=0.735), and information source diversity (r=0.749). Age showed a positive correlation (r=0.745), while annual income and education demonstrated moderate positive correlations. Interestingly, landholding and occupation showed no significant relationships with knowledge, indicating that KCC knowledge was more influenced by socio-demographic and informational factors rather than economic variables. The findings emphasized the critical role of social networks and multi-channel information access in ICT extension adoption among farmers.

Table 3. Correlation analysis between respondent profile and KCC knowledge

Variables	Correlation Coefficient (r)
Age	0.745**
Social participation	0.827**
Mass media exposure	0.735**
Information sources	0.749**
Annual income	0.244*
Education	0.178*
Landholding	0.015
Occupation	0.018

Significant at 0.01(*) and 0.05(*) levels; NS = non-significant

The regression analysis identified two significant predictors of farmers' KCC knowledge shown in Figure 1. Age emerged as the strongest positive predictor ($\beta = 0.251$, $p < 0.001$), indicating that older farmers possessed significantly higher knowledge levels about KCC services. Conversely, Progressiveness demonstrated a negative relationship ($\beta = -0.160$, $p < 0.05$), suggesting that more progressive farmers had lower KCC knowledge levels. This counterintuitive finding implied that progressive farmers might rely on alternative

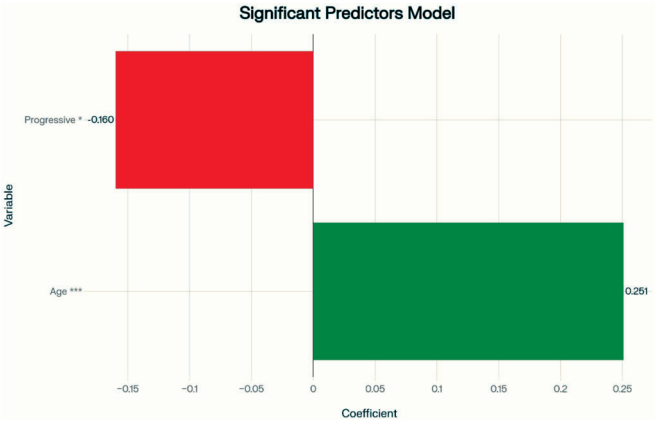

Figure 1. The regression predictors Model of KCC knowledge

information sources rather than traditional extension services. Age proved to be the most influential factor, with each unit increase associated with a 0.251 unit increase in knowledge scores, highlighting the complex relationship between farmer characteristics and ICT-based extension service adoption patterns.

DISCUSSION

The high level of basic awareness (93.49%) about KCC existence indicates successful initial outreach efforts by agricultural extension agencies, though this awareness does not necessarily translate into comprehensive utilization of services. This phenomenon aligns with observations from Monikha et al. (2021) who studied the effectiveness of different extension tools among paddy farmers and found that while farmers showed high awareness of ICT-based extension services, their knowledge about advanced features remained limited. The substantial variation in specific knowledge aspects, particularly the low awareness about KCC objectives (17.88% fully correct), reflects common challenges in ICT-based extension systems. The partial knowledge phenomenon, where 73.17% of respondents possessed an incomplete understanding of KCC objectives, suggests what researchers have termed surface-level adoption in digital extension platforms. This indicates that while farmers are willing to engage with ICT services, deeper understanding requires more intensive extension efforts (Aker, 2011). The impressive awareness about regional language support (95.90%) demonstrates the success of localization strategies, highlighting the critical importance of linguistic accessibility in ICT-based agricultural extension services. Godara et al., (2024) Calls are categorised based on crops and query type, providing a sense of the major crop-based Challenges to underscore data-driven insights in enhancing agricultural support systems. The district-wise breakdown has highlighted farmers' diverse challenges, emphasizing the need for localized, region-specific interventions. Further insights from cropwise data reveal the array of crops (Godara et al., 2024).

The pronounced knowledge gaps regarding advanced features such as conference call facilities (8.13% fully aware) and weather information services (9.94% fully aware) highlight significant underutilization of KCC's full potential. This finding is consistent with broader patterns observed in agricultural technology adoption, where farmers tend to use only basic functions of digital platforms, missing opportunities for more sophisticated advisory services. The poor awareness about governing agencies (65.04% completely unaware) reflects institutional disconnect, indicating need for better integration between technology platforms and institutional awareness campaigns (Sulaiman & Sadamate, 2000). The knowledge distribution analysis revealing that 92.69% of farmers possessed medium to high knowledge levels suggests a reasonably informed user base, which contradicts common assumptions about limited rural digital literacy. This finding supports arguments for recognizing farmers' adaptive capacity in technology adoption. However, the 7.31% in the low knowledge category represents a vulnerable group requiring targeted interventions, emphasizing the need for inclusive extension strategies that address diverse knowledge levels within farming communities (Slathia et al., 2011; Babu et al., 2012).

The highly significant association between age and knowledge levels ($\chi^2 = 166.66$, $p < 0.01$) confirms the pronounced digital divide across age groups, consistent with findings from Silva (2023) who observed that younger farmers in Sri Lankan agricultural extension networks demonstrated better technology adoption capabilities. This age-technology divide necessitates differentiated extension approaches, with younger farmers serving as potential change agents while older farmers require additional support for technology adoption. The non-significant association between formal education and KCC knowledge challenges conventional assumptions about education's role in technology adoption, supporting findings from Singh et al. (2019) who demonstrated that experiential learning through extension exposure may be more critical determinants than formal educational qualifications. The strong positive correlations between knowledge and social participation (r=0.827), mass media exposure (r=0.735), and information source diversity (r=0.749) underscore the importance of multi-channel communication strategies in agricultural extension. These findings validate the significance of social learning networks in technology adoption, where farmers learn through peer interactions and multiple information channels (Bandura, 2001 and Sonu & Jha, 2025). Silva (2023) similarly emphasized that social networks play crucial roles in accelerating agricultural technology adoption, particularly through contact farmer approaches that bridge extension officers and farming communities. The importance of social participation suggests that community-based extension approaches can enhance individual technology adoption, while mass media exposure indicates the complementary role of traditional and digital media in agricultural knowledge dissemination. The effectiveness of integrated extension approaches that combine traditional methods with ICT platforms for optimal knowledge transfer (Monikha et al., 2021). The absence of significant correlations between knowledge and economic variables (landholding, occupation) suggests that KCC's effectiveness transcends economic stratification, supporting arguments for ICT-based extension as potentially equalizing force in agricultural development. This democratizing potential indicates that small and marginal farmers can access the same quality of technical information as larger farmers, provided they have adequate awareness and digital literacy support.

These findings have important implications for extension policy and practice. The results suggest need for age-specific

extension strategies, enhanced awareness campaigns about advanced KCC features, and integration of social learning approaches with digital extension platforms. Furthermore, the importance of multi-channel communication indicates that ICT-based services should complement rather than replace traditional extension methods, creating comprehensive extension systems that leverage both digital and interpersonal communication channels.

CONCLUSION

The study shows that Kisan Call Centre (KCC) has achieved moderate success in improving wheat farmers' knowledge in Prayagraj. Awareness is high (93.49%), but major gaps persist in advanced features, weather advisories, and institutional aspects. Younger farmers adopt technology more easily than older ones, indicating the need for targeted support. Education had little effect, while social participation, extension exposure, and mass media access strongly influenced ICT use. The study recommends digital literacy for older and marginalized farmers, wider promotion through multiple media and local networks, improved connectivity and advisory quality, and region-specific content to strengthen KCC's effectiveness.

DECLARATIONS

Ethical Approval and Consent to Participate: Our study did not require ethical approval; however, the informed consenst of the participants was sought.

Consent of Publication: Participants provided consent for publication

Availability of supporting data: Supporting data are available upon request.

Competing interests/Author contributions: No competing interests were declared. Conceptualization of research (RK, SHM); Designing of the experiments (RK, SHM); Contribution of experimental materials (RK, SHM); Execution of field survey and data collection (RK, AV, VS); Analysis of data and interpretation (KS); Preparation of manuscript (KS).

Conflict of interest: No conflicts of interest among the authors

The authors declare that during the preparation of this work, 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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (20-25)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Selective Complementarity of Indigenous Leadership: Ninik Mamak's Role in Livestock Development in Minangkabau, Indonesia

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HIGHLIGHTS

- Ninik Mamak's decision-making role demonstrates a significant positive influence across all livestock development dimensions.
- Cooperation facilitation exhibits paradoxical negative effects on the technical and economic aspects of livestock development.
- The selective complementarity concept extends institutional theory by demonstrating function-specific rather than universal complementarity patterns.

ARTICLE INFO

Keywords: Informal institutions, Social capital, Institutional theory, Livestock groups, Matrilineal system.

https://doi.org/10.48165/IJEE.2026.62204

Citation: Putra, R. A., Hariadi, S. S., & Muzayyanah, M. A. U. (2026). Selective Complementarity of Indigenous Leadership: Ninik Mamak's Role in Livestock Development in Minangkabau, Indonesia. *Indian Journal of Extension Education*, *62*(2), 20-25. https://doi.org/10.48165/IJEE.2026.62204

ABSTRACT

Indigenous leadership plays an important role in rural development, but Ninik Mamak's specific contribution as an indigenous leader of the Minangkabau people to livestock development has not been empirically documented. Present research analyzes the influence of Ninik Mamak's role on livestock development from technical, social, and economic aspects. A quantitative method was used in this study to collect data from 210 respondents from 42 livestock groups in West Sumatra Province. A validated and reliable Likert-scale questionnaire was employed for data collection, and multiple linear regression was used for data analysis. The results show that all regression models are statistically significant. Ninik Mamak's decision-making role shows a strong positive effect on all aspects. However, the role of information dissemination does not show a significant impact, whereas the role of cooperation facilitation has significant negative effects on the technical and economic aspects. This study confirms that Ninik Mamak has a significant role in the development of farms with complex patterns. These findings introduce the concept of "selective complementarity" in institutional theory and recommend selective engagement strategies to optimize the role of indigenous leadership.

INTRODUCTION

Livestock development has been vital for economic establishment in developing countries, particularly in providing food supply, income sources, livelihood security, and employment (Banda & Tanganyika, 2021; Herrero et al., 2013; Verma et al., 2025). However, overcoming the challenges of livestock development requires more than technical interventions alone, as socio-cultural and institutional factors fundamentally shape the adoption of agricultural innovations and the sustainability of development outcomes in rural communities (Curry et al., 2021; Makate, 2020). Social capital theory shows the fundamental role of informal institutions and local leadership to encourage innovations, build community trust, and improve the sustainability of agricultural development (Liu et al., 2025; Yang et al., 2024).

Indigenous leadership, as culturally rooted informal institutions, has shown considerable importance in facilitating rural development (Bansal et al., 2024; Olaopa et al., 2023). Research shows that indigenous institutions play essential roles in farmers' decision-making regarding agricultural innovations and access to

Received 09-02-2026; Accepted 23-02-2026

heritage land, financial institutions, and production inputs (Makate, 2020; Yami & van Asten, 2018). The Minangkabau people in West Sumatra, Indonesia, display uniqueness with their matrilineal kinship system, which gave birth to a customary leadership structure called Tungku Tigo Sajarangan, where Ninik Mamak (tribal traditional leader) occupies a central position with authority over the socio-economic life of the community (Azwar et al., 2018; Elfia et al., 2024; Hakim et al., 2025). In a theoretical framework, Ninik Mamak, in his position as an institutional entrepreneur, plays a role in bridging traditional values with the needs of today's development. Institutional theory posits that the interaction of formal and informal institutions can give birth to patterns of complementary, substitutive, accommodating, or competitive adaptation (Helmke & Levitsky, 2004), a framework that continues to be applied and extended in contemporary development research (Dau et al., 2022; Mbalyohere & Lawton, 2022).

West Sumatra has strategic potential in livestock development (Indrayani et al., 2022). However, development activities through farmer groups face obstacles, including stagnant livestock populations, poor management, and low sustainability (Madarisa et al., 2024; Putra et al., 2023). Given that almost 90% of West Sumatra's population is Minangkabau people with strong Ninik Mamak leadership structures, a critical question arises regarding the indigenous leadership's role in livestock development. Previous studies on Ninik Mamak have focused primarily on customs, culture, and ulayat land management (Ahmad & Zulfidar, 2023; Dewi et al., 2024). Studies that examine the special role of Ninik Mamak in the development of the productive sector are still very minimal. This creates a theoretical and empirical gap: there is no conceptual framework that outlines the functions of indigenous leadership in the context of livestock modernization, and its real economic impact has not been systematically documented.

This study analyzes Ninik Mamak's role influence on livestock development across technical, social, and economic aspects. It examines the hypothesis that the three roles of Ninik Mamak (decision-making, information dissemination, and facilitation of collaboration) simultaneously have a significant impact on livestock development, based on the proposition that traditional leadership with high social legitimacy can be a catalyst for the adoption of innovation and economic development (Beaman et al., 2021; Yami & Asten, 2018). This research contributes by enriching the understanding of the mechanisms by which informal institutions operate in modern economic development and by identifying optimal interaction patterns between formal and informal institutions. In practice, it provides evidence-based recommendations for policymakers to optimize the roles of indigenous institutions in livestock development programs.

METHODOLOGY

This quantitative research was conducted in West Sumatra Province during January-March 2025, which covers three districts, namely: Pesisir Selatan, Sijunjung, and Lima Puluh Kota. The districts were selected based on the largest livestock group population, geographical representation, and active Minangkabau customary institutional presence.

The study population consisted of all livestock farmer groups, i.e., 84, which received government assistance during the period 2014-2024. Forty-two groups (14 per district) were selected using stratified random sampling method, and further five members per group were selected, for a total of 210 respondents (Hariadi, 2011). Respondents were members of the Minangkabau ethnicity selected purposively based on active group involvement.

Independent variables measure three roles of Ninik Mamak: (1) Decision making: strategic involvement in livestock group activities including discussions, business management, activity planning, customary land utilization, and decision-making support; (2) Information dissemination: the distribution of livestock information includes communal resources, technical aspects, government assistance, and nagari policies (3) Cooperation facilitation: facilitating internal-external group cooperation through stakeholder dialogue, government coordination, financial institution access, and conflict mediation. Dependent variables assess the development of livestock through: (1) Technical aspects: adoption of modern technology with 15 indicators which include seed selection, maintenance, feed management, health control, and marketing; (2) Social aspects: group cohesiveness with 12 indicators that measure social services, use of community halls, planning, and group spirit; (3) Economic aspects: business achievement with 12 indicators including productivity, capital access, marketing expansion, and revenue.

Primary data collected through a Likert scale validated questionnaire (1=never to 5=very often) and analyzed using the summated rating method (Azwar, 2015). The validity test used the Pearson Product-Moment correlation ($r>0.30$), which has shown adequate validity for all variables ($r=0.206$ to 0.835). Reliability testing using Cronbach's Alpha has demonstrated excellent reliability ($\alpha=0.850$ to 0.894) for all constructs (Bujang et al., 2018).

Data analysis included descriptive statistics with five-level categorization (Cohen et al., 2017; Salkind, 2007), classical assumption tests (normality, multicollinearity, heteroscedasticity, and linearity), and multiple linear regression using SPSS 26. The regression models were:

$$Y_1 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_1$$
$$Y_2 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_2$$
$$Y_3 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_3$$

Where $Y_1/Y_2/Y_3$ represents technical/social/economic aspects; X_1, X_2, X_3 represent decision-making, information dissemination, and cooperation facilitation; β_0 is the constant; β_1, β_2, β_3 are partial regression coefficients; and ε is the error term. Hypothesis testing employed the F-test for simultaneous effects and the t-test for partial effects at $\alpha = 0.05$ significance level, with R^2 quantifying the proportion of variance explained.

RESULTS

Descriptive analysis of research variables

The results of the descriptive analysis show a consistent pattern in the role of *Ninik Mamak* in livestock development, as shown in Table 1.

Table 1. Descriptive Statistics of Research Variables

Variable	Average Score	Percentage Achievement	Category
Decision Making (X_1)	0.597	24.37	Low
Information Dissemination (X_2)	0.645	29.32	Low
Cooperation Facilitation (X_3)	0.527	17.50	Very Low
Technical Aspects (Y_1)	1.518	36.21	Low
Social Aspects (Y_2)	1.630	47.51	Moderate
Economic Aspects (Y_3)	1.395	38.24	Low

Source: Research Results, 2025

Note: The varying percentage of achievement is categorized into five levels based on the same interval classification: Very Low (0–20%), Low (21–40%), Moderate (41–60%), High (61–80%), and Very High (81–100%), adapted from Cohen et al. (2017) and Salkind (2007).

Achievement of Ninik Mamak's role variables

The achievement of the decision-making variable was in the low category (24.37%) of the five indicators measured; the highest achievement was the involvement of *Ninik Mamak* as a determinant of the use of ulayat land for group business (42.14%), while involvement in the discussion of livestock group activity plans only reached 15.56%. These findings indicate that although the *Ninik Mamak* still retain traditional authority in communal resource management, their involvement in the operational planning of livestock groups is still minimal.

The achievement of information dissemination variables is also in the low category (29.32%). The highest achievement in this variable was providing information on the management of resources such as land and water sources (44.52%), while the delivery of technical information on livestock farming was only 12.38%. This shows that *Ninik Mamak* still plays a role in traditional resource management. Still, it has not yet become an effective channel for disseminating technical knowledge about modern animal husbandry.

The achievement of the cooperation facilitation variable was very low (17.50%). This variable had the lowest achievement among the three roles of *Ninik Mamak*, with the majority of respondents (68.57%) stating that *Ninik Mamak* "never" facilitated cooperation. The highest achievement was the facilitation of the use of resources (21.79%), while the facilitation of cooperation with financial institutions was only 10.79%.

Achievements of livestock development variables

The achievement of the technical aspect variable is in the low category (36.21%). Of the 15 indicators measured, the highest achievement was to sanitize the cage (53.65%) and contact the veterinarian when the livestock was sick (52.06%). However, marketing shows very low achievements, such as selling cattle at the animal market (13.10%) and using digital platforms for promotion (13.65%).

The achievement of the social aspect variable was relatively better, namely in the moderate category (47.51%). This aspect shows the highest achievement among the three aspects of livestock development. The indicators with the best achievements were mutual aid between members (57.74%) and providing encouragement and support (57.02%). This reflects the still strong social cohesion in the Minangkabau livestock group.

Meanwhile, the variable of economic aspects is in the low category (38.24%). The highest achievement was to carry out planned cattle marriage (55.24%), while the lowest achievement was to obtain subsidized capital from the government (20.95%). These figures illustrate that the achievement of livestock development in the economic aspect is still not in accordance with what it should be.

Regression analysis results

The results of the regression analysis for the three aspects of livestock development, presented in Table 2.

Table 2. Recap of Multiple Linear Regression Analysis Results

Variable	Technical Aspects (Y_1) β (Sig.)	Social Aspects (Y_2) β (Sig.)	Economic Aspects (Y_3) β (Sig.)
Decision-making (X_1)	0.309*	0.222*	0.492*
Information dissemination (X_2)	0.150	0.157	-0.080
Cooperation Facilitation (X_3)	-0.323*	-0.193	-0.310*
R^2	0.097	0.064	0.141
Adjusted R^2	0.084	0.051	0.129
F-statistic	7.370*	4.727*	11.280*

Note: *$p < 0.05$

According to the findings of multiple linear regression analysis, the research hypothesis states that "the three roles of *Ninik Mamak* (decision-making, information dissemination, and facilitation of cooperation) simultaneously have a significant effect on livestock development in technical, social, and economic aspects", so that the hypothesis is accepted.

Statistical evidence shows that all three regression models show significant simultaneous influences on 99% confidence levels: technical aspects ($F = 7.370$; $p = 0.000$), social aspects ($F = 4.727$; $p = 0.003$), and economic aspects ($F = 11.280$; $p = 0.000$). Although the direction of influence of each independent variable varies, the overall role system of *Ninik Mamak* has been proven to influence livestock development significantly.

The analysis showed that the economic aspect had the highest explanatory power ($R^2 = 0.141$), followed by the technical aspect ($R^2 = 0.097$) and the social aspect ($R^2 = 0.064$). This relatively low R^2 value is consistent with the nature of research on informal institutions in the context of social and agricultural development, where the phenomena studied are inherently complex and influenced by a variety of factors (Helmke & Levitsky, 2004). Livestock development outcomes are influenced by a variety of factors outside of local leadership, including individual farmer characteristics, access to inputs and markets, biophysical conditions, and macroeconomic environment all of which were not included in the scope of this study. Low R^2 values in these kinds of studies do not signal model failure; rather, they reflect the limited but tangible contribution of specific institutional variables in complex systems (Cohen et al., 2017). The consistent statistical significance of all three F tests confirms that the role of Ninik Mamak is an authentic and replicable determinant in livestock development, especially through mechanisms of social legitimacy and strategic resource governance.

DISCUSSION

The role in decision making: Indigenous leadership legitimacy

The significant positive influence of Ninik Mamak's decisions on all aspects of livestock development, as shown in Table 2, confirms the institutional theory proposition that informal institutions can function complementarily with formal institutions in the development process (Helmke & Levitsky, 2004). The legitimacy of *Ninik Mamak* in decision-making in farmer groups, although with relatively low achievement (24.37%), still has a substantial impact when activated, especially in the context of using communal resources such as ulayat land.

These findings are in line with studies showing that indigenous leadership plays an important role in agricultural development through collective decision-making based on traditional values and local wisdom (Makate, 2020), including the management of communal resources such as ulayat land (Widianingsih et al., 2023). In the Minangkabau context, the authority of *Ninik Mamak* in the management of heritage and strategic decision-making in the tribe provides the foundation of trust necessary for the development of productive businesses, including livestock businesses (Elfia et al., 2024).

The most substantial effect was seen in the economic aspect ($\beta = 0.492$), indicate that the support of *Ninik Mamak* in strategic decision-making gave confidence to group members to carry out activities and develop livestock businesses. This is consistent with findings that social legitimacy and support from indigenous leaders significantly shape community trust and collaborative success (Liu et al., 2025; Olaopa et al., 2023). Other findings also confirm that traditional leadership with authority in natural resource management can increase the effectiveness of development programs through decision-making mechanisms already understood and accepted by the community (Yami & Asten, 2018). Recent research in India further confirms that the economic security of rural households is meaningfully influenced by livelihood strategies and decision-making processes at the community level (Jatav, 2024).

Role in the dissemination of information: Insignificant

Table 2 explains that the role of information dissemination does not show a significant effect on the three aspects. The absence of a significant influence on the dissemination of Ninik Mamak information across all aspects of livestock development is a finding that can be explained by a multifactor analysis. The low achievement of this variable (29.32%) indicates that *Ninik Mamak* has not functioned as an agent for disseminating technical information on livestock or government programs, which may be due to limited technical capacity and access to information. Data shows that *Ninik Mamak* still plays a role in delivering information about resource management (44.52%), but is very low in providing technical information on livestock farming (12.38%). This reflects the gap in capacity between the need for disseminating modern technical knowledge and the traditional competence of *Ninik Mamak*. These findings are in line with studies showing that traditional leadership often faces obstacles in bridging local knowledge with the needs of modern technology in agricultural development (Pali et al., 2023). Technical information is more effectively conveyed via social networks grounded in technical expertise and social learning, rather than through symbolic or traditional figures (Beaman et al., 2021). Previous literature has shown that the success of dissemination of information depends on the availability of adequate training programs and the strengthening of technical capabilities for both leaders and breeders (Sharma & Singh, 2023).

Facilitating cooperation: Significant negative, a paradox of indigenous leadership

The discovery of a significant negative influence of Ninik Mamak's role in facilitating cooperation on livestock development is a paradoxical result and provides valuable theoretical insights. Three interacting factors explain this counterproductive outcome.

First, the mismatch of capacity with the demands of the sector. Although Ninik Mamak has legitimacy in indigenous resource management and conflict resolution, the modern livestock sector requires technical knowledge of breeding, feed, market access, and financial networks competencies that lie outside traditional authority (Adisa, 2015; Webster, 2013). When leaders' skills do not match the needs of implementation, they risk hindering the acceleration of development (Curry et al., 2021; Kiptot & Franzel, 2014).

Second, political contamination. Field findings suggest that Ninik Mamak is often involved in practical politics as candidates or supporters in nagari, district, and legislative elections which undermines their roles and causes social envy and community conflicts (Hakim et al., 2025; Rahmat et al., 2023). This is further complicated because cattle assistance programs are often funded from legislators' discretionary funds (POKIR), creating complex political-economic linkages (Anas et al., 2024) dynamics consistent with findings in Zimbabwe, where the political involvement of traditional leaders undermines public trust (Zhou, 2023).

Third, the gap between expectations and reality. The cooperation facilitation variable recorded the lowest achievement among the three roles (17.50%), with 68.57% of respondents stating that Ninik Mamak had never facilitated group cooperation. This absence creates an institutional vacuum: members of the group culturally expect support from figures with high social legitimacy, but those expectations are not met in practice. This gap between cultural expectations and empirical reality is known to erode community trust and institutional beliefs (Chili & Ngxongo, 2017; Matsiliza, 2024).

The convergence of these three factors results in a paradox: a figure with high social capital produces negative development outcomes when placed in an operational facilitation role. These findings have important implications for institutional theory. Contrary to the assumption that traditional authority comprehensively complements formal institutions, this study suggests that complementarity is function-specific. The role of Ninik Mamak operates as complementary at the strategic level where social legitimacy supports decision-making and management of communal resources but shifts to competitive adaptation at the operational level, where technical capacity and political neutrality are required. The pattern introduces the concept of "selective complementarity," expanding on the institutional interaction framework of Helmke and Levitsky (2004) by showing that formal-

informal institutional relationships can vary across multiple dimensions of the same leadership function, not just between different institutions.

CONCLUSION

The research proves that the role of indigenous leadership in livestock development displays complex patterns through selective complementarity. Ninik Mamak's decision-making function has shown a significant positive impact on all aspects of development, confirming that social legitimacy in managing communal resources provides an essential foundation of trust for collaboration and adoption of innovation. Information dissemination shows no significant impact, reflecting traditional leaders' limitations in conveying modern technical knowledge. The most significant finding is the significant negative influence of cooperation facilitation on technical and economic aspects, explained by capacity mismatches with modern sector demands, political contamination, and minimal involvement, thus creating a gap between expectations and reality. Results confirm that not all forms of traditional authority benefit contemporary development, requiring a strategy of selective engagement to optimize the role of indigenous leadership. The concept of selective complementarity provides practical guidance for integrating traditional values with the need for modernization without giving rise to institutional conflicts.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the farmer respondents of the study during the course of the research.

Acknowledgements: We would like to thank: (1) Indonesian Education Scholarship, (2) Center of Higher Education Funding and Assessment, Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, (3) Indonesian Endowment Fund for Education, for the financing assistance provided so that this research could be held. We also express our gratitude to LPPM of Andalas University, the Animal Husbandry Service throughout West Sumatra, and livestock groups who have assisted in the implementation of this research.

Conflict of interest: 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.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (26-32)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Enhancing Decision-Making Attributes of Rural Women in Odisha Under Mission-Shakti Programme

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HIGHLIGHTS

- Decision-making ability of rural women is shaped by enterprise, marketing and financial domains under the Mission Shakti programme.
- Socio-economic and socio-psychological factors exhibited strong associations with the overall decision-making behaviour of rural women in Keonjhar and Khurdha districts.
- Comparative analysis highlighted marginal yet meaningful differences in decision-making scores across the two districts, reflecting the programme's role in strengthening women's empowerment.

ARTICLE INFO

Keywords: Decision-making behaviour, Rural women, Socio-economic activities, Mission Shakti programme.

https://doi.org/10.48165/IJEE.2026.62205

Citation: Mohapatra, S. S., Mohapatra, B. P., Das, S., Dash, D., & Mahapatra, S. S. (2026). Enhancing Decision-Making Attributes of Rural Women in Odisha Under Mission-Shakti Programme. *Indian Journal of Extension Education*, *62*(2), 26-32. https://doi.org/10.48165/IJEE.2026.62205

ABSTRACT

Decision-making constitutes a core dimension of women's empowerment and requires systematic strengthening through participatory and context-specific interventions. The present study, undertaken during 2023–24 in Keonjhar and Khurdha districts of Odisha, evaluates the decision-making behaviour of rural women engaged in the Mission Shakti programme. A sample of 200 respondents (100 from each district) was assessed across three critical decision-making domains: enterprise, marketing and financial decisions. Findings revealed marginal yet noteworthy inter-district variations, with mean scores for enterprise decision (13.48 in Keonjhar; 13.44 in Khurdha), marketing decision (7.60 in Keonjhar; 7.85 in Khurdha), and financial decision (7.65 in Keonjhar; 7.60 in Khurdha). Correlation analysis indicates that decision-making authority positively influences enterprise, marketing and financial decisions, which highlights the importance of autonomy. Social independence and decision-making ability were positively associated with marketing decisions. Regression results showed that socio-psychological factors, especially group membership and perception, significantly influenced enterprise decision-making, while marketing and financial decisions were mostly affected by structural and external factors. Model accuracy confirmed that marketing decisions are relatively more consistent. The study concludes that Mission-Shakti has played a constructive role in enhancing rural women's decision-making capacity, but targeted interventions are required to address the persistent gap.

INTRODUCTION

Women's empowerment has been widely recognized as a critical dimension of socio-economic development, particularly in rural regions of India. In Odisha, the Mission Shakti programme plays a pivotal role in strengthening women's economic conditions, income-generating activities, and decision-making capacities, especially across tribal and non-tribal districts. Earlier research on women's empowerment and demographic processes (Kishor, 2000; Nain & Kumar, 2010; Slathia et al., 2014; Singh et al., 2017)

Received 17-12-2025; Accepted 23-02-2026

highlighted that empowerment is closely linked with decision-making autonomy within households and communities. Women constitute about 48.46% of India's population (Census, 2011), representing a significant human resource whose development is essential for sustainable and inclusive economic growth. Relevant studies (World Bank, 2012; Klapper & Singer, 2011; Hausmann et al., 2011) have emphasised the role of economic stratification in shaping women's financial inclusion and prosperity. In Odisha, women account for 49.5% of the total population, where 32.59 per cent of state's populace living below the poverty line, placing the state sixth in poverty rankings (Panda & Bhol, 2025). To address deep-rooted poverty and promote socio-economic upliftment, the Government of Odisha launched the Mission Shakti programme in 2001. As a flagship initiative, Mission Shakti focuses on holistic empowerment through capacity building, income-generation support, and strengthening women's participation in economic activities.

The programme enhances women's livelihoods by facilitating micro-enterprise development, promoting technical, procurement, and marketing decisions, and supporting financial inclusion through savings mobilisation, credit access, and enterprise loans. Women's economic activities include the collection and sale of minor forest products, honey production through apiary units, and value addition of forest-based resources (Mohanty, 2013). Mission Shakti also strengthens creditworthiness by building SHG corpus funds, enabling women to access institutional finance for micro-enterprise expansion. Women's empowerment is a long-term process involving greater agency, improved access to resources, and enhanced control over life choices (Mathew, 2013). Empowerment of rural women requires access to material, human, and social resources, supported by strategies that enable participation in economic opportunities (Kabeer, 1999). Malhotra et al. (2002) further emphasised that empowered women must possess not only resources but also the capability to identify, utilise, and transform these resources into meaningful outcomes. This study is grounded in the broader framework of rural women's empowerment, focusing specifically on their rights to land, leadership roles, participation in policymaking, and involvement in community-level programmes. Central to this empowerment is decision-making behaviour, which acts as a catalyst for advancing economic independence and strengthening women's participation in livelihood systems under the Mission Shakti programme.

METHODOLOGY

The study was conducted during 2023–24 in Keonjhar and Khordha districts of Odisha, representing two socio-economically and culturally distinct regions of the state. A multistage random sampling technique was employed to ensure representativeness. The two districts were selected purposively due to their substantial participation of rural women in Mission Shakti activities. Odisha comprises 30 districts, of which 18 are predominantly non-tribal and 12 are tribal-dominated. In Keonjhar district, two blocks Anandapur and Ghasipura were selected through random sampling from a total of thirteen blocks. Similarly, in Khordha district, two blocks Balianta and Balipatna were chosen randomly from among ten blocks. Subsequently, two Gram Panchayats (GPs) were randomly selected from each chosen block. These included Mochinda and Fakirpur from Anandapur block, Balarampur and Bailo from Ghasipura block, and Bhingarpur and Kakarudrapur from Balianta block, along with Deulidharpur and Majhihara from Balipatna block. Selection at each stage was carried out using the lottery method to minimize bias.

From each selected Panchayat, Self-Help Groups (SHGs) were randomly chosen, followed by the random selection of individual members. The distribution of SHGs included: Mochinda (4 SHGs), Fakirpur (3 SHGs), Balarampur (3 SHGs), Bailo (7 SHGs), Bhingarpur (6 SHGs), Kakarudrapur (6 SHGs), Majhihara (6 SHGs), and Deulidharpur (5 SHGs). Based on SHG membership, the number of respondents selected from each Panchayat was as follows: Bhingarpur (28), Kakarudrapur (30), Majhihara (31), Deulidharpur (11), Mochinda (19), Fakirpur (15), Balarampur (17), and Bailo (49). A total sample of 200 rural women respondents actively engaged in Mission Shakti activities constituted the final study group. Data were collected to assess decision-making behaviour across three key areas, namely enterprise decision, marketing decision, financial decision. The mean scores were computed by dividing the total obtained score by the number of respondents in each decision-making dimension. Gap percentage was also calculated using the formula:

$$\text{Gap Percentage} = \frac{\text{Maximum Score - Obtained Score}}{\text{Maximum Score}} \times 100$$

Data were analysed using a combination of descriptive and inferential statistical techniques. Descriptive statistics such as mean, standard deviation, frequency, percentage, and gap analysis were employed to summarise the decision-making performance of rural women across different dimensions. Pearson's correlation coefficients were computed to examine the association between socio-personal variables and the three major decision categories. Multiple linear regression analysis was used to determine the influence of socio-psychological factors including personality traits, motivation, attitudes, group membership, and perception on enterprise, marketing, and financial decisions. Model accuracy was assessed using RMSE (Root Mean Square Error) and MAE (Mean Absolute Error) to evaluate the reliability and consistency of regression outputs. Trend analysis further facilitated comparative interpretation of decision gaps across the two districts and decision categories.

RESULTS

Decision-making behaviour of rural women under mission shakti

The decision-making performance of rural women engaged in the Mission Shakti programme was assessed across three functional domains: enterprise, marketing, and financial decisions. A consolidated analysis of the two districts (Table 1) revealed varying levels of decision gaps across decision criteria. In enterprise decisions, both Keonjhar and Khordha districts exhibited consistent gaps in value chain analysis and selection of area. In Keonjhar respondents reported higher gaps in raw material selection and

Table 1. Enterprise decision, Marketing and Financial decision of rural women of Keonjhar district and Khordha district

Decision Category	Criteria of Decision	Keonjhar Mean Score	Keonjhar Gap (%)	Khordha Mean Score	Khordha Gap (%)
Enterprise Decisions	Selection of an enterprise	2.28	24.00	1.98	34.00
	Selection of area	1.85	38.33	1.52	49.33
	Selection of raw materials	1.75	41.66	2.05	31.66
	Processing procedures	2.05	31.66	2.04	32.00
	Value chain analysis	1.75	41.66	1.75	41.66
	SHG enterprise promotion of producer group	2.05	31.66	2.05	31.66
	Food product and value addition	1.75	41.66	2.05	31.66
Marketing Decisions	Cost price decision	1.75	41.66	2.05	31.66
	Selection of area where market will be established	2.05	31.66	2.05	31.66
	Selecting materials to be disposed in the market	1.75	41.66	1.73	57.66
	Analysing the sale activities	2.05	31.66	2.02	67.33
Financial Decisions	Taking money from bank/institutions	2.05	31.66	2.05	31.66
	Buying and selling opportunities	1.80	40.00	1.80	40.00
	Value chain analysis of the products	1.75	41.66	1.73	57.66
	Disposing products with good price	2.05	31.66	2.02	67.33

value-addition processes, suggesting limited knowledge of input quality and enterprise structuring. Conversely, Khordha women demonstrated substantially higher gaps in selecting enterprise area (49.33%) and moderately high gaps in value chain analysis (41.66%), indicating weaker exposure to enterprise planning and site-based decision-making. Marketing decisions showed the widest performance gaps, especially in Khordha district. While Keonjhar respondents exhibited moderate gaps in cost price determination (41.66%) and selection of materials (41.66%) for sale, women in Khordha displayed significantly higher gaps in selecting materials for disposal (57.66%) and analysing sales activities (67.33%). These results highlight a pronounced need for skill enhancement in pricing strategies, demand forecasting, and understanding market dynamics. Financial decision-making displayed similar constraints across both districts. The highest decision gaps were observed in value chain analysis of products (41.66% in Keonjhar; 57.66% in Khordha) and buying–selling opportunities (40% in both districts). Khordha women experienced the greatest difficulty in disposing products at profitable prices (67.33%), suggesting limitations in negotiation skills, price estimation, and financial literacy. Overall, marketing decisions demonstrated the largest performance gaps, followed by enterprise and financial decisions, indicating the need for targeted capacity-building interventions in value chain management, marketing intelligence, pricing strategies, and financial decision-making.

The comparison of decision-making performance among rural women in Keonjhar and Khordha districts reveals distinct gaps across enterprise, marketing, and financial decision categories under the Mission Shakti programme. In enterprise decisions, both districts exhibit notable deficiencies in value chain analysis and selection of enterprise area, with Keonjhar women additionally showing higher gaps in raw material selection and value-addition processes, indicating limited understanding of input quality, process flow, and enterprise structuring. Khordha women demonstrate substantially higher gaps in enterprise area selection (49.33%) and similarly elevated gaps in value chain analysis (41.66%), suggesting weaker exposure to enterprise planning and location-based decision-making. Marketing decisions reflect the widest performance gaps, especially in Khordha, where women reported severe limitations in selecting materials for market disposal (57.66%) and analysing sales activities (67.33%), underscoring the need for improved competencies in pricing strategy, demand forecasting, and market analysis; in contrast, Keonjhar women show comparatively moderate gaps in cost pricing and product selection. Financial decisions display similar constraints across both districts, with significant gaps in value chain analysis (41.66% in Keonjhar; 57.66% in Khordha) and buying–selling opportunities (40% in both districts), while Khordha women face the greatest difficulty in disposing products at profitable prices (67.33%), indicating limitations in negotiation skills, profitability assessment, and financial literacy. Overall, marketing decisions present the most substantial challenges, particularly in Khordha, while enterprise and financial decision gaps point toward structural weaknesses in planning, resource assessment, and value chain comprehension, highlighting the need for targeted capacity-building interventions in enterprise planning, market intelligence, pricing strategy, and financial management across both districts.

Correlation between socio-personal variables and decision-making behaviour

Correlation analysis (Table 2) revealed that decision-making authority is positively correlated with enterprise, marketing, and

Table 2. Correlation coefficients of decision-making categories with socio-personal variables

Variables	Enterprise Decision	Marketing Decision	Financial Decision
Age	-0.1937	0.0387	0.0612
Education	-0.1679	0.0301	-0.0771
Housing	0.0931	-0.0387	-0.1542
Social independence	-0.1467	0.2384	0.0355
Decision-making ability	-0.1326	0.2252	-0.3792
Decision-making authority	0.0334	0.0277	0.4683
Employment creation	-0.2020	0.3220	-0.4694

financial decisions, indicating that higher autonomy enhances the decision-making ability of rural women across economic domains. Decision-making ability exhibited a significant positive correlation only with marketing decisions, while showing a negative association with enterprise and financial decisions. Social independence demonstrated positive correlations with marketing and financial decisions, emphasizing the importance of mobility and community engagement in building confidence and knowledge for economic decision-making.

Influence of socio-psychological factors on decision-making behaviour

Multiple regression analysis (Table 3) revealed that group membership and perception significantly influence enterprise decision-making, highlighting the role of collective participation and cognitive awareness in empowering rural women. For marketing and financial decisions, none of the socio-psychological factors showed statistical significance, suggesting that these decisions are more strongly influenced by external structural factors such as market access, resource availability, and financial support systems rather than psychological attributes. Nevertheless, positive coefficients for perception, attitudes, and group membership indicate that these factors still contribute directionally to decision-making performance.

The coefficient plot (Figure 1) provides a visual comparison of how socio-psychological factors influence enterprise, marketing, and financial decisions of rural women participating in the Mission Shakti programme. A clear pattern emerges from the graph: enterprise decisions show the strongest positive responsiveness to socio-psychological factors, particularly group membership and perception. These two factors display the highest positive coefficients, indicating that women who are more engaged in SHG activities and possess clearer understanding and awareness of their enterprise environment tend to make more informed enterprise-related decisions. In contrast, marketing decisions exhibit generally lower and less consistent coefficients, suggesting that marketing-related decision-making is less influenced by internal psychological traits and more dependent on external factors such as market exposure, price fluctuations, and demand conditions. The slight positive role of group membership implies that socially connected women are marginally better at navigating marketing choices, though the influence remains limited. For financial decisions, the coefficients remain low across all factors, highlighting that financial decision-making is more structurally driven shaped by access to credit, financial literacy, institutional support, and previous financial experience. Nevertheless, small positive coefficients for perception and attitude indicate that women with better awareness and more positive orientations may show marginal improvement in financial decision-making.

The graphical pattern depicts that perception and group membership exert the most consistent positive influence across all three decision domains, establishing them as key levers for strengthening women's decision-making capabilities. Interventions aimed at enhancing awareness, confidence, and SHG participation therefore hold strong potential for improving enterprise, marketing, and financial decisions among rural women.

Model accuracy: RMSE and MAE

To evaluate the predictive strength and stability of the models used for assessing the decision-making behaviour of rural women, two standard error metrics Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) were computed for enterprise, marketing, and financial decision models (Table 4). Lower RMSE and MAE values indicate better model accuracy, reduced prediction error, and greater consistency in estimating decision scores. Among the three models, the marketing decision model displayed the lowest RMSE (1.1230) and MAE (0.8964) values, signifying superior predictive performance and relatively uniform decision-making patterns among respondents in marketing-related tasks. This enhanced consistency may be attributed to the regular exposure of SHG women to market-based activities such as selling, pricing, and

Table 3. Combined regression analysis of enterprise, marketing and financial decisions with socio-psychological factors

Decision Category	Factors	Estimated Value	Standard Error	t-value	p-value
Enterprise Decision	Intercept	14.5531	1.1863	12.268	0.0000000000000002
	Personality trait	-0.3230	0.2422	-1.334	0.1838
	Motivation	0.1592	0.2329	0.684	0.4951
	Attitudes	-0.1600	0.2195	-0.729	0.4669
	Group membership	0.3806	0.2115	1.799	0.0736
	Perception	0.4331	0.2016	2.148	0.0330
Marketing Decision	Intercept	10.86234	0.86507	12.557	0.0000000000000002
	Personality trait	0.07226	0.17659	0.409	0.683
	Motivation	-0.27194	0.16982	-1.601	0.111
	Attitudes	-0.14815	0.16008	-0.926	0.356
	Group membership	0.19123	0.15426	1.240	0.217
	Perception	0.11666	0.14703	0.793	0.428
Financial Decision	Intercept	10.143430	1.104642	9.183	0.0000000000000002
	Personality trait	-0.224436	0.225490	-0.995	0.321
	Motivation	0.004779	0.216855	0.022	0.982
	Attitudes	0.066819	0.204410	0.327	0.744
	Group membership	0.034597	0.196986	0.176	0.861
	Perception	0.103238	0.187748	0.550	0.583

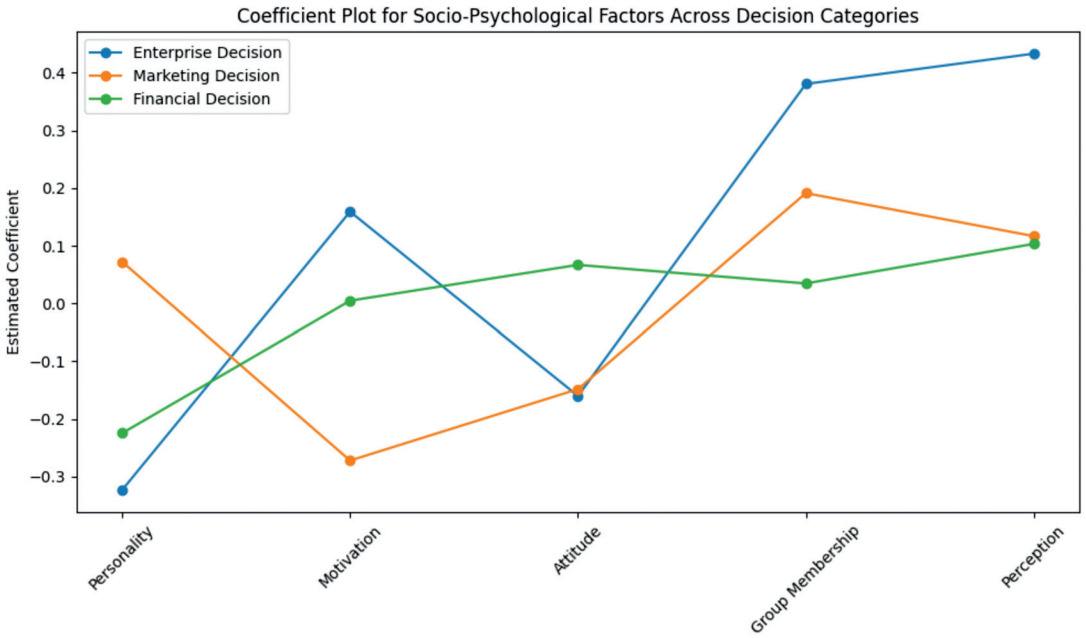

Figure 1. Coefficient plot for socio-psychological factors across decision categories

Table 4. RMSE and MAE Values for Decision-Making Models

Model	RMSE	MAE
Enterprise decision	1.5400	1.1971
Marketing decision	1.1230	0.8964
Financial decision	1.4340	1.1650

product handling, which form routine components of their livelihood operations. As these activities are frequently conducted collectively within SHGs, the resulting shared learning environment likely contributes to reduced variability in marketing decisions.

The enterprise decision model exhibited the highest RMSE (1.5400) and MAE (1.1971) values, indicating wider variability in enterprise-related decision-making. This variability may stem from differences in individual experience, technical knowledge, exposure to enterprise management practices, and access to training. Similarly, the financial decision model showed moderate error levels (RMSE = 1.4340; MAE = 1.1650), suggesting that financial decision-making remains uneven among respondents, possibly due to varying degrees

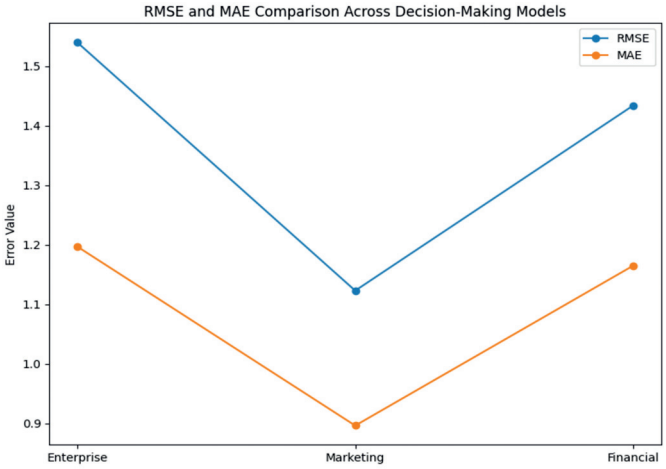

Figure 2. RMSE–MAE comparison graph

of financial literacy, credit access, and familiarity with value chain concepts. Overall, the findings suggest that while rural women exhibit relatively consistent marketing decisions, significant scope exists for targeted interventions to improve enterprise and financial decision-making skills.

The RMSE–MAE comparison plot (Figure 2) illustrates the predictive accuracy of the three decision-making models enterprise, marketing, and financial used in the study. The marketing decision model exhibits the lowest RMSE (1.1230) and MAE (0.8964), indicating that predictions generated for marketing decisions are more consistent and closer to actual values. This suggests that rural women demonstrate more uniform behaviour in marketing-related decision-making, likely due to regular exposure to market interactions through SHG activities. Conversely, the enterprise decision model shows the highest RMSE (1.5400) and MAE (1.1971), implying greater variability and reduced model precision in enterprise-related decisions. This variability may be attributed to differing levels of training, experience, and resource access among women engaged in enterprise activities. The financial decision model displays moderate error values (RMSE = 1.4340; MAE = 1.1650), indicating uneven financial decision-making skills across respondents. Overall, the plot confirms that marketing decision-making is the most consistent among rural women, while enterprise and financial decisions reflect broader disparities requiring targeted capacity-building interventions.

DISCUSSION

The study assessed the decision-making behaviour of rural women under the Mission Shakti programme across enterprise, marketing, and financial domains in Keonjhar and Khordha districts. Results revealed notable decision gaps in enterprise planning in both districts, particularly in the selection of enterprise area and value chain analysis. While women in Keonjhar also struggled with raw material selection and value-addition processes, Khordha women displayed similar gaps but with stronger constraints in location

selection, reflecting limited exposure to enterprise planning and supply chain understanding. Marketing decisions showed the widest gaps, especially in Khordha, where women faced difficulties in analysing sales activities and selecting products for market disposal. Keonjhar women performed comparatively better, suggesting greater practical market exposure. Financial decision-making remained a challenge across both districts, with Khordha showing higher gaps in pricing decisions, value chain analysis, and buying–selling opportunities, indicating limited financial literacy and weaker market-linked financial understanding.

Socio-personal factors demonstrated varied influences. Decision-making authority was positively associated with all decision categories, highlighting the importance of autonomy. Age, education, decision-making ability, and employment creation positively influenced marketing decisions but showed negative associations with enterprise and financial decisions. Housing status was positively linked with enterprise decisions but negatively with marketing and financial decisions.

Among socio-psychological factors, group membership and perception consistently showed positive effects across all decision categories, emphasizing the role of collective participation and awareness-building. The lower RMSE and MAE values for marketing decisions further indicate greater consistency in marketing behaviour compared to enterprise and financial decisions. Overall, the findings suggest that decision-making among rural women is shaped by intertwined socio-personal and psychological factors, underscoring the need for targeted capacity-building in enterprise planning, market intelligence, pricing, and financial literacy within the Mission Shakti framework.

CONCLUSION

The study demonstrates that the decision-making behaviour varies significantly across enterprise, marketing, and financial domains, reflecting differences in exposure, experience, and socio-economic conditions. While marketing decisions showed comparatively higher consistency, substantial decision gaps were evident in enterprise planning and financial management, particularly in value chain analysis, pricing, and selection of enterprise area. Socio-personal variables such as decision-making authority and socio-psychological factors like group membership and perception emerged as strong positive determinants of decision performance, underscoring the critical role of autonomy, collective learning, and awareness-building. These findings highlight the need for strengthening SHG-based capacity-building strategies. Policy initiatives should prioritise district-specific strategies, improved market linkages, digital learning tools, and enhanced access to financial services to reduce decision gaps and promote sustainable livelihood outcomes. The study affirms that empowering rural women through targeted interventions, participatory leadership, and continuous mentoring can significantly enhance their decision-making capabilities, thereby advancing the broader objectives of Mission Shakti.

DECLARATIONS

Ethical approval and informed consent: Informed consent was sought from the rural women respondents of the study during the course of the research.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be constructed as a personal conflict of interest. The authors declare that during the preparation of this work, 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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (33-38)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Storytelling as A Pedagogical Tool for Moral Development in Rural Children

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HIGHLIGHTS

- Storytelling is linked to improved moral scores in rural children; all four moral dimensions under study showed significant post-test gains.
- Age related to improvement; gender differences were not significant.
- Storytelling supported culturally relevant value learning and indicated the feasibility of storytelling as an extension strategy.

ARTICLE INFO

Keywords: Rural, Pre-adolescents, Extension pedagogy, Moral development, Age, Gender.

https://doi.org/10.48165/IJEE.2026.62206

Citation: Godara, K., & Dube, S. (2026). Storytelling as A Pedagogical Tool for Moral Development in Rural Children. *Indian Journal of Extension Education*, *62*(2), 33-38. https://doi.org/10.48165/IJEE.2026.62206

ABSTRACT

The research carried out in 2025, examined the effectiveness of storytelling as an educational intervention for enhancing moral values among rural children. A pre-intervention-to-post-intervention assessment design was used. The sample included 60 students aged 10 to 12 years studying in rural primary schools in Bhaniyana village, Jaisalmer district, Rajasthan. The Moral Values Scale developed by Gupta and Singh (2016) was administered before and after a six-week storytelling programme. The programme consisted of twelve sessions based on culturally relevant moral stories highlighting honesty, empathy, fairness, cooperation, and responsibility. Each session included story narration followed by structured discussion and reflection activities that encouraged children to connect moral ideas with real-life experiences. The findings showed a significant increase in mean scores across all moral dimensions lying, dishonesty, stealing, and cheating after the intervention. Repeated measures ANOVA indicated significant effects of intervention and age, while gender differences were statistically nonsignificant. Correlation analysis revealed a positive association between age and moral value enhancement. The study suggests that story narration may function as an effective and culturally responsive strategy for moral education and could be integrated into rural extension and educational initiatives aimed at promoting value-based learning and holistic development.

INTRODUCTION

Moral values constitute the foundation of children's character formation, interpersonal sensitivity, and responsible citizenship. Their development during the pre-teen years is particularly crucial, as this period marks a transition from externally guided behaviour to more autonomous moral reasoning (Turiel & Banas, 2020). In rural India, moral development is increasingly influenced by socio-cultural shifts, disparities in educational quality, and exposure to digital media. While value-based learning forms a core expectation of India's educational vision as articulated in the National Education Policy 2020 (GoI, 2020) rural schools often face challenges in translating these ideals into practice due to limited pedagogical innovation, teacher preparedness gaps, and sociocultural diversities in value transmission (Sarangapani et al., 2023; NCERT, 2012; Arya & Vig, 2023). Traditional character-education frameworks emphasise respect, responsibility, and prosocial engagement but require innovative methods for contemporary learners (Lickona, 2009).

Storytelling has long been recognised as a culturally grounded and pedagogically effective strategy for shaping children's moral

Received 24-12-2025; Accepted 25-02-2026

understanding. Developmental and educational research shows that narratives foster empathy, perspective-taking, and reflective reasoning, enabling children to internalise abstract moral concepts through engagement with relatable scenarios (Gasser et al., 2022). Evidence from diverse contexts indicates that storytelling promotes honesty, prosocial behaviour, and ethical reflection, particularly when children identify with characters and interpret situational dilemmas (Ding et al., 2023; Adnyani & Landrawan, 2022; Ibrahim et al., 2025). In India, folk tales, puppet shows, and traditional narratives have historically functioned as conduits of value transmission, and their relevance in contemporary pedagogy has been reaffirmed (Dey, 2015; Halimah et al., 2020; Kumari, 2025).

Beyond moral cognition, storytelling-based approaches contribute to socio-emotional and life-skill development. Research demonstrates improvements in empathy, cooperation, resilience, and emotional regulation through narrative engagement (Ramamurthy et al., 2024; Chan et al., 2021; Zuffianò et al., 2023). Neuroscientific findings show that storytelling activates neural pathways associated with attention, emotional attuning, and perspective-taking (Yabe et al., 2018). Such evidence positions storytelling as an adaptable, low-cost, and psychologically meaningful pedagogical tool, particularly suited for resource-constrained rural schools (Rahiem et al., 2020; Rahiem, 2021).

The rapid penetration of digital devices in rural India introduces additional challenges for children's learning and moral development. Unsupervised gadget exposure reduces motivation, attention spans, and socio-emotional sensitivity (Monika & Dube, 2025; Yadav & Dube, 2025). In this context, pedagogical approaches that push towards the revival of interpersonal interaction, reflective thinking, and ethical dialogue become increasingly necessary. Storytelling offers a medium that counters these trends while reinforcing experiential, participatory, and learner-centred methods aligned with extension education principles (Thebar & Upadhyay, 2023; Thebar & Upadhyay, 2024; Sarangapani et al., 2023). Accordingly, the study was undertaken to assess the effectiveness of a storytelling-based intervention in enhancing moral values among rural pre-teen schoolchildren aged 10 to 12 years, providing a culturally grounded and developmentally appropriate approach to moral education in contemporary rural classrooms.

METHODOLOGY

The study used a single-group pre–post intervention design to examine storytelling as an educational intervention associated with moral value development among rural children. The study was carried out in 2025 in rural primary schools of Jaisalmer district, Rajasthan. The site was purposively selected to represent the cultural and socio-economic characteristics of rural areas. A multistage random sampling procedure was used. At Stage 1, seven rural primary schools out of 17 were selected to represent the study area. At Stage 2, students were randomly selected within each school. A total of 60 children aged 10–12 years studying in classes V–VII were included, with equal numbers of boys and girls intentionally balanced. Institutional permission was obtained from school authorities, and informed written parental consent was secured prior to participation. The study adhered to standard ethical guidelines for research involving children. Ethical approval was given by the Ethics Committee (H.Sc./EC/034/23-04-2025).

The storytelling intervention was designed to promote moral development through culturally relevant stories in the local language, emphasising honesty, empathy, fairness, cooperation, and responsibility. The storytelling content was derived from the standardised moral dilemma statements in the Moral Values Scale (MVS) developed by Gupta and Singh (2016), which were transformed into culturally appropriate local narratives to ensure alignment between the intervention and the measured constructs. The intervention was implemented over six weeks and comprised 12 sessions of approximately 40 minutes each. Each session involved narration of a moral story followed by group discussion, reflection, and activity-based engagement to help children relate story-based morals to everyday experiences. All intervention sessions were personally delivered by the researcher following a standardised session plan to maintain implementation fidelity across schools. The approach aimed to combine cognitive understanding with emotional engagement for meaningful value internalisation.

Data were collected before and after the intervention using the Moral Values Scale (MVS) developed by Gupta and Singh (2016). The scale measures moral values across four dimensions lying, dishonesty, stealing, and cheating as well as total moral value scores. Higher scores indicated lower engagement in negative behaviours and therefore reflected stronger moral functioning. The instrument has been widely used in Indian educational contexts and has demonstrated acceptable reliability and validity.

The collected data were analysed using JASP software (Version 0.18). Descriptive statistics, including mean, standard deviation, and percentage, were used to describe participant characteristics and moral value levels. To evaluate intervention outcomes, paired-samples t-tests were performed to compare pre-intervention and post-intervention mean scores, while repeated measures ANOVA examined the effects of time, age, and gender on moral values. Correlation analysis was conducted to explore associations between age and moral value dimensions. Statistical significance was set at $p < .05$.

RESULTS

Table 1 presents the percentage distribution of participants by age and gender across levels of moral values in pre-test and post-test conditions. The data show that all age groups displayed reductions in the lower moral value categories and corresponding increases in the higher categories. Among ten-year-olds, the percentage in the low category decreased from 25% to 5%, and in the high category increased from 15% to 30%. Similar changes occurred in eleven-year-olds, where the high category rose from 15% to 35%, and in twelve-year-olds from 15% to 45%. Gender-wise, boys showed increases in moderate and high levels from 40% and 3.3% to 60% and 23.3%, respectively, while girls' high category increased from 6.7% to 33.3%. The total group values indicate that participants shifted from lower to higher moral value levels after the storytelling intervention.

Table 2 presents the contrast of pre- post intervention mean scores of participants on the four moral dimensions and total moral values. The data indicate increases in all post-test means compared

Table 1. Percentage distribution of participants based on age, gender, and level of moral values

Level of Moral Values	Age 10 (Pre → Post) (N = 20)	Age 11 (Pre → Post) (N = 20)	Age 12 (Pre → Post) (N = 20)	Boys (Pre → Post) (N = 30)	Girls (Pre → Post) (N = 30)	Total (Pre → Post) (N = 60)
Extremely Low	10 → 5	5 → 0	5 → 0	6.7 → 0	13.3 → 13.3	10 → 6.7
Very Low	5 → 0	10 → 5	5 → 0	13.3 → 6.7	0 → 0	6.7 → 3.3
Low	25 → 5	25 → 5	20 → 0	36.7 → 3.3	26.7 → 0	31.7 → 1.7
Moderate	40 → 45	40 → 40	40 → 35	40 → 60	53 → 43	46.7 → 51.7
High	15 → 30	15 → 35	15 → 45	3.3 → 23.3	6.7 → 33.3	5 → 28.3
Very High	5 → 15	5 → 15	5 → 15	0 → 6.7	0 → 10	0 → 8.3
Extremely High	0 → 0	0 → 0	0 → 0	0 → 0	0 → 0	0 → 0

1. The level of Moral Values is defined based on the score of the participant on the moral value scale (MVS), 2. Values before the arrow show pre-test percentage proportions; values after the arrow show post-test percentage proportions, 3. The arrow (→) indicates the change from pre-test to post-test percentages, 4. Percentages were calculated separately for each subgroup based on their respective N values, 5. N represents the number of participants in each subgroup (Age groups: N = 20; Gender groups: N = 30; Total: N = 60).

Table 2. Comparison of pre-test and post-test moral values scores of participants

Moral Dimension	Pre-Test (Mean ± SD[4])	Post-Test (Mean ± SD)	[3]*t*	[2]*p value*
Lying	3.00 ± 1.50	4.47 ± 1.73	10.67	< .001***
Dishonesty	3.05 ± 1.31	4.37 ± 1.55	9.43	< .001***
Stealing	4.93 ± 1.66	5.75 ± 1.68	7.41	< .001***
Cheating	3.23 ± 1.42	4.63 ± 1.80	10.55	< .001***
Total Moral Values	14.22 ± 5.03	19.22 ± 6.21	12.99	< .001***

1.*** denotes a statistically significant result with p < .001, 2. p-value indicates the statistical significance of the difference between pre- and post-test scores, 3. t represents the t-value from the paired-sample t-test comparing pre- and post-test scores, 4. SD refers to the standard deviation, indicating how much individual scores vary from the mean.

to pre-test means. For lying, the mean rose from 3.00 to 4.47 (t (59) = 10.67, $p < .001$), and for dishonesty, from 3.05 to 4.37 (t (59) = 9.43, $p < .001$). Similarly, mean scores for stealing increased from 4.93 to 5.75 (t (59) = 7.41, $p < .001$), and for cheating, from 3.23 to 4.63 (t (59) = 10.55, $p < .001$). The total moral values improved from 14.22 to 19.22 (t (59) = 12.99, $p < .001$). All differences were statistically significant, confirming measurable change between pre- and post-assessments.

Table 3 presents the repeated measures ANOVA results describing the effects of time, age, and gender on moral value dimensions. The main effect of time (pre–post) was significant across all dimensions, with p < .001, indicating consistent change between pre- and post-test assessments for lying, dishonesty, stealing, cheating, and total moral values. The main effect of age was significant for stealing (F = 4.48, p = .016) and total moral values (F = 3.42, p = .040), while age effects were not significant for lying (p = .16) and dishonesty (p = .13), and were marginal for cheating (F = 3.10, p = .051). The gender effect was not significant for any dimension, indicating no overall gender differences in moral value scores. The time × age interaction was significant only for lying (F = 3.23, p = .04), whereas no significant time × age interactions were observed for the remaining dimensions. The time × gender interaction was not significant for any dimension, suggesting that changes over time were similar for boys and girls. Overall, the findings indicate that moral values improved significantly over time, with age influencing specific dimensions, while gender did not considerably affect moral value outcomes.

Table 4 presents the comparison of post-test moral value scores by gender and age. Mean scores for girls were slightly higher than those for boys across all moral dimensions, though none of these gender differences were statistically significant at the .05 level. One-way ANOVA results for age showed substantial differences

Table 3. Repeated measures ANOVA for main and interaction effects of time, age, and gender

Effect	Lying		Dishonesty		Stealing		Cheating		Total Moral Values	
	F	p value	F	p value	F	p value	F	p value	F	p value
[3]Time (Pre–Post)	114***	< .001	85***	< .001	50***	< .001	115***	< .001	167.20***	< .001
Age	1.8	0.16	2.16	.13	4.48	.016*	3.1	.051	3.42*	.040
Gender	0.22	0.63	0.64	.42	.04	.83	0.09	0.76	0.23	.63
[4]Time × Age	3.23	.04*	1.02	.36	0.2	.81	2.14	.12	1.85	.167
[4]Time × Gender	0.15	0.6	.41	.52	.65	.42	3.18	.08	1.49	.228

1 F represents the F-statistic from the repeated measures ANOVA, 2 p-value shows the statistical significance of each effect with *** as p <.001; and * as p < .05, 3 Time refers to the within-subject factor comparing pre-test vs. post-test scores, 4 Time × Age and Time × Gender indicate interaction effects, showing whether changes over time differ across age groups or genders.

Table 4. Cross-sectional comparison of post-intervention moral value scores by gender and age

Moral Dimension	Boys (Mean ± SD)	Girls (Mean±SD)	t	p-value	Age 10 (Mean ± SD)	Age 11 (Mean±SD)	Age 12 (Mean±SD)	F	p-value
Lying	4.46 ± 1.59	4.46 ± 1.9	.001	1.0	3.8 ± 1.67	4.45 ± 1.39	5.15 ± 1.9	3.27*	.045
Dishonesty	4.33 ± 1.44	4.4 ± 1.67	0.16	.87	3.8 ± 1.67	4.4 ± 1.35	4.9 ± 1.48	2.6	.078
Stealing	5.83 ± 1.23	5.67 ± 2	0.38	0.7	4.9 ± 2	6 ± 1.12	6.3 ± 1.49	3.89*	.026
Cheating	4.76 ± 1.65	4.5 ± 1.96	.57	.57	3.85 ± 1.95	4.65 ± 1.4	5.4 ± 1.72	4.0*	.022
Total Moral Values	19.4± 5.33	19.0 ± 7	.23	.82	16.4 ± 6.74	19.5 ± 4.76	21.75 ± 6.0	4.13*	.021

SD is the standard deviation, * Denotes statistical significance with; p <.05

for lying ($F = 3.26$, $p = .046$), stealing ($F = 4.12$, $p = .021$), cheating ($F = 3.69$, $p = .032$), and total moral values ($F = 4.58$, $p = .015$). Differences in dishonesty were not significant ($F = 3.04$, $p = .056$). The data indicate that moral value scores tended to increase with age, while gender did not account for major variation in outcomes.

Table 5 presents the correlations among age, total moral value scores, and the four post-test moral dimensions. Age showed a positive relationship with total moral values at both the pre-test ($r = 0.28$, $p = .016$) and post-test ($r = 0.36$, $p = .003$) levels. The total pre- and post-test scores were highly correlated ($r = 0.88$, $p < .001$), indicating stability between assessments. High positive correlations were found among all post-test moral dimensions, with coefficients ranging from 0.72 to 0.84, all significant at $p < .001$. These values indicate that improvements in each moral aspect were associated with a concurrent rise in the others.

Table 5. Correlations among age, total moral scores, pre- and post-test moral dimensions

Variable Pair	Pearson's '*r*'	p-value
Age – Total Pre	0.278*	.016
Age – Total Post	0.355**	.003
Total Pre – Total Post	0.880***	< .001
Cheating Post – Dishonesty Post	0.721***	< .001
Cheating Post – Stealing Post	0.834***	< .001
Cheating Post – Lying Post	0.799***	< .001
Dishonesty Post – Stealing Post	0.737***	< .001
Dishonesty Post – Lying Post	0.838***	< .001
Stealing Post – Lying Post	0.796***	< .001

*p < .05, ** p < .01, *** p < .001, All correlations are one-tailed for positive association

DISCUSSION

The study suggests that storytelling was associated with improvements in children's understanding of honesty, fairness, empathy, and responsible behaviour, indicating a shift toward prosocial orientations. Story-based sessions appeared to engage learners emotionally and cognitively, enabling them to internalise values rather than merely recall them. These outcomes align with evidence indicating that experiential and participatory learning environments support moral development more effectively than purely didactic instruction (Lickona, 2009; Chan et al., 2021; Kaßecker et al., 2025). The narrative format made abstract values more accessible and relatable, supporting the view that moral learning deepens when children interpret lived situations rather than receive prescriptive lessons (Gasser et al., 2022).

The observed patterns are consistent with mechanisms proposed in Bandura's social learning theory (1977), which emphasises modelling, imitation, and reinforcement. Story characters may function as behavioural models, allowing children to observe consequences and engage in vicarious reasoning. Contemporary research suggests that identification with protagonists can support ethical reflection and perspective-taking (Gasser et al., 2022; Ding et al., 2023). Neurocognitive studies using brain imaging methods further indicate that storytelling activates processes related to attention, emotion regulation, and perspective-taking (Yabe et al., 2018), which may help explain why narrative-based learning encourages affective engagement alongside reflective judgement. The improvements observed in this study may reflect similar integrative processes, particularly when narratives are culturally meaningful (Ibrahim et al., 2025).

The findings also converge with intervention literature suggesting that storytelling can support socio-emotional and moral competencies. Previous studies in primary contexts report gains in empathy, cooperation, and behavioural regulation following structured storytelling programmes (Rahiem et al., 2020), while narrative-based approaches have been linked to increased emotional resilience (Ramamurthy et al., 2024). Digital storytelling research similarly indicates benefits for engagement and perspective-taking when thoughtfully implemented (Rahiem, 2021). Such approaches are relatively low-cost and developmentally appropriate, which is particularly relevant for rural schools with limited pedagogical resources (Adnyani & Landrawan, 2022).

Within the Indian context, the use of local narratives may add cultural relevance and contextual depth. Indigenous storytelling traditions connect moral values with children's everyday realities and can strengthen a sense of belonging in multilingual classrooms (Dey, 2015; Kumari, 2025). Active participation observed during the intervention suggests that contextual storytelling may revitalise moral education in settings where textbook-driven instruction feels distant from lived experience. Developmental patterns were also consistent with prior research: older children tended to show more mature moral reasoning (Du et al., 2024; Kaßecker et al., 2025) while minimal gender differences align with evidence that socio-emotional interventions benefit boys and girls similarly when learning environments emphasise empathy and interaction (Wainryb, 2005; Eisenberg et al., 2015).

The study gains additional relevance in light of increasing digital exposure among young learners. Excessive unsupervised device use has been associated with reduced attention and socio-emotional sensitivity (Yadav & Dube, 2025; Monika & Dube, 2025).

Storytelling offers a counterbalance by encouraging reflective listening, imagination, and interpersonal dialogue. Educator presence remains central, as teacher warmth and responsive facilitation influence socio-emotional outcomes (Halimah et al., 2020; Arya & Vig, 2023). In this sense, storytelling may represent a culturally grounded and developmentally appropriate pedagogical tool aligned with contemporary educational frameworks such as NEP 2020 and UNICEF's Life Skills Framework (GoI, 2020; Zuffianò et al., 2023). These findings should be interpreted within the limitations of the study. The sample was drawn from a single rural village and involved a relatively small group of participants with short-term follow-up. Without a control group, improvements cannot be attributed exclusively to the intervention. The results, therefore, represent preliminary evidence and highlight the need for larger, controlled, and longitudinal research to confirm the observed patterns.

CONCLUSION

As a preliminary investigation, the study provides indicative evidence that storytelling may support moral value development among rural children in a culturally relevant way. Improvements across the four moral dimensions lying, dishonesty, stealing, and cheating suggest that participants engaged with and reflected on the moral themes presented, rather than demonstrating definitive behavioural change. Age-related variation was observed, with older children showing comparatively greater gains, while gender differences were statistically non-significant. These patterns indicate that storytelling may support inclusive moral learning across developmental stages, although the limited scale of the study requires cautious interpretation. Rooted in India's oral traditions, storytelling aligns with rural social contexts and represents a feasible, low-cost, and participatory strategy for value education. The exploratory findings highlight the potential of integrating narrative-based activities into school and extension settings to encourage moral reflection, empathy, and social awareness, warranting further research with larger and more diverse samples.

DECLARATIONS

Ethical approval and informed consent: Informed consent was sought from the parents of the selected school students and permission from the school administration was sought to conduct 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 personal conflict of interest. The authors declare that during the preparation of this work, 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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (39-46)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Post-Adoption Satisfaction and Policy Demand Paradox among Household Solar Users in Ladakh

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HIGHLIGHTS

- Financially stable and satisfied households showed the strongest demand for continued subsidies, contradicting equity assumptions.
- Financial barriers significantly reduced post-adoption satisfaction but did not increase subsidy demand among poorer households.
- Financial capability, not satisfaction or attitude, significantly predicts policy support demand, whereas K-means clustering exposed a dominant Happy Rent-Seeker group benefiting disproportionately from universal subsidy schemes.

ARTICLE INFO

Keywords: Solar energy adoption, Post-adoption satisfaction, Principal component analysis, K-means cluster analysis.

https://doi.org/10.48165/IJEE.2026.62207

Citation: Shah, I. A., Para, I. A., Zargar, R. N., Bashir, I., & Peer, Q. J. A. (2026). Post-Adoption Satisfaction and Policy Demand Paradox among Household Solar Users in Ladakh. *Indian Journal of Extension Education*, *62*(2), 39-46. https://doi.org/10.48165/IJEE.2026.62207

ABSTRACT

The study aimed to identify factors that influence satisfaction after-adoption and explain why households continue to request government support despite owning functional solar systems. Using a quantitative cross-sectional design, primary data were collected in 2025 from 440 selected solar-adopting households in Ladakh through a primary field study. A structured questionnaire captured demographic, financial, attitudinal, technical, and environmental variables. The analysis employed Principal Component Analysis (PCA) to extract latent constructs, logistic regression to determine predictors of policy demand, and K-means clustering to segment adopters into behavioural groups. The results showed that financially stable and highly satisfied households unexpectedly exhibit the strongest demand for continued subsidies, while financially constrained users report lower satisfaction but have limited policy influence. Three clusters emerged: Happy Rent-Seekers, Contented Independents, and Struggling Dissatisfied, revealing subsidy capture by wealthier users. The study concluded that universal subsidies contribute to inequitable resource distribution and recommends shifting toward targeted, performance-based support, enhanced maintenance services, and improved post-adoption monitoring. This research contributed novel empirical evidence on post-adoption dynamics in high-altitude regions, highlighting the need for policy frameworks that align financial support with household needs.

INTRODUCTION

The world now understands that sustainable energy stands as a basic requirement because countries work to solve climate change, their growing energy vulnerabilities, and ongoing environmental damage (Najam & Cleveland, 2003; Elum & Momodu, 2017). Solar energy stands as the primary renewable energy source because it provides an abundant supply that can be expanded easily while being friendly to the environment (Haq et al., 2024; El-Afifi, 2024). The photovoltaic system produces electricity through an emission-free process, which needs only occasional maintenance for rural areas with their spread-out settlements (Hosseini & Wahid, 2020). The worldwide implementation of solar power systems has increased because solar panel installation expenses have dropped while PV

Received 31-01-2026; Accepted 26-02-2026

module efficiency has improved (Al-Mohamad, 2004; Upreti et al., 2023). The adoption of solar power systems in households depends on various social and economic factors, like public knowledge about solar power, the costs of installation, the reliability of solar systems, and environmental protection concerns (Zegeye et al., 2025; Kumar & Rathore, 2023). The Indian environment provides an excellent setting to research solar power systems because the country houses 18% of worldwide inhabitants, and its power consumption relies on coal (Khare et al., 2013). The Indian government launched major renewable energy programs through the National Solar Mission to create self-sufficient solar technology systems (Chandel et al., 2016).

The Union Territory of Ladakh is cold desert climate, scattered settlements, and fragile ecosystem create persistent challenges for grid-based electrification (Joshi & Kothari, 2025). The winter season brings temperatures below –25 °C, while hydropower operations become limited because of frozen water resources; thus, the system depends on backup power systems (Namgyal & Sarkar, 2025). The Ladakh region receives more than 300 sunny days annually with strong solar radiation, which makes solar power an ideal solution, but users encounter various system performance issues and battery breakdowns when temperatures reach extreme lows, and they do not have access to suitable maintenance services (Lahmouri et al., 2019). Research has thoroughly studied how Indian consumers first adopted solar power through different factors, which include their financial status and educational background, their level of knowledge, and their environmental concerns (Etongo & Naidu, 2022; Ahmed et al., 2022). The post-adoption research field lacks sufficient studies because scholars focus on user satisfaction assessment, system performance, system maintenance difficulties, and policy adaptation requirements. The present system reduces the operational duration of systems and decreases user satisfaction. The amount of financial help families need for adoption depends on their adoption process, requiring support from adoption policies (Dhami et al., 2007; Penner, 2024). In an ecologically fragile and remote region like Ladakh, where solar energy is not merely an alternative but a necessity, optimizing post-adoption support is vital for ensuring long-term sustainability, reducing dependency on fossil-based backup systems, and preventing resource misallocation through unintended subsidy capture. The study examines three main research questions, which include how satisfied households need state assistance, how financial constraints affect household policy needs, and how environmental motivations affect government scheme dependency.

METHODOLOGY

The study was conducted in the Union Territory of Ladakh during the year 2025. The Survey was conducted in the districts of Leh and Kargil because these districts presented the best conditions for solar energy exploitation through their distinctive high-altitude cold desert environment (Singh et al., 2023; Namgyal & Sarkar, 2025). The study design used quantitative methods to study solar technology adoption by conducting a cross-sectional survey, which measured all relevant factors. A total of 440 sample households were surveyed, having operational solar energy systems. The study used a structured questionnaire to collect data, which measured different elements of solar adoption. The survey instrument contained five separate sections that assessed different essential areas of study. The survey collected demographic data from participants about their age and gender, their educational background, professional work, financial situation, and family composition. The survey measured how people use energy and their understanding of solar technology systems. The survey evaluated respondents' attitudes and their perceptions about solar technology advantages and disadvantages. The survey evaluated financial aspects through three questions about budget constraints, investment readiness, and the need for financial support. The field work survey assessed environmental and geographical factors by asking participants about their contentment levels, how their community views them, and what policy support they receive.

The survey included nominal-scale questions together with 5-point Likert-scale statements, which measured both participant awareness and their household agreement and perception responses for statistical analysis. The study used a structured multi-stage analytical framework to study how households choose solar energy and their patterns of energy usage. The collected primary data were systematically processed and analyzed using the R statistical programming environment. The study used Data Pre-processing and Reliability Testing, which required them to clean the dataset by fixing missing values and resolving logical errors (Famili et al., 1997). The study used Principal Component Analysis (PCA) to decrease data dimensions while creating three latent factors that represent customer attitudes, financial aspects, and satisfaction levels (Merlino et al., 2022; Yadav et al., 2026; Khalkho et al., 2023). The derived latent scores were subsequently incorporated into a logistic regression model to assess their influence on households' demand for solar-related policy support (Jatav, 2024). The study also applied K-means cluster analysis to analyse adopter diversity because this method enabled researchers to group households based on their actions to determine how subsidies affect their adoption choices by following (Hemalatha & Nayaki, 2014; Pundir et al., 2025; Ofetotse et al., 2021). The study investigated which factors affect the current solar system to keep government solar policy advantages after they install solar panels. The study investigated which particular factors among Ladakh Union Territory solar users drive them to pursue ongoing government financial support and policy support. The study establishes three fundamental hypotheses that combine behavioral economic principles with energy policy theoretical foundations.

RESULTS

The results section revealed and explained the post-adoption satisfaction and solar energy adopters' ongoing need for policy backing in Ladakh's Union Territory. The regression results and adopter segmentation revealed that how economic requirements differ from what actual policy makers prefer. The adoption process mainly involves financially stable family members who serve as the decision-makers for their households.

The adopters show higher educational attainment because more than 58% of them possess undergraduate or postgraduate degrees, which enables them to understand technology and access information better. The data in Figure 1 and 2 demonstrates how education levels

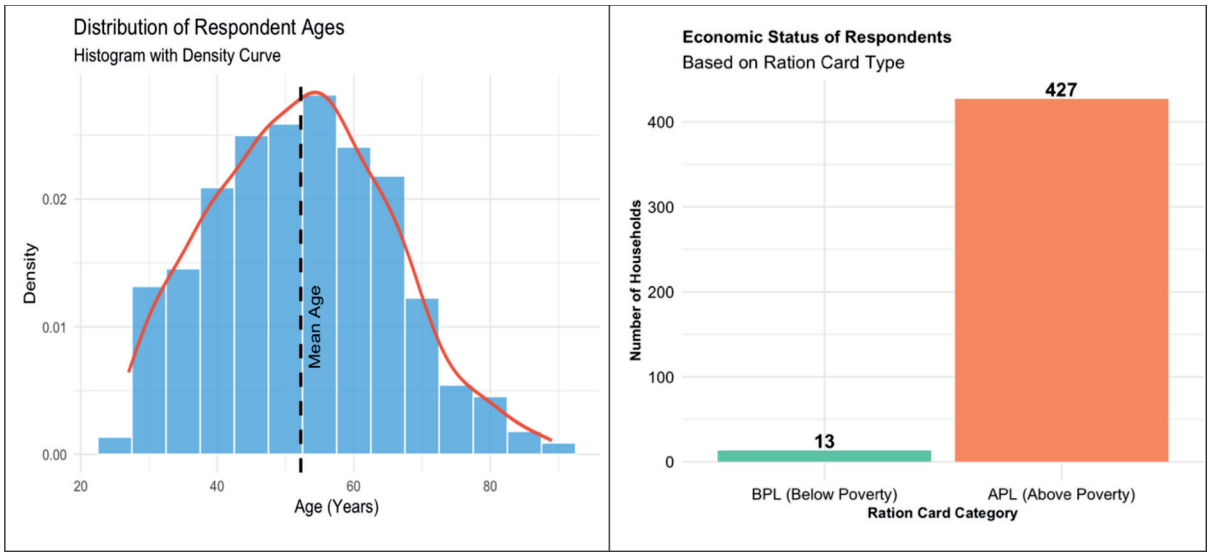

Figure 1. Distribution of respondents' age and economic status (ration card classification)

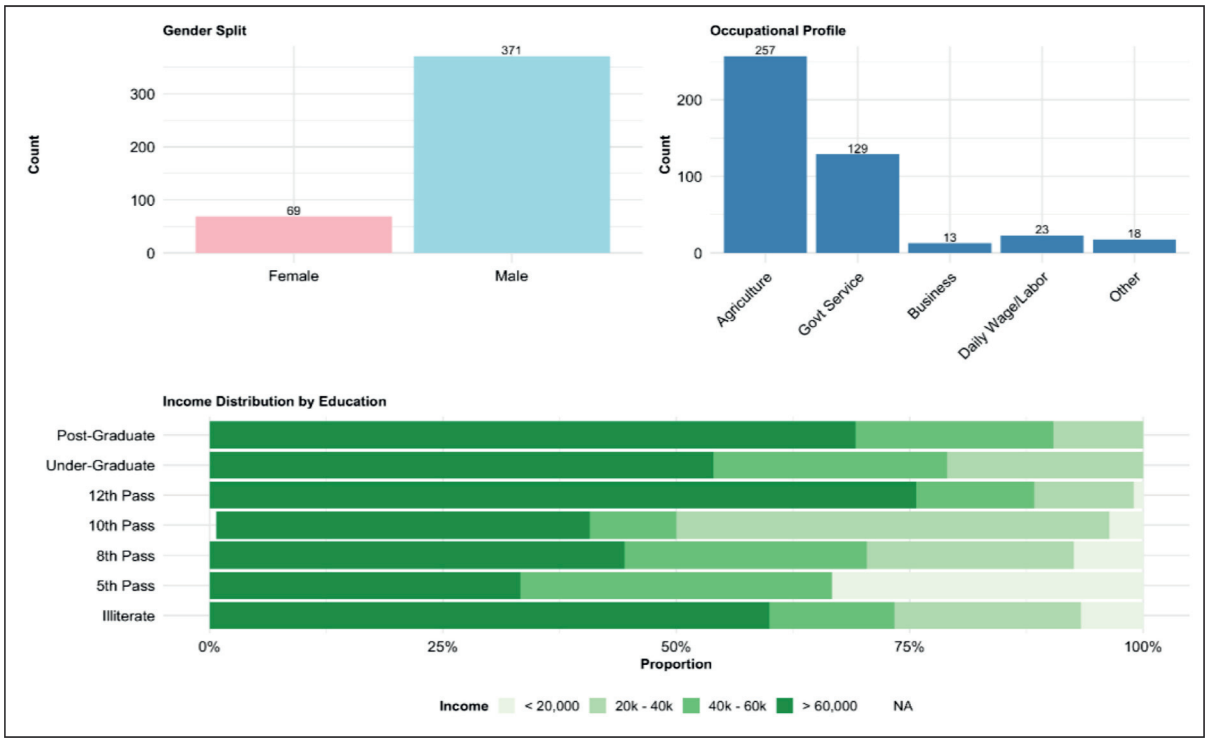

Figure 2. Gender split, occupation profile, and income distribution by education of respondents

affect both income and occupation because government workers and professionals make up the majority of adopters. The absolute numbers show that agriculture continues to be the largest employment sector despite income data showing that solar adopters who used to work in agriculture now earn better salaries. The research findings indicated that high initial expenses, together with institutional entry obstacles, prevent most people from joining the program because they belong to wealthy households that have higher education levels. People need to understand the current social and economic conditions because these factors will determine their reactions to satisfaction assessments and policy standards.

Determinants of policy demand among solar adopters

The research question about existing adopter policy support demand requires a logistic regression model, which uses PCA-derived latent scores to answer the question in Table 1.

The results yield a counter-intuitive but policy-critical insight. Contrary to the Financial Barrier Hypothesis (H2), the logistic regression results indicate that the Financial Barrier Score has a statistically significant negative association with policy demand ($\beta = -1.795$, $p < 0.01$). The odds ratio (OR = 0.166) suggests that a one-unit increase in financial barriers reduces the odds of demanding continued policy support by approximately 83.4%, holding other

Table 1. Logistic regression analysis: Determinants of continued policy demand among adopters

Predictor	Coefficient (β)	Std. Error	z-value	p-value	Odds Ratio (OR)	Sig.
(Intercept)	5.942	2.767	2.15	0.032	380.54	*
Satisfaction Score	-0.537	0.486	-1.11	0.269	0.584	
Financial Barrier Score	-1.795	0.572	-3.14	0.002	0.166	**
Attitude Score	-0.066	0.115	-0.58	0.564	0.936	

Model Fit Statistics: Observations: 440; Null Deviance: 451.22 (df = 439); Residual Deviance: 441.43 (df = 436); AIC: 449.43

factors constant. This implies that households facing greater financial constraints are substantially less likely to request additional subsidies compared to financially stable households. In contrast, post-adoption satisfaction and attitudinal commitment were not statistically significant predictors, indicating that changes in these factors do not meaningfully alter the likelihood of policy demand. The research findings show that economic problems do not affect the amount of subsidy assistance that people require. The financial data showed that capable adopters actively seek out subsidy opportunities because they want to maximize their returns from their successful current investments. The research data indicated that post-adoption satisfaction (H_1) and attitudinal commitment (H_3) do not affect policy demand to any significant extent. Users who achieve complete satisfaction will keep asking for financial help through subsidies because their environmental knowledge does not affect their capacity to develop policies. The research findings demonstrate that financial ability stands as the primary factor that drives policy enforcement rather than need requirements, thus it contradicts the fundamental principle of equity, which supports wide-ranging subsidy programs.

Drivers of post-adoption satisfaction

The Linear regression analysis of post-adoption satisfaction produced different results than the policy demand patterns, which wealthy households controlled, Table 2. The model explains 32% of satisfaction variation through its statistical model (Adjusted $R^2 = 0.314$, $F = 68.09$, $p < 0.001$). Financial stress serves as the main factor that determines how satisfied people become. The Financial Barrier Score shows a powerful negative relationship with satisfaction because households who faced difficulties with system funding costs experienced lower satisfaction after the system became operational ($\beta = -0.722$, $p < 0.001$). Users continue to experience the "pain of paying" effect because they keep their unfavorable financial views about the product even after they have installed it. Users base their satisfaction on financial factors instead of using their overall system usage time during the day. The financial situation of households creates a vital difference because they show lower satisfaction levels, but they do not lead to the demand for subsidies, which proves that current policy systems maintain unfair distribution of benefits.

Demographic concentration of policy demand

The regression results receive additional support from cross-tabulation and chi-square analysis, which examine how different population groups affect the "paradox of policy demand." As shown in Table 3, income level is strongly associated with subsidy demand ($\chi^2 = 23.14$, $p < 0.001$). The highest income group, which earns more than Rs. 60,000, has 179 high-demand households that exceed the total demand from all lower-income groups. The research data includes only a few low-income families who actively participate in policy decisions, yet their collective influence on policy development remains restricted. The data indicated that various professions share the same distribution pattern. The majority of households that need continuous support consist of people who work in government and business ($\chi^2 = 25.01$, $p < 0.001$). The two groups maintain financial stability, which enables them to use their influence to shape institutional decisions according to the theory that subsidy requests originate from dominant economic and political forces rather than vulnerable communities. This demographic concentration confirms that the "cry for support" is emanating from the top of the socio-economic pyramid, raising concerns about distributive inefficiency and policy mis-targeting.

Adopter segmentation and the emergence of happy rent-seekers

To synthesize these findings, K-means cluster analysis (k = 3) was employed to identify distinct adopters (Table 4). The

Table 2. Linear regression results: Technical and financial drivers of post-adoption satisfaction

Variable	Coefficient (β)	Std. Error	t-value	p-value	Sig.
(Intercept)	5.582	0.081	68.57	< 0.001	***
Hours of Daily Access	0.041	0.017	2.48	0.013	*
No Outages (1=Stable)	-0.055	0.022	-2.46	0.015	*
Financial Barrier Score	-0.722	0.053	-13.66	< 0.001	***
Model Summary					
Observations	440				
Multiple R^2	0.319				
Adjusted R^2	0.314				
F-statistic	68.09	(df = 3; 436)		< 0.001	***
Residual Std. Error	0.23				

**Note*: Level of Significance is 5%

Table 3. Household Income, Occupation, and Policy Support Demand: Cross-Tabulation and Chi-Square Results

Income Level	High Demand (Count)	Low Demand (Count)	Total (N)	% High Demand
Level 1 (< Rs. 20k)	6	4	10	60.00%
Level 2 (Rs. 20k–40k)	100	11	111	90.10%
Level 3 (Rs. 40k–60k)	63	9	72	87.50%
Level 4 (> Rs. 60k)	179	67	246	72.80%
Imputed (Mean)	0	1	1	0.00%
Total	348	92	440	79.10%
Chi-Square Statistics	Value: 23.14	df: 4	p-value:	< 0.001*
Primary Occupation				
Govt. Service	210	47	257	81.70%
Business	101	28	129	78.30%
Agriculture	11	2	13	84.60%
Private Sector	20	3	23	87.00%
Other	6	12	18	33.30%
Total	348	92	440	79.10%
Chi-Square Statistics	Value: 25.01	df: 4	p-value:	< 0.001*

Table 4. Taxonomy of solar adopters: cluster analysis of satisfaction, financial barriers, and policy demand

Cluster	Name	Size (N)	Avg. Satisfaction	Fin. Barriers	Policy Demand
1	The Happy Rent-Seekers	320 (73%)	5.0 (Max)	1.04 (Low)	100% (High)
2	The Contented Independents	83 (19%)	5.0 (Max)	1.08 (Low)	0% (None)
3	The Struggling Dissatisfied	37 (8%)	4.0 (Low)	1.46 (High)	76% (High)

resulting segmentation provides the most compelling evidence of subsidy capture.

The largest group, Cluster 1 "The Happy Rent-Seekers", comprises 73% of the sample as shown in Figure 3. The highest level of satisfaction exists in these households because they have no financial challenges, but they require permanent policy support to succeed. The research showed that users who need no financial assistance and have no technical issues continue to request financial assistance at the highest rate. In contrast, Cluster 3 – "The Struggling Dissatisfied", represents only 8% of the sample.

The financial struggles of most households lead to lower satisfaction levels because their collective power does not impact national policy decisions. The "The Contented Independents" cluster from Cluster 2 showed that people who have money but feel unhappy with their life choose to avoid policy work, although this group remains small in numbers. The adopter clusters imply differentiated policies: stricter eligibility and performance-based subsidies for "Happy Rent-Seekers," targeted financial and maintenance support for "Struggling Dissatisfied," and phased subsidy withdrawal for self-reliant "Contented Independents.

DISCUSSION

The research results showed multiple unexpected, important patterns that describe how people of Ladakh use solar energy after adopting it, and these results contradicted the typical findings from previous studies. The results consistently showed that financially stable and highly satisfied households exhibit the strongest demand for continued government subsidies and policy support. The study differs from previous studies because users who have limited resources need monetary help because they cannot find suitable services (Penner, 2024; Dhami et al., 2007; Yang & Zhao, 2015). In the context of Ladakh, however, the relationship is reversed. These findings have important implications for agricultural extension systems that promote renewable energy technologies for rural development and farm resilience. In remote regions like Ladakh, solar energy functions as a critical support technology for agriculture, enabling irrigation, protected cultivation, and post-harvest activities where conventional electricity supply is unreliable. The finding is in line with Gupta et al. (2022). The logistic regression analysis results showed that post-adoption satisfaction and environmental attitudes do not affect policy demand at all. Instead, financial capacity emerges as the strongest predictor. The data showed that users who have more economic resources can initiate policy requests, and they also gain access to existing subsidy programs. The theory of subsidy capture explained this behavior because wealthy households use benefits that were intended to help disadvantaged population groups. The evidence contradicts the Financial Need Hypothesis and confirms that economic vulnerability does not translate into higher policy demand in this region. The demographic analysis supported this interpretation because it showed that 97% of adopters come from households that exceed the poverty line, and high-income groups demonstrate an unusual rise in their policy requests. Research studies about Indian energy adoption show that poor families need financial assistance to decrease their energy costs (Etongo & Naidu, 2022; Ahmed et al., 2022). The region of Ladakh stands as an exception because it follows different solar adoption patterns than the rest of the nation. Research data indicated that people showed approval for policies, yet their actual behavior differed from their stated satisfaction with these policies. Users experiencing the highest satisfaction, including stable electricity access and minimal outages, nevertheless demand

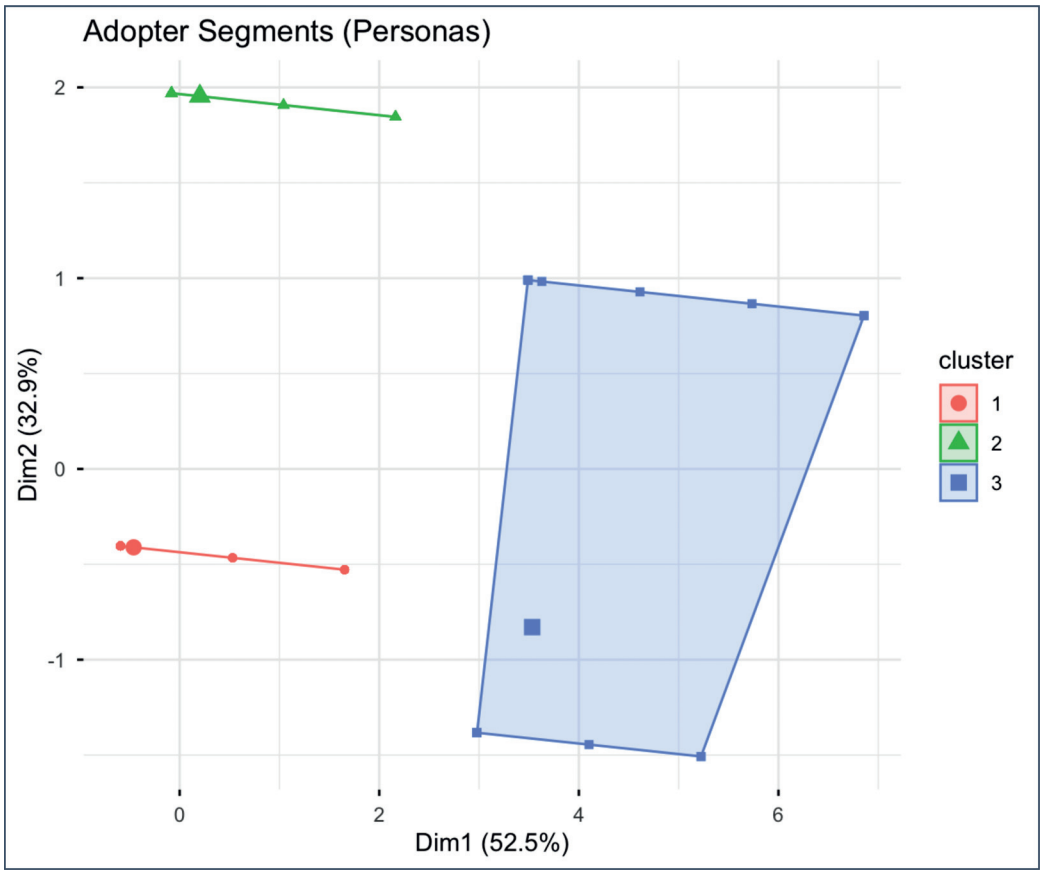

Figure 3. Visualizing adopter personas: K-means cluster plot of satisfaction vs. financial barriers

ongoing subsidies. Users who face financial difficulties show decreased satisfaction after installing because they must continue paying money, but they do not request higher financial support from the government. The outcome demonstrated the pain of paying effect because people experience financial stress, which decreases their satisfaction, but they do not actively work to change policies. The research method of cluster analysis produced the most compelling evidence, which showed that 73% of participants belong to the "Happy Rent-Seekers" group. These users achieve the highest level of satisfaction because they encounter minimal financial obstacles while requiring complete policy backing. The "Struggling Dissatisfied" cluster makes up only 8% of households because it does not have enough economic power to determine which policies should receive priority. This reinforces the argument that universal subsidies benefit those with power rather than those with need. The study showed that the present subsidy system in Ladakh allows people to commit illegal activities for financial benefit, while public funds are distributed incorrectly. The system requires performance-based support systems, which should deliver particular help through better maintenance protocols and ongoing evaluation following implementation to support families who need financial and operational support.

CONCLUSION

The results from descriptive analysis, regression, and cluster methods showed that the aims of solar policies don't really match with the ground happenings. Many users who already have solar systems keep demanding more government help, not because they face technical or financial problems, but mostly because they are already well-off and satisfied. The subsidy requests are not based on financial need, which goes against common assumptions. A small group of users struggles with real money issues, but they form a minority and don't shape policy demand. Cluster results show "happy rent-seekers," users who face no difficulty yet still want support. The study suggests targeted subsidies, better monitoring, and policy reforms for Ladakh's unique conditions. A potential limitation is endogeneity between post-adoption satisfaction and policy demand, as expectations of continued subsidies may influence reported satisfaction; future longitudinal or instrumental-variable studies could better address this and strengthen causal inference.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection.

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.

Acknowledgment: The authors gratefully acknowledge the Indian Council of Social Science Research (ICSSR) under the Solar Energy & Sustainability Scheme (2024–25), File No. 01/2024-25/SES/GEN/

RP/ICSSR, for providing the needed support and necessary funding for carrying out this research. The authors are also grateful to the Kargil Renewable Energy Development Agency (KREDA), the Ladakh Renewable Energy Development Agency (LREDA), the Ladakh Power Development Department, the PM Surya Ghar Consumer Center EPD Leh, Ladakh Solar Energy Pvt. Ltd., the Solar Power Plant at Tangste, the Repair Center for Solar Devices at Tangste, and M/S Pradeep Electricals and Builders Pvt. Ltd. for their valuable support, cooperation, and assistance during the course of this study.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (47-53)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Assessing the Role of Digital Platforms in Strengthening Agricultural Extension Services: Advisory to Empowerment

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HIGHLIGHTS

- The use of digital platforms among small farmers in Uttar Pradesh has increased their knowledge, adoption capacity, and yield.
- Taking into account socio-economic factors, the empowerment score of farmers using digital platforms is 13% higher than that of non-users.
- Hybrid digital-traditional extension systems are required for inclusive empowerment and equity of farmers.

ARTICLE INFO

Keywords: Digital platforms, Agriculture, Extension, PCA, Regression, Uttar Pradesh.

https://doi.org/10.48165/IJEE.2026.62208

Citation: Yadav, B., Maurya, A. S., Patel, S., Kumar, R., & Kumar, A. (2026). Assessing the Role of Digital Platforms in Strengthening Agricultural Extension Services: Advisory to Empowerment. *Indian Journal of Extension Education*, *62*(2), 47-53.https://doi.org/10.48165/IJEE.2026.62208

ABSTRACT

The study conducted during 2025 explores the contribution of digital platforms in strengthening agricultural extension services and empowering farmers in Uttar Pradesh, India. Using a cross-sectional survey of 400 farmer households selected by stratified random sampling, the study compares digital platform users and non-users in terms of knowledge, empowerment, technology adoption, yield, and income. Validated multi-item scales and indices were used to measure perceived usefulness, digital use, and empowerment, which were supported by reliability and factor analysis. Group differences were tested with t-tests and chi-square statistics, while logistic regression assessed the probability of adopting at least three recommended practices, and a multiple regression modelled the determinants of empowerment. The results show that even after controlling for socio-economic and extension variables, digital platform users have significantly higher knowledge, empowerment scores, adoption indices, yield, and net farm income than non-users. Structural analysis shows that digital use influences empowerment both directly and indirectly through knowledge and information self-efficacy, underscoring the role of digital platforms as catalysts to drive the transition from consultation to empowerment.

INTRODUCTION

Smallholder farmers, who account for 86 per cent of agricultural land, face persistent challenges such as fragmented land, unstable markets, climate risks, and limited access to timely, reliable information (Mehmood, 2025). Traditional agricultural extension systems, operated primarily through government field staff, farmer field schools, and demonstration plots, are struggling to keep pace with these demands due to manpower shortages, geographical spread, and resource constraints (Nandi & Nedumaran, 2019). Agricultural extension coverage is inadequate in Uttar Pradesh, India's most populous state, and a major agricultural producing centre (Chaturvedi & Vatta, 2025). Here, the ratio of farmers to agricultural extension workers often exceeds 1,000:1, leading to uneven dissemination of knowledge and low adoption of productivity-enhancing practices (Satapathy et al., 2024). This gap has driven a

Received 01-02-2026; Accepted 26-02-2026

significant shift towards comprehensive solutions such as digital platforms (Panda et al., 2017; Sondarva et al., 2023; Geethalaxmi et al., 2024), and agri-tech services to overcome information asymmetries and empower farmers (Dhamija & Bhide, 2011). Digitization has gained momentum since the launch of initiatives like Digital India, Kisan Suvidha, and Agri Stack Ecosystem. These initiatives aim to deliver personalized, real-time advice on weather, pests, markets, and input optimization directly to farmers' smartphones. By 2025, smartphone penetration in rural India reached approximately 70%, supported by affordable data plans and connectivity expansion led by Jio, creating an enabling environment for information and communications technology (ICT) based expansion. Platforms such as farmer call centres, m-Kisan portals, and private apps like Agrostar and Dehat are spreading rapidly, providing multilingual content and networks beyond official channels (Yashvardhan et al., 2022). Although these tools will guarantee increased access and efficacy, their revolutionary nature will be determined by whether they offer mere advisory knowledge or facilitate greater empowerment, which assists farmers in making choices independently and responding to uncertainties (Kumar et al., 2021). Empowerment within the agricultural extension field includes the transfer of information as well as self-reliance, activism of farmers, and building up of the collective bargaining power (Sindakis & Showkat, 2024). Theoretically, the use of theories such as empowerment theory and the Unified Theory of Acceptance and Use of Technology (UTAUT) which postulates that the adoption of information and communication technology (ICT) influences behavioural intentions with respect to the perceived usefulness, ease of use and trust and eventually develop outcomes such as innovation adoption and livelihood security (Ibrahim & El-Kassim, 2024; Godara et al., 2024; Mehla et al., 2025). However, in India, it has been demonstrated that digital technologies have both positive and negative impacts; the tools lead to a 10-20 per cent overall yield gain among users, although literacy and barriers to access tend to lock out older and marginalized farmers and women. The state Uttar Pradesh, where the majority are smallholder farmers, is endangered by climatic variability; policymakers must learn how digital communities can be used to change agricultural extension approaches to do less telling and more empowering. The findings generalize application of initial measures such as PM-Kisan, e-NAM, and state-level applications in agriculture to vow that digital transformation can ensure even-handed and climate-resilient farming (Chander & Rathod, 2020).

METHODOLOGY

The study involved cross-sectional survey based on quantitative approach, performed in Uttar Pradesh, India, selected owing to its agrarian significance, and increasing digital extension initiative of ingenuity (Balkrishna et al., 2023). It was performed on three districts that have middle-level, and backward agro-economic statuses, in terms of coverage of irrigation, cropping intensity, and digital connectivity measures. Four villages in each district, 12 in total, were randomly chosen with a sufficient network coverage and operational digital counselling channels with involvement of extension and panchayat offices (Rajkhowa & Qaim, 2021).

Target population consisted of all working agricultural households, split into two groups: users of digital platforms - people who visit digital consultations at least 3 times a year, and non-users. Sample size was determined using formula:

$$no = \frac{Z^2\, pq}{e^2}$$

Where, Z = 1.96 (95% confidence),
p = q = 0.5 (maximum variance assumption), and e = 0.05

Where possible, there are limited population changes by providing mostly a sample of about 385 farmers. They stratified a random sample of 400 farmers at final stage to represent well various farm sizes and social categories. Finally, sample was distributed proportionally across district, villages, and user's level of sample.

Primary data was collected through structured personal interviews, which included socio-economic profiles, patterns of access, farm characteristics, and use of digital platforms (frequency, type, duration), decision-making autonomy, perceived quality of consultation, adoption of better practices, and outcome indicators such as yield and net farm income. Key concepts: trust in digital information, perceived usefulness, ease of use, and empowerment in decision making, were evaluated using a multi-item 5-point Likert scale (Lamm et al., 2021). Cronbach's alpha assessed scale of reliability.

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{j=1}^{k} \sigma_j^2}{\sigma_T^2}\right)$$

All structures achieved $\beta \geq 0.81$. Exploratory factor analysis confirmed dimensionality of scale through KMO value > 0.76; Bartlett test $p < 0.001$. A digital platform use index (DPUI) was constructed by aggregating standardized scores of frequencies, platform variety, and duration of use.

Descriptive statistics summarized respondents' profile and usage patterns. Independent t-tests and χ^2 tests were used for group comparisons. Logistic regression tested likelihood of adoption (Rajkhowa & Qaim, 2021).

$$\ln [P/(1-P)] = \beta_0 + \beta_1 DPUI_i + \beta_2 EC_i + \Sigma\beta_k X_{ki}$$

Empowerment determinants were modelled by multiple linear regression:

$$Y_i = \beta_0 + \beta_1 DPUI_i + \Sigma\beta_k X_{ki} + \varepsilon_i$$

SEM tested mediating pathways from digital use to empowerment through knowledge. Analyses were conducted using several appropriate software, including necessary diagnostics for model fit (R^2, CFI > 0.90, RMSEA < 0.05) (Douxchamps et al., 2017; Lazar et al., 2020).

RESULTS

In the primary investigation with the information acquired emphasizes over socio-economic profile of the 400 farmers sampled and establishes the contextual baseline against which the role of digital platforms in agricultural extension is interpreted. It reflects a situation where digital platforms have the potential for strong reach among smallholder farmers, but equity concerns remain important for extension planning (Balkrishna et al., 2023).

Table 1. Pattern of digital platform use among farmers

Indicator	Users (n = 240)	Non-users (n = 160)	Overall (N = 400)
Proportion of digital-platform users (%)	240 (60.0)	160 (40.0)*	–
Mean number of platforms used (± SD)	2.1 ± 0.8	0.3 ± 0.5	1.4 ± 1.1
Weekly frequency of digital advisory access	3.8 ± 1.6	0.4 ± 0.9	2.4 ± 2.1
% accessing mobile apps	62.5	8.1	39.0
% using WhatsApp groups	71.7	10.0	46.3
% using YouTube agri channels	54.6	6.3	34.5
% using IVR/Call centres	38.8	2.5	24.0
Average years of digital use	3.2 ± 1.4	0.5 ± 0.9	2.1 ± 1.8
% receiving advisory in local language	86.3	21.3	59.8

*Non-users refer to those not using any platform regularly; they may have incidental exposure.

The Table 1 describes the patterns of use of digital platforms, showing clear differences between users and non-users and showing how actively farmers engaged with digital advice channels. 60% of farmers are classified as users, showing that there is a majority in digital extension, yet 40% of farmers are largely deprived of regular digital consultation, which confirms that traditional methods are still important for inclusive extension. Users use, on average, more than two different platforms (2.1), while the diversity among non-users is almost negligible. This shows that once farmers enter the digital sphere, they start experimenting with multiple channels like apps, WhatsApp groups and YouTube. The frequency of weekly access to counseling (3.8 times for users vs. 0.4 times for non-users) reflects the difference between active, demand-based information-seeking behavior and sporadic, often incidental contact. The high proportion of users relying on WhatsApp groups (71.7%) and YouTube channels (54.6%) reflects the growing importance of peer-shared content and audio-visual learning in extended education, while mobile apps and IVR or call centers complement these as more formal or institutional channels. The average duration of digital use (about three years among users) shows that digital extension is not simply a new trend, but a mature component of the counseling setting, providing ample time for behavior change and adoption of practices. Importantly, more than 80% of users receive advice in local languages, underscoring the role of localization for usability and trust and providing a strong justification for investment in language-appropriate content by public and private providers. Table shows that digital platforms, particularly social and video-based platforms, are playing a central role in many farmers' information systems, while also highlighting a segment that is at risk of being left behind.

Results focus on the measurement quality of the key latent constructs in the study and confirm that the scales used to measure usefulness, ease of use, trust, empowerment, and use of digital platforms are psychometrically sound (Table 2). Cronbach alpha values for all constructs show high internal consistency between 0.81 and 0.90, suggesting that the items belonging to each scale reliably measure the same underlying concept. This is important when concluding intangible dimensions such as empowerment and trust, which cannot be directly observed and must be measured through multiple indicators. KMO values (0.76–0.86) and highly significant Bartlett tests support the suitability of the data for factor analysis, meaning that the correlation patterns between items are strong enough to justify the extraction of latent factors. Eigenvalues and percentage of explained variance show that each construct is dominated by a strong first factor (eigenvalues above 2.5 and approximately 49–53% of explained variance), which is consistent with theoretical expectations that these are essentially one-dimensional scales in an applied extension context. The Cronbach alpha of the empowerment scale is 0.90, and approximately half the variance is explained by the main factor, making it particularly strong. This allows the empowerment scores in the study to be confidently used as outcome variables in subsequent regression and structural models. Similarly, the reliability of the DPUI index supports its role as a central explanatory variable representing the intensity and prevalence of digital engagement. These results ensure that the quantitative analysis is based on well-established and validated constructs, thereby reducing measurement error and increasing the credibility of the observed relationships between digital platforms, empowerment, and performance.

The result compares key outcome indicators between digital platform users and non-users and presents the first direct evidence linking digital engagement to extension outcomes (Table 3). Across all variables, users significantly outperformed non-users, with large and statistically significant differences. Knowledge scores and empowerment scores among users are significantly higher, indicating that regular interaction with digital advisories not only increases information stores but also strengthens farmers' self-confidence and decision-making autonomy. The technology adoption index indicates

Table 2. Reliability and factor structure of key scales

Construct / Factor	No. of items	Cronbach's α	KMO	Bartlett's test (χ^2, p)	Eigenvalue	% Variance explained
Perceived usefulness of digital platforms	8	0.88	0.82	612.4, $p < 0.001$	3.95	49.3
Perceived ease of use	6	0.84	0.79	441.8, $p < 0.001$	3.10	51.6
Trust in digital information	5	0.81	0.76	328.6, $p < 0.001$	2.62	52.4
Empowerment in farm decision-making	9	0.90	0.86	735.7, $p < 0.001$	4.38	48.7
Digital platform utilization index (DPUI)	7	0.87	0.80	589.3, $p < 0.001$	3.72	53.1

Table 3. Comparison of users and non-users of digital platforms

Variable	Users Mean ± SD	Non-users Mean ± SD	t-value	p-value
Knowledge score (0–30)	21.8 ± 4.2	17.3 ± 4.6	9.72	< 0.001
Empowerment score (0–45)	31.4 ± 6.1	25.8 ± 6.7	8.22	< 0.001
Technology adoption index (0–1)	0.64 ± 0.15	0.48 ± 0.17	9.03	< 0.001
Wheat yield (q/ha)	48.6 ± 6.8	43.1 ± 7.4	7.05	< 0.001
Net farm income (Rs./ha)	34,500 ± 8,200	28,400 ± 7,950	6.91	< 0.001
Extension contact score (0–20)	13.7 ± 3.9	11.2 ± 4.1	5.96	< 0.001
Risk management practices adopted (0–10)	6.2 ± 1.9	4.9 ± 2.0	6.41	< 0.001

that users have adopted a larger proportion of recommended practices, which is consistent with the idea that frequent, timely, and customized information reduces the uncertainty and transaction costs associated with adopting an innovation. The yield difference between users (about 5.5 quintals per hectare in wheat) and the increase in net farm income per hectare point to solid productivity and economic benefits, which are central to the theory of digital platforms moving extension from mere advisory functions to empowerment and livelihood enhancement. Although causality should be analysed more thoroughly in multivariate models, such clear mean differences indicate that digital use is at least strongly associated with better performance. Extension contact scores for users are also high, meaning that digital platforms often complement rather than replace traditional face-to-face extension; Digitally connected farmers may be more active overall in seeking out diverse information sources. Finally, risk management practices show that users implement more strategies such as crop diversification, weather-based decisions, and input planning, which supports the argument that digital advisories, especially advisories with real-time weather and market data, enable more informed risk management. Overall, the Table presents a consistent picture of digital platform users being better informed, more empowered, and economically better off, confirming the core proposition of the study.

Table 4 indicates a logistic regression model which examines the probability of farmers utilizing at minimum 3 suggested practices in view of utilizing at least one digital platform and choosing socio-economic and extension variables. The model (Odds Ratio, Nagelkerke R-squared 0.32 and the Hosmer-Lemeshow is non-significant) is analyzed to indicate that the model has reasonable explanatory power and fits the data. The most noteworthy finding is that there is a positive and highly significant coefficient of the DPUI score with odds ratio of about 1.30. This implies that, other factors held constant, every single unit of increase in the utilization of digital platforms will raise the likelihood of adoption of at least three suggested practices by about 30%. This explains the hunch that exists between digital engagement and the adoption of practice and goes beyond mere comparisons of groups. The positive significant effect of extension contact is also to be noted, therefore, the traditional extension remains relevant, as well as the digital tools are most effective when incorporated into a larger system of advising, rather than standing alone. The use of digital technologies is positively correlated with education, farm size and household income. This demonstrates that farmers who are better resourced and highly educated can much easier attempt and become acculturated to the suggested technologies. Though the effect of age is observed to be negative, it is not significant. This implies that younger farmers might be a bit more flexible in adopting digital technologies, but once the digital use and other aspects are put into consideration, age is not a good predictor of the probability of adoption. The negative sign of the constant shows that the probability of adoption at the base is rather low without the digital use and other conditions. On the whole, the Table highlights that despite consideration of socio-economic features and conventional extension contact, digital platforms play a crucial role in enhancing the likelihood of adoption of meaningful practices, which can reinforce their application as a transformative tool in the field of extension services delivery.

Table 5 contains the multiple regression analysis using the score of empowerments as the dependent variable and demonstrates the joint impact of the digital use and other variables on the sense of autonomy in the choices of farmers in agriculture. This model describes nearly fifty percent of the variance in empowerment (adjusted $R^2 = 0.47$) and this means that this model is a good overall fit to the social science context, and F-test supports the fact that the combination of predictors is significant. The standardized coefficient of DPUI has the most significant value ($\beta = 0.46$) and is significant, i.e., the most influential predictor of empowerment in the investigated variables. This is aligned with the notion that

Table 4. Logistic regression for adoption of at least three recommended practices (Y = 1 if adopted ≥3 practices)

Predictor	Coefficient (β)	Std. error	Wald χ^2	Odds ratio (e^β)	p-value
Constant	-2.10	0.52	16.27	0.12	<0.001
DPUI score (0–10)	0.26	0.04	42.25	1.30	<0.001
Extension contact (0–20)	0.07	0.02	12.44	1.07	0.0004
Education (years)	0.05	0.02	6.89	1.05	0.0086
Farm size (ha)	0.11	0.04	7.48	1.12	0.0063
Age (years)	-0.01	0.01	1.84	0.99	0.1750
Household income (Rs. lakh/year)	0.09	0.04	5.25	1.09	0.0219

Model statistics: -2 Log likelihood = 412.7; Nagelkerke $R^2 = 0.32$; Hosmer–Lemeshow $\chi^2 = 6.18$ ($p = 0.63$).

Table 5. Multiple regression: determinants of empowerment score (0 - 45)

Predictor	Unstandardized β	Std. error	Standardized β	t-value	p-value
Constant	12.45	2.38	–	5.23	<0.001
DPUI score	1.14	0.15	0.46	7.79	<0.001
Knowledge score	0.32	0.07	0.24	4.57	<0.001
Extension contact score	0.28	0.09	0.18	3.11	0.0020
Education (years)	0.21	0.07	0.14	2.93	0.0036
Farm size (ha)	0.37	0.16	0.09	2.31	0.0214
Age (years)	-0.05	0.02	-0.11	-2.52	0.0120

Model diagnostics: $R = 0.69$; $R^2 = 0.48$; Adjusted $R^2 = 0.47$; $F(6,393) = 60.4$, $p < 0.001$.

through digital platforms, farmers are able to access, to evaluate and to take action on information more independently, and therefore, their autonomy to make decisions is fortified. The knowledge scores also play a significant role in the field of empowerment, implying that the route between the digital advice and the empowerment is partly laid through the increments in technical and market knowledge levels; Better-informed farmers feel more confident negotiating, innovating and making calculated risks. The beneficial impact of extension contact is maintained which enhances the complementary nature of digital and tangible extension contact. There are small positive impacts that education and the size of the farms have, which imply that human capital and resource base continue to play a significant role in perceptions of empowerment even though not as much as the use of digital. The age factor has a small negative impact, which means that younger farmers are more empowered to exploit digital information as compared to the older ones, perhaps because of higher levels of digital literacy and receptivity to change. In general, Table 6 proves the underlying value that, when incorporated into an enabling atmosphere of extension, digital platforms can change farmers into active and empowered decision makers, rather than passively receiving advice.

Findings give a more detailed view of empowerment by sub-classifying the items of empowerment by using exploratory factor analysis into three latent factors. The first one, which is called decision autonomy, aggregates the items concerning the independent choice of crops, inputs, time of work, and marketing decision and reflects the greatest amount of variance meaning that the ability to make the major agricultural decisions is the most important dimension of empowerment, in this case. Information self-efficacy is the second factor and is represented by the confidence of the farmers in seeking, confirming, and utilising digital information which directly depend on the experience with the digital platforms; This factor underlines that empowerment does not only concern the availability of information, but also the perceived capability to use it. The third reason is collective voice and activism which represents the involvement of farmers in the groups, bargaining power with the buyers and interaction with the authorities indicating that the idea of empowerment has social and institutional aspect connected with collective action and representation. The overall variance (approximately 65 per cent) and the pattern of explainable factors suggest that the concept of empowerment in the paper is multidimensional and coherent, and each dimension has the definite practical consequences with respect to the extension strategies. Online platforms can change these aspects in various ways, such as directly enhancing information self-efficacy and indirectly affect decision autonomy and collective voice via knowledge and network effects. This factor structure therefore offers a conceptual basis to the further analysis of SEM and means that extension planners can focus on particular areas of empowerment with the help of tailored digital interventions.

Results from the Table 7 summarize the goodness-of-fit indices for the structural equation model linking digital platform use, knowledge, and empowerment, and show that the proposed theoretical model is statistically acceptable. The χ^2/df ratio is less than 2, and the CFI and TLI values are greater than 0.90, indicating that the hypothesized relationships between the latent variables and their indicators, as well as between the latent variables themselves, fairly accurately reproduce the observed covariance structure. The RMSEA and SRMR values are less than 0.05, which generally falls within the goodness-of-fit range and suggests that discrepancies between the model-based and observed covariance

Table 7. Goodness of fit indices for the SEM model of digital platforms, knowledge, and empowerment

Fit index	Value	Acceptable threshold (reference)
χ^2/df	1.94	< 3.0
Comparative Fit Index (CFI)	0.95	≥ 0.90
Tucker–Lewis Index (TLI)	0.93	≥ 0.90
Root Mean Square Error of Approximation (RMSEA)	0.049	≤ 0.08
Standardized Root Mean Square Residual (SRMR)	0.041	≤ 0.08

Table 6. Summary of exploratory factor analysis for empowerment-related items

Factor label	Key high-loading items (loading ≥ 0.50)	Eigenvalue	% Variance explained
F1: Decision autonomy	Choice of crop, input purchase, timing of operations, marketing choice	3.10	34.4
F2: Information self-efficacy	Ability to search, verify, and apply digital advice	1.62	18.0
F3: Collective voice and agency	Participation in groups, negotiation with buyers, dealing with officials	1.12	12.5

Total variance explained = 64.9%; rotation method = Varimax.

matrices are small. These indices collectively show that conceptualizing digital platform use as an exogenous indirect factor influencing knowledge and empowerment, with potential mediating pathways, is supported by the data. Although detailed path coefficients are not shown here, satisfactory matching provides confidence in partitioning the total effects using SEM outputs into direct effects of digital use on empowerment and indirect effects through mediating factors such as knowledge and information self-efficacy. This is important for extension research and practice because it shows that digital platforms empower farmers directly by increasing their sense of control and indirectly by increasing their knowledge and confidence in information management. Therefore, good model matching validates the study's broader theoretical framework, which suggests that "from advice to empowerment" is not a simple linear outcome of providing information, but rather a mediated process shaped by digital engagement, learning, and evolving farmer capabilities.

DISCUSSION

The results are strong evidence that digital platforms help a great deal to improve the agricultural extension services and empower farmers among the Uttar Pradesh smallholders but the benefits of using digital platforms are moderated by the complementary variables and access equity. Users of digital-platforms all exhibited higher results than non-users on all assessed outcomes, in part knowledge (21.8 vs 17.3), empowerment (31.4 vs 25.8), technology adoption (0.64 vs 0.48), wheat yields (48.6 vs 43.1 q/ha) and net farm incomes (Rs. 34,500 vs Rs. 28,400/ha) which all showed significant practical effects. Even when the socio-economic traits and traditional extension contact were held constant in multivariate analyses, these disparities remained established which substantiates the fact that digital engagement is a unique advantage in addition to selection implications. The odds ratio of 1.30 of DPUI implies that every unit change in digital utilization increases the likelihood of the adoption of ≥3 recommended practices by 30 percent and the empowerment regression implies that 46 percent of the standardized variance is explained by digital utilization, which is why digital utilization is the most significant predictor. The findings are consistent with UTAUT models, in which familiar usefulness and ease of use are the factors that influence technology acceptance and behavioral intentions. The fact that WhatsApp groups (71.7%), YouTube (54.6%), and other applications that involve dialogic and peer-mediated content and visual information are more frequently used by farmers implies that social learning is an effective tool in increasing the coverage of digital extension to farmers. Greater success in adoption (86.3) is also attributed to high local-language delivery, because culturally relevant content can foster trust and understanding in low-literacy farmers. The factor analysis yielding the three dimensions of empowerment, including decision autonomy, information self-efficacy, and collective voice, provides conceptual clarity, where digital platforms empower the agency of individual-level (crop/input choices) and empower the action of networked collectives (collective voice). Digital and traditional extension complements one another, which is of particular interest. The positive effect of extension contact on the adoption ($\beta = 0.07$) and empowerment ($\beta = 0.28$) suggests that hybrid systems can be employed in which digital tools extend frequency/personalization, and human agents can be used to build contextual trust. This disputes the digital first solutions, upholding blended approaches in successful Indian programs such as mKisan and Kisan Call Centres (Maulika et al., 2024). These equity issues are still urgent. The non-users (40%), which are concentrated among the marginal farmers who lack smartphones (20%), as well as the internet (12.5%), may widen the divides unless measures are taken by using collective devices, village kiosk, and literacy programs. The negative impact of age as an empowering factor implies that young farmers gain more than older, whereas the education/farm size gradients do not disappear with the digital leveling potential. Although it is not described in this paper, gender disaggregation is a promising subject worth examining in the future due to women being underrepresented in digital space. The implications of the policy are evident: Multilingual, video/social media content should be scaled, whereas the frontline extension should be enhanced to interpret digital cues. The Digital Agriculture Mission of Uttar Pradesh must focus on the last-mile connectivity, trainings to farmers, and collaboration with the private sector in order to be inclusive. Limitations such as not being a causal study due to cross-sectional design and self-reported outcomes would be enhanced by longitudinal studies with objective yield/market data. Effects of interventions should be tested in future, and women/youth sub-groups should be studied.

All in all, extension on the digital platform sparks the transition of dissemination of information to empowerment, yet implementation requires a conscious effort to integrate with human systems and equity protection (Guntukougula et al., 2023). This makes Uttar Pradesh a policy to emulate with smallholder digital transformation in India, with a balance between scale, inclusion and sustainability.

CONCLUSION

It has been empirically found that farmers with high levels of digital use, including mobile applications, WhatsApp groups, YouTube channels, and call centres, tend to have a higher knowledge level, adopt recommended practices, better yields, and better net farm income compared to non-users. The findings further suggest that empowerment is a multidimensional concept, which is comprised of decision-making autonomy, informational self-efficacy, and collective expression, and digital platforms affect these dimensions directly and indirectly via enhanced knowledge and confidence in information management. Nonetheless, the fact that non-users are usually poor and less connected in large numbers demonstrates that digitalization can be a source of an enlarged difference when mismanaged. This paper thus states that the proposed extension efforts in the future ought to foster the hybrid approaches in which digital platforms increase reach and personalization, whereas human extension agents are used to guarantee inclusion, contextualization, and trust building.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection.

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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (54-58)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Determinants of Food Insecurity in Africa and Asia: A Comparative Analysis

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HIGHLIGHTS

- Higher cereal productivity consistently reduced food insecurity, precision agriculture adoption enhanced efficiency and food security, and climate adaptation reduced vulnerability; GHG emissions increased insecurity.
- Agricultural R&D investment showed strong food-security gains.
- Africa–Asia cooperation is critical for resilient food systems.

ARTICLE INFO

Keywords: Food insecurity, Precision agriculture adoption, Climate adaptation, Environmental sustainability, Africa–Asia cooperation.

https://doi.org/10.48165/IJEE.2026.62209

Citation: Raj, M., Arulmanikandan, B., Chahal, P. K., Singh, B., & Malik, J. S. (2026). Determinants of Food Insecurity in Africa and Asia: A Comparative Analysis. *Indian Journal of Extension Education*, *62*(2), 54-58. https://doi.org/10.48165/IJEE.2026.62209

ABSTRACT

Food insecurity remained a persistent challenge in Africa and Asia due to interacting agricultural, technological, climatic, and environmental factors. The study conducted during 2025 examined the determinants of food insecurity across selected African and Asian countries using cross-country data from 2020 to 2024. It assessed the effects of agricultural productivity, technological adoption, research investment, climate adaptation spending, and environmental pressure on food insecurity. A quantitative cross-sectional design was employed, and data were analysed using Pearson's correlation and multiple linear regression. The results indicated that cereal yield, precision agriculture adoption, research and development expenditure, and climate adaptation spending showed significant negative associations with food insecurity. In contrast, greenhouse gas emissions and higher agricultural value added exhibited positive associations. The regression model explained 82 per cent of the variation in food insecurity, indicating strong explanatory power. The findings demonstrated that productivity enhancement, technological diffusion, research investment, and climate-responsive measures were critical determinants of reduced food insecurity across the selected countries.

INTRODUCTION

Food insecurity continues to be a persistent structural challenge, particularly in Africa and Asia, where a substantial proportion of the world's smallholder farmers and malnourished populations reside (FAO, 2023; World Bank, 2024). While earlier discourse primarily emphasized aggregate food production shortfalls, contemporary scholarship recognizes food security as a multidimensional outcome shaped by agricultural productivity, technological capacity, environmental sustainability, and climate resilience (Jin et al., 2024; van Dijk et al., 2025). Variations in these structural determinants have contributed to uneven progress toward sustainable food and nutrition security across both regions. Agricultural productivity, especially cereal yield, remains a fundamental determinant of food availability and access. Empirical evidence consistently shows that yield-enhancing interventions and sustained productivity growth reduce vulnerability to food insecurity, particularly in smallholder-dominated systems (Hazell et al., 2010; Ravi et al., 2023; Bharat et al., 2022; Kumbhare et al., 2023). Beyond production gains, technological innovation has emerged as a key driver of efficiency, risk mitigation, and resilience. Studies on precision agriculture adoption report improvements in input-use efficiency, yield stability, and resource optimization

Received 20-12-2025; Accepted 05-03-2026

(Lowenberg-DeBoer & Erickson, 2019; Kendall et al., 2021; Nowak, 2021; Pandeya, 2025). These findings align with diffusion theory, which emphasises the role of innovation characteristics and institutional support in shaping adoption outcomes (Rogers, 2003; Baliwada et al., 2017; Kademani et al., 2026). Complementing technological diffusion, sustained investment in agricultural research and development (R&D) generates significant social returns through productivity enhancement, knowledge spillovers, and long-term system resilience (Copenhagen Consensus, 2023; Jin et al., 2024).

Climate variability and environmental degradation further complicate food security dynamics. Evidence from diverse agro-ecological contexts demonstrates that erratic rainfall, rising temperatures, and land degradation increase production risks and household vulnerability (Meena et al., 2022; Sarkar et al., 2022). Investments in climate adaptation measures, including climate-smart agricultural practices, have been associated with improved resilience and dietary outcomes (Madaki et al., 2024; Shin et al., 2024). In contrast, environmentally unsustainable agricultural intensification, particularly greenhouse gas (GHG) emissions, poses long-term threats to food system stability (Pretty et al., 2011; Baraj et al., 2024). These interrelated factors underscore the need to examine productivity growth, technological advancement, adaptation investment, and environmental pressure within an integrated analytical framework.

Despite extensive scholarship, important gaps persist. Much of the literature remains region-specific, focusing separately on African or Asian contexts, or concentrates on micro-level analyses of household food security and localized adoption behaviour (Gautam & Jha, 2022; Jairu et al., 2023; Imrankhan Jiragal et al., 2025). Comparatively fewer macro-level studies integrate agricultural productivity, technological diffusion, research investment, climate adaptation, and environmental sustainability within a unified cross-country empirical model. Consequently, consolidated comparative evidence explaining how these structural determinants jointly influence food insecurity across Africa and Asia remains limited.

Addressing this gap, the present study conducted a cross-country comparative analysis using data from 2020–2024 to examine the combined effects of agricultural value added, cereal yield, R&D expenditure, precision agriculture adoption, climate adaptation spending, and GHG emissions on food insecurity across selected African and Asian nations.

METHODOLOGY

The study employed a quantitative cross-sectional design based on secondary data to examine the determinants of food insecurity across selected African and Asian countries for the period 2020–2024. Cross-country analysis was adopted to capture regional variation and enable comparative assessment of structural determinants. Data were compiled from internationally recognized databases, including the Food and Agriculture Organization (FAO), World Bank World Development Indicators, Consultative Group on International Agricultural Research (CGIAR), United Nations Environment Programme (UNEP), and the International Food Policy Research Institute (IFPRI). These sources provide standardized and internationally comparable indicators widely used in food security and agricultural policy research.

A total of 15 countries (10 Asian and 5 African) were included based on data availability for all study variables during the reference period. Food insecurity, measured as the percentage of the population experiencing moderate to severe food insecurity, was treated as the dependent variable. Independent variables included agricultural value added (% of GDP), cereal yield (kg/ha), research and development (R&D) expenditure (% of GDP), precision agriculture adoption (%), climate adaptation spending (% of agricultural GDP), and greenhouse gas (GHG) emissions (tonnes per hectare). These indicators were selected to represent productivity, technological advancement, research investment, climate resilience, and environmental pressure dimensions.

Descriptive statistics were computed to examine regional patterns. Pearson's correlation analysis was used to assess bivariate associations among variables. To estimate the combined influence of explanatory variables on food insecurity, multiple linear regression using the ordinary least squares (OLS) method was applied. The model specification was:

$$\text{Food Insecurity} = \beta_0 + \beta_1 \bullet (\text{Agri Value Added}) + \beta_2\,(\text{Cereal Yield}) + \beta_3\,(\text{R\&D Expenditure}) + \beta_4\,(\text{Precision Agriculture Adoption}) + \beta_5\,(\text{Climate Adaptation Spending}) + \beta_6\,(\text{GHG Emissions}) + \varepsilon$$

where β_0 represented the intercept, β_1 to β_6 denoted regression coefficients of the respective predictors, and ε represented the error term.

RESULTS

The results of the cross-country analysis highlighted significant regional differences in food insecurity, agricultural performance, technological adoption, and environmental indicators across the selected African and Asian countries during the period 2020–2024.

The determinants of food insecurity were first examined through multiple regression analysis to assess the combined influence of productivity, technological, research, climate, and environmental variables. The regression results (Table 1) demonstrated strong explanatory power, with the model accounting for a substantial proportion of cross-country variation in food insecurity during 2020–2024. Cereal yield, research and development (R&D) expenditure, precision agriculture adoption, and climate adaptation spending exerted statistically significant negative effects, confirming that productivity enhancement, technological diffusion, and adaptive investment function as protective structural factors.

Table 1. Regression estimates for determinants of food insecurity

Predictor	Coefficient (β)
Intercept	32.10
Agricultural value added (% GDP)	+0.12[b]
Cereal yield (kg ha^{-1})	-0.0042[a]
R&D expenditure (% GDP)	-3.80[a]
Precision agriculture adoption (%)	-0.25[a]
Climate adaptation spending (% agri GDP)	-0.90[b]
GHG emissions (t ha^{-1})	+4.10[a]

Model statistics: $R^2 = 0.82$; F-statistic = significant at $p < 0.01$; Durbin–Watson = 2.1, [a]Significant at $p < 0.01$; [b]Significant at $p < 0.05$

Among these, R&D expenditure and precision agriculture adoption showed comparatively stronger effects, underscoring the importance of innovation systems and modernization in reducing food insecurity. Conversely, greenhouse gas (GHG) emissions exhibited a statistically significant positive effect, indicating that higher emission intensity was associated with increased food insecurity after controlling for other factors. Agricultural value added (as a percentage of GDP) also showed a positive association, suggesting that structural dependence on agriculture, without sufficient technological upgrading or diversification, may heighten vulnerability. The Durbin–Watson statistic indicated no evidence of autocorrelation, supporting model reliability (Table 2).

Table 2. Correlation between food insecurity and key variables

Variables	Correlation (r)
Food insecurity – Cereal yield	-0.78[a]
Food insecurity – Precision agriculture adoption	-0.72[a]
Food insecurity – R&D expenditure	-0.60[b]
Food insecurity – Climate adaptation spending	-0.55[b]
Food insecurity – GHG emissions	+0.70[a]
Food insecurity – Agricultural value added (% GDP)	+0.50[b]

[a]Correlation significant at $p < 0.01$; [b]Correlation significant at $p < 0.05$.

To examine the direction and strength of association between food insecurity and selected agricultural, technological, and environmental variables, Pearson's correlation analysis was conducted (Table 2). The results revealed strong negative associations between food insecurity and cereal yield as well as precision agriculture adoption, reinforcing the central role of productivity and technology in food system stability. R&D expenditure and climate adaptation spending were moderately and negatively associated with food insecurity, while GHG emissions showed a strong positive association. These bivariate patterns were consistent with the regression findings, indicating structural coherence across analytical levels.

Descriptive statistics (Table 3) highlighted notable regional disparities between African and Asian countries. On average, food insecurity levels were higher in the selected African countries, accompanied by lower technological adoption and research investment. Asian countries generally demonstrated higher cereal productivity and greater diffusion of precision agriculture technologies, alongside moderately stronger climate adaptation spending. These structural contrasts provide contextual grounding for the regression and correlation results.

Overall, the integrated findings indicate that food insecurity across Africa and Asia is systematically shaped by differences in agricultural productivity, technological advancement, research investment, climate responsiveness, and environmental sustainability.

Table 3. Regional comparison of food insecurity and key indicators

Region	Food insecurity (%)	Precision agriculture adoption (%)	R&D expenditure (% GDP)
Asia	13.2	27	0.7
Africa	24.8	11	0.5

Africa and Asia; mean values, 2020–2024

DISCUSSION

The findings demonstrate that structural determinants, particularly agricultural productivity, technological diffusion, research investment, climate adaptation, and environmental sustainability, systematically shaped food insecurity across the selected African and Asian countries. Rather than reflecting isolated production shortfalls, food insecurity appeared strongly associated with broader innovation and resilience capacities. The negative association between cereal yield and food insecurity confirms that staple crop productivity remains a foundational driver of food availability and access, particularly in systems dominated by smallholder agriculture. This aligns with earlier evidence showing that sustained productivity growth reduces structural vulnerability (Hazell et al., 2010; Ravi et al., 2023). However, the regression results indicate that productivity alone was not sufficient; its protective effect operated alongside technological and institutional factors.

Precision agriculture adoption and R&D expenditure showed comparatively strong negative effects, underscoring the role of innovation systems in stabilizing food outcomes. This supports literature emphasizing the efficiency gains and risk-reduction benefits of technological modernization (Lowenberg-DeBoer & Erickson, 2019; Kendall et al., 2021; Shitu and Nain, 2024) and the long-term social returns of agricultural research investment (Jin et al., 2024). The results suggest that countries with stronger research ecosystems and higher technological diffusion were better positioned to mitigate food insecurity, reinforcing the argument that structural transformation, rather than input intensification alone, underpins resilience. Climate adaptation spending also exhibited a protective association, consistent with findings that climate-responsive agricultural measures reduce vulnerability to production shocks (Madaki et al., 2024; Shin et al., 2024). However, the magnitude of this effect was moderate, indicating that adaptation complements but does not substitute for productivity and innovation investments.

In contrast, greenhouse gas emissions were positively associated with food insecurity, suggesting that environmentally unsustainable intensification may undermine long-term food system stability. This finding is consistent with sustainability literature highlighting the risks of emission-intensive growth pathways (Shitu et al., 2018; Pretty et al., 2011; Baraj et al., 2024). Similarly, the positive association between agricultural value added and food insecurity implies that economic dependence on agriculture, without adequate modernization or diversification, may increase exposure to systemic shocks. The results support an integrated policy orientation that combines productivity enhancement, technological upgrading, research investment, and sustainability measures within a coherent food system framework.

CONCLUSION

The study establishes that food insecurity across Africa and Asia is systematically shaped by differences in agricultural productivity, technological adoption, research investment, climate adaptation efforts, and environmental sustainability. The findings

confirm that higher cereal yields, greater diffusion of advanced agricultural technologies, increased investment in agricultural research, and stronger climate adaptation measures consistently correspond to lower food insecurity, while environmentally unsustainable practices and excessive reliance on agriculture without diversification intensify vulnerability. These results validate the central hypothesis that innovation-driven and climate-resilient agricultural systems form the foundation of sustainable food and nutrition security. The study further demonstrates that regional disparities in food insecurity reflect unequal access to technology and research capacity, underscoring the practical importance of cross-regional cooperation. Strengthening collaborative knowledge exchange, innovation partnerships, and climate-responsive agricultural strategies emerges as an essential pathway for building resilient food systems and advancing long-term food, nutrition, environmental, and health security.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection.

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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (59-65)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Solar-Powered Irrigation and Farm Performance: An Impact Evaluation from Kashmir Valley, India

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HIGHLIGHTS

- Diversified crops with high market value have improved, and overall plant growth has seen considerable progress since adopting solar water pumps.
- Improvements in fruit size, colour, hardness, and consistency were frequently observed by fruit farmers, particularly apple orchardists.
- A considerable reduction in farm expenditures was reported.

ARTICLE INFO

Keywords: Impact, Sustainable irrigation, Agricultural productivity, Solar water pumps, Adoption.

https://doi.org/10.48165/IJEE.2026.62210

Citation: Peer, Q. J. A., Rashid, I., Tabina, Kubrevi, S. S., Shah, I. A., & Para, I. A. (2026). Solar-Powered Irrigation and Farm Performance: An Impact Evaluation from Kashmir Valley, India. *Indian Journal of Extension Education*, *62*(2), 59-65. https://doi.org/10.48165/IJEE.2026.62210

ABSTRACT

The growing demand for energy and the rising costs of traditional irrigation methods have increased the need for sustainable options in agriculture. Solar water pumps are a practical and eco-friendly choice, especially in regions with high solar exposure like Jammu and Kashmir. According to data collected from JAKEDA (2024), a total of 1,309 beneficiaries have used solar water pumps under the PM-KUSUM scheme. The study conducted during 2025, evaluated how adopting solar water pumps affects important agricultural aspects, such as irrigation costs, crop production, crop quality, diversification, and plant growth in three selected districts, namely; Anantnag, Pulwama, and Baramulla (with a large number of functioning solar water pumps). By applying the results of the Wilcoxon signed-rank test to data collected from growers, significant differences between the conditions before and after adoption were recorded. A significant decrease in labor and diesel expenses, along with notable gains in both crop yield and quality, was found. Diversified crops with high market value have improved, and overall plant growth has seen considerable progress since adopting solar water pumps.

INTRODUCTION

Most of India's agriculture depends on regular irrigation; however, farmers face persistent challenges such as unstable power supply, rising labor costs, and increasing diesel prices. These constraints delay timely irrigation and adversely affect crop quality, productivity, and farmers' ability to diversify into higher-value crops. Consequently, sustainable irrigation practices have become increasingly important, particularly in regions such as Jammu and Kashmir, where climatic variability and fragile landscapes demand efficient water management. Effective institutional interventions must prioritise cultural sensitivity, participatory governance, and inter-agency convergence. Strengthening institutional responsiveness alongside local social networks is essential for building resilient, community-driven food systems in tribal regions (Rout et al., 2025).

Since the mid-1980s, groundwater has emerged as the dominant source of irrigation in India. During 2019–20, groundwater-irrigated area expanded from about 6 million hectares in 1950–51 to nearly 48 million hectares, accounting for over two-thirds of the country's

Received 22-01-2026; Accepted 05-03-2026

net irrigated area (MoAFW, 2022). This expansion has contributed significantly to increased cropping intensity, agricultural output, and rural employment. However, it has also raised serious sustainability concerns, including declining groundwater levels, aquifer depletion, and deterioration of water quality due to contamination and salinization

The rapid growth of groundwater irrigation has been closely linked to the electrification of agricultural pump sets, which increased from 5.13 lakh in 1965–66 to 217.99 lakh in 2019–20 (CEA, 2021). Electrification increased access to irrigation, but it also put more strain on groundwater supplies. In order to ensure inclusive and sustainable agricultural development, integrated policies that prioritize resource efficiency, human capacity building, and institutional strengthening are necessary. Evidence from Punjab demonstrates the multifaceted nature of rural livelihoods, shaped by both traditional resources and institutional factors (Yadav et al., 2026).

Solar irrigation has become more well-known as a sustainable solution to these problems. Numerous studies have looked at the factors and obstacles influencing adoption (Kumar et al., 2019) as well as its effects on irrigated area, crop patterns, productivity, and farm income (Meena et al., 2020). Initiatives like Karnataka's "Surya Raitha" program have investigated solar irrigation as a source of revenue (Durga et al., 2021). While applied and policy-oriented studies focus on operational, groundwater use, and management issues related to Solar Irrigation Pumps (SIPs) (Shah et al., 2018; Sahasranaman et al., 2021), comparative analyses of diesel and solar water pumping systems highlight the economic and environmental benefits of solar-based irrigation (Anjum, 2025; Sreedharan et al., 2020).

The significance of digital agricultural interventions is further highlighted by recent research. ICT services that are timely, pertinent, and easy to use are valued by farmers; adoption is influenced by trust and personalization. Policymakers and extension organizations can better understand farmer needs and enhance the design of advisory services by using empirically tested tools, which support evidence-based planning (Upreti et al., 2023; Paliwal et al., 2026).

METHODOLOGY

The Kashmir Valley consists of ten districts. A list of respondents who utilized solar water pumps under the PM-KUSUM program was supplied by the Jammu and Kashmir Energy Development Agency (JAKEDA). A total of 1309 respondents from all ten districts said they used solar pumps. From the current study, three districts–Anantnag, Pulwama, and Baramulla–were specifically selected because they had the highest number of program participants. An analytical and descriptive research design was used. The analytical component concentrated on the effects of the adoption, whereas the descriptive component described the intervention and its aftermath. To incorporate the results from various research channels, both primary and secondary research methods were used. In all districts, there were 1309 recipients. The current study's sample size was calculated using Slovin's formula:

$$n = N/(1+Ne2)$$

where n is the sample size (to be determined), N is the total population, and e is the error tolerance.

Assuming a 5% margin error (e=0.05), the necessary sample size was n= [1309/ {1+1309 (0.05)2}]

n = 306.377, for the current study, a total sample size of 306 was therefore required.

The data was collected in the Kashmir valley in the year 2025, having the maximum number of beneficiaries with Solar Water pumps. The study used a structured questionnaire to collect data, which measured the solar adoption process. The study assessed a range of socio-economic indicators to capture the demographic, economic, and agricultural dimensions of respondents. The key variables included: Age, Family type, Family size, Marital status, Education level, Annual income, Total landholding, Farming experience, Source of irrigation, Access to drinking water and sanitation, Ownership of agricultural implements and Cropping intensity. The study used multi-stage sampling and data processing, and a reliability test was carried which required them to clean the data set by fixing the missing values and resolving the errors. Spreadsheets and statistical software (MS Excel and SPSS) were used to code and analyse the data gathered from the field survey. As explained below, a mix of descriptive and inferential tools were used.

Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise socio-economic characteristics of respondents. To determine whether there were any significant differences between the two related samples before and after the solar water pump was implemented, the Wilcoxon signed rank test was employed. This non-parametric test was chosen because the data did not have a normal distribution. By comparing the population mean ranks of paired observations, the test ascertains whether they differ. Data were analysed using descriptive and inferential statistics. To test whether the SWP usage significantly alters farm expenses and production outcomes, the Chi-square test was applied.

RESULTS

Impact of solar water pumps on agricultural productivity parameters

People who had installed solar water pumps were asked to report on the state of certain indicators (crop yield, crop quality, crop diversification, plant development, and labour and diesel costs) both before and after the installation. A three-point directional scale with the options of increase, decrease, and no change to measure each indicator was used. The answers were coded and put into pairs of before-and-after datasets for each agricultural parameter. Directional changes were transformed into ordinal differences, allowing for a meaningful comparison of conditions before and after solar pump installation. The Wilcoxon Signed Ranks Test was then performed to determine whether the observed shifts were statistically significant.

Impact of solar water pumps on crop yield

The findings in Table 1 analysed the impact of solar water pump installation on crop yield through a before-and-after comparison. The Wilcoxon Signed Ranks Test revealed a strong and statistically significant increase in crop yield following the adoption

Table 1. Wilcoxon Signed Ranks Test – Crop Yield (Before vs After Solar Water Pump Installation)

Comparison	Category	N	Mean Rank	Sum of Ranks
Crop Yield (After–Before)	Negative Ranks	0[a]	0.00	0.00
	Positive Ranks	268[b]	134.50	36,046.00
	Ties	38[c]	-	-
	Total	306		
a: Negative Ranks: Crop yield after installation < crop yield before installation				
b: Positive Ranks: Crop yield after installation > crop yield before installation				
c: Ties: Crop yield after installation = crop yield before installation				
Z-value		–15.231		
Asymptotic Significance (2-tailed)(p-value)		0.000		

of solar water pumps. There were 268 positive ranks and no negative ranks, which shows that all but 38 respondents said their crop yield improved after installation. There were also 38 cases where there was no change.

The Z-value (–15.231) and the very significant p-value ($p < .001$) showed that the increase in crop yield was not just random chance. This strong positive shift suggested that access to reliable and timely irrigation enabled by solar water pumps substantially enhanced crop productivity. Farmers were probably able to water their crops at important growth stages thanks to better access to water, which led to higher overall yields.

Impact of solar water pumps on crop quality

Table 2 shows the results of changes in crop quality after installing a solar water pump. The findings indicated a strong and statistically significant improvement in crop quality after the intervention. 271 people said that the quality of their crops got better, while none said it got worse and 35 said it stayed the same.

The Wilcoxon Signed Ranks Test yielded a Z-value of –15.310 (Table 2) and a p-value of less than .001, validating the significance of this enhancement. The results suggested that consistent and sufficient irrigation made possible by solar pumps led to healthier crops, better grain or produce formation, and higher overall quality. Better water management may have made plants less stressed and more uniform, which could have led to better outputs.

Impact of solar water pumps on crop diversification

Table 3 provides a summary of how the use of solar water pumps affects crop diversification. Diversification, in contrast to yield and quality, increased moderately but statistically significantly. 143 respondents said that diversification had increased, 7 said it had decreased, and 156 said it had not changed.

The Wilcoxon test result ($Z = –11.104$, $p < .001$) verified that the overall change was statistically significant in spite of the ties (Table 3). This implied that some farmers were able to diversify into other or water-intensive crops thanks to access to solar-powered irrigation, though other factors like market access, risk tolerance, and land availability may also play a role. The findings showed that, despite their slow adoption, solar water pumps offer chances for diversification.

Table 2. Wilcoxon Signed Ranks Test – Crop Quality (Before vs After Solar Water Pump Installation)

Comparison	Category	N	Mean Rank	Sum of Ranks
Crop Quality (After – Before)	Negative Ranks	0[a]	0.00	0.00
	Positive Ranks	271[b]	136.00	36856.00
	Ties	35[c]	-	-
	Total	306		
a: Negative Ranks: Crop quality after installation < crop quality before installation				
b: Positive Ranks: Crop quality after installation > crop quality before installation				
c: Ties: Crop quality after installation = crop quality before installation				
Z-value		–15.310		
Asymptotic Significance (2-tailed)(p-value)		0.000		

Table 3. Wilcoxon Signed Ranks Test – Crop Diversification (Before vs After Solar Water Pump Installation)

Comparison	Category	N	Mean Rank	Sum of Ranks
Crop Diversification (After – Before)	Negative Ranks	7[a]	75.50	528.50
	Positive Ranks	143[b]	75.50	10796.50
	Ties	156[c]	-	-
	Total	306		
a: Negative Ranks: Crop diversification after installation < crop diversification before installation				
b: Positive Ranks: Crop diversification after installation > crop diversification before installation				
c: Ties: Crop diversification after installation = crop diversification before installation				
Z-value		–11.104		
Asymptotic Significance (2-tailed)(p-value)		0.000		

Table 4. Wilcoxon Signed Rank Test – Plant Development (Before vs After SWP Installation)

Comparison	Category	N	Mean Rank	Sum of Ranks
Plant Development (After – Before)	Negative Ranks	0[a]	0.00	0.00
	Positive Ranks	270 [b]	135.50	36585.00
	Ties	36[c]	-	-
	Total	306		
a: Negative Ranks: Plant development after installation < plant development before installation				
b: Positive Ranks: Plant development after installation > plant development before installation				
c: Ties: Plant development after installation = plant development before installation				
Z-value		-15.294		
Asymptotic Significance (2-tailed) (p-value)		0.000		

Table 5. Wilcoxon Signed Ranks Test – Labour and Diesel Costs (Before vs After SWP Installation)

Comparison	Category	N	Mean Rank	Sum of Ranks
Labour and Diesel Costs (After – Before)	Negative Ranks	280 [a]	140.50	39340.00
	Positive Ranks	0 [b]	0.00	0.00
	Ties	26 [c]	-	-
	Total	306		
a: Negative Ranks: Labour and diesel costs < Labour and diesel costs before installation				
b: Positive Ranks: Labour and diesel costs after installation > Labour and diesel costs before installation				
c: Ties: Labour and diesel costs after installation = Labour and diesel costs before installation				
Z-value		-16.074		
Asymptotic Significance (2-tailed) (p-value)		0.000		

Impact of solar water pumps on plant development

The findings shown in Table 4 investigate how plant development is impacted by the installation of solar water pumps. Plant development improved significantly and statistically after solar water pumps were installed, according to the Wilcoxon Test. 36 respondents indicated no change, while 270 of the 306 respondents reported a positive shift in plant development, as evidenced by 270 positive ranks and no negative ranks.

The observed improvement in plant development was confirmed to be statistically significant and not the result of random variation by the Z-value (–15.294) and the highly significant p-value (p <.001) (Table 4). This outcome demonstrates how well solar water pumps promote plant growth, probably by offering a steady and dependable water supply that promotes healthy plant development, particularly during crucial growth stages.

Impact of solar water pumps on labour and diesel costs

The comparison of the labour and diesel costs associated with irrigation before and after the intervention is shown in Table 5. This factor revealed a significant reduction after the installation of solar water pumps, unlike the productivity measures. Out of the total, 280 farmers reported a reduction in the cost, 26 did not experience any changes, and no farmer faced any increase.

The result from the Wilcoxon Signed Ranks test gave a Z-statistic of -16.074 with p<0.001, indicating a highly significant decrease in operational costs (Table 5). This was attributed to the elimination or reduction in the use of diesel fuel and the minimized human labor needed to run solar-powered water pump systems. The significance of solar water pumps and their impact on harnessing solar power was exhibited in their ability to make water pump operations more cost-effective and less dependent on conventional forms of power.

Economic and production-related outcomes of solar water pump adoption in the study area

Based on Table 6, the information indicates that out of the 306 respondents, 69.3% noticed a considerable reduction in farm expenditures, whereas 27.5% noticed a slight reduction in farm expenditures following the installation of SWPs. Irrigation sessions per week improved for 94.8% of the respondents. Crop performance for the large number of respondents improved, where 61.1% noticed

Table 6. Impact of solar water pump usage-economic and production-related outcomes of solar water pump.

Response Category	Percentage
Impact on monthly farm expense	
No change	3.3
Reduced slightly	27.5
Reduced significantly	69.3
Total	100.0
X^2	148.62
p	0.000
Frequency of irrigation increased after SWP	
No	5.2
Yes	94.8
Total	100.0
X^2	241.75
p	0.000
Impact of SWP on crop	
No impact	4.6
Improved slightly	34.3
Improved Significantly	61.1
Total	100.0
X^2	132.48
p	0.000

Table 6 contd...

Response Category	Percentage
Impact on soil moisture	
Decreased	18.6
No change	10.1
Increased	71.2
Total	100.0
X^2	156.90
p	0.000
Impact on availability of irrigation	
Decreased	3.6
No change	13.7
Increased	82.7
Total	100.0
X^2	186.43
p	0.000
Has SWP lead to cultivate additional crops	
No	31.0
Yes	69.0
Total	100.0
X^2	56.78
p	0.000
Has SWP reduced dependency on rainfall	
No	5.9
Yes	94.1
Total	100.0
X^2	249.67
p	0.000
Impact on annual income	
No impact	3.9
Improved slightly	32.7
Improved Significantly	63.4
Total	100.0
X^2	138.92
p	0.000
Do you feel financially secure after adopting SWP	
No	7.2
Yes	92.8
Total	100.0
X^2	232.41
p	0.000
Did installation of SWP influence your decision to invest more in agriculture	
No	12.4
Yes	87.6
Total	100.0
X^2	180.56
p	0.000

considerable improvement, whereas 34.3% noticed slight improvement with chi-square values of 148.62, 241.75, 132.48, respectively and p value of 0.000. Conditions in the soil moisture were favourable for 71.2% of the farmers, with irrigation availability increased for 82.7%. Moreover, an increased percentage of farmers at 69% could grow supplemental crops, while 94.1% of the farmers could depend less on rainfall with chi-square values of 156.90, 186.43, 56.78 and 249.67, respectively and p value of 0.000.

Adoption of SWP practices was also important in increasing financial well-being, with 63.4% of farmers experiencing a significant increase in yearly income, while 92.8% of respondents felt financially secure. Moreover, 87.6% of farmers found that other farmers have been encouraged to invest more in agriculture, which shows that irrigation services have encouraged farmers to invest in agri-business with chi-square of 138.92 and 232.41, respectively and p-value of 0.000.

DISCUSSION

The high improvement in agricultural output, as indicated by most of the respondents, was a key finding. Most of the farmers depended on either rainfall or seasonal water sources, which would often dry up during the peak seasons for irrigation but later depended on solar water pump technologies. During critical stages of plant phenology, water stress would, therefore, be experienced, eventually hampering crop performance. With the aid of solar water pump technologies, farmers could, therefore, be able to enjoy an uninterrupted and reliable water supply source for the whole planting season. It is, however, widely accepted that water availability, through its ability to regulate soil moisture, promote nutrient uptake, and relieve physiological stress, remains one of the most critical determinants of agricultural productivity (FAO, 2016). This finds support from the statements offered by the respondents, who indicated that the continuous water supply increased agricultural output. According to a number of studies, including those by Burney et al. (2010), Hossain et al. (2014), Campana et al. (2015), and Ali et al. (2016), solar irrigation allows farmers to switch from shortfall irrigation to a secured water supply, which greatly boosts crop yields and cropping intensity.

The respondents also reported improvements in plant development and crop quality. Improvements in fruit size, color, hardness, and consistency were frequently observed by fruit farmers, particularly apple orchardists. This is consistent with well-established horticultural research showing that fruit quality characteristics including cell expansion, sugar accumulation, and color development are much improved when ideal moisture conditions are maintained during flowering and fruit-set stages. Timely and even irrigation improved marketable quality for growers of vegetables and paddy by reducing deformities and physiological abnormalities. These results verify that solar irrigation raises the market value of products in addition to increasing output volume. Reliable irrigation with solar pumps increases crop quality by boosting plant vigor and uniformity. The findings are in line with those of Hossain et al. (2014), Campana et al. (2015) and Ali et al. (2016). Recent research supports that maintaining optimal moisture during flowering and early fruit-set enhances fruit quality traits. Controlled irrigation and moderate water stress at key developmental stages improve sugar accumulation, size, and coloration in apples (Tao et al., 2023; Ananthakrishnan et al., 2025).

Additionally, a moderate but considerable increase in crop diversification was shown by the data. The positive trend is consistent with empirical findings that irrigation security encourages farmers to diversify into high-value crops, horticulture, and multi-cropping systems, even though the degree of diversification was less noticeable (than improvements in yield or plant development)

(Kumar et al., 2022). However, market access, land availability, agronomic knowledge, and farmers' risk preferences all have an impact on diversity in addition to irrigation; these factors may account for the increase in diversification, albeit not to the same degree as other factors. Therefore, different farmer diversification trends are consistent with global results that diversity is not entirely driven by irrigation technology alone. Amede (2014) and Hossain et al. (2014) reported similar results.

The sharp decline in labour and diesel prices was one of the biggest effects of solar water pump adoption. The decrease in these operating costs was statistically significant and practically significant. Previous research by Rana et al. (2021), Guno and Agaton (2022), Jovanoviæ et al. (2023), and Upadhyay et al. (2024) demonstrates that solar irrigation systems significantly lower operational costs, enhancing net farm revenue and long-term economic outcomes. The substantial cost savings also enhanced financial stability for small and marginal farmers, who are disproportionately affected by rising fuel prices. The study supports the findings of IRENA (2020), which said that farmers are encouraged to increase cultivated areas, diversify crops, and use modern inputs when irrigation reliability is increased.

CONCLUSION

The Wilcoxon Signed Rank Test results show that the installation of solar water pumps led to significant improvements in key agricultural parameters. Large negative z-scores with p-values of 0.000 for labour and diesel costs, agricultural output, productivity, diversification, and overall growth confirm highly significant differences between pre- and post-adoption conditions. Unfavourable ranks for labour and diesel expenses indicate substantial reductions in operational costs, while positive ranks for agricultural output, crop quality, and plant growth reflect notable gains in production. Positive diversification ranks further suggest that access to low-cost and reliable irrigation encouraged crop diversification. Overall, the findings confirm that solar water pumps enhance agricultural performance by reducing costs and improving productivity, making solar irrigation an economically viable technology for farmers.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents and their organisations regarding the study during the course of the data collection.

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.

Acknowledgements: The authors express sincere gratitude to the Indian Council of Social Science Research (ICSSR) vide file No.: 32/2024-25/SES/GEN/RP/ICSSR for providing the financial support and academic encouragement necessary for undertaking this research project. We deeply appreciate the support of Jammu and Kashmir Energy Development Agency (JAKEDA) and their invaluable cooperation and supplying the essential data that significantly contributed to the progress of this study. The authors extend their appreciation to the Division of Agriculture Extension and Communication, Faculty of Agriculture, SKUAST-Kashmir for providing crucial research-related documents, guidance and support that strengthened the quality and depth of this work. Their assistance has been instrumental in the smooth execution and completion of the project.

Data availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. Due to ethical considerations and farmer privacy concerns, individual-level data cannot be made publicly available. Aggregated data and analysis codes are available upon request for research purposes subject to appropriate data use agreements.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (66-73)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Exploring Livelihood Structures of Paddy Farmers in Koraput District of Odisha

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HIGHLIGHT

- Income, livestock and landholding jointly define the primary wealth dimension among farmers.
- PC1 (35.9%) separated older experienced farmers from younger educated farmers.
- PC2 (17.0%) quantified land, income and livestock inequality.
- PC3 (9.7%) captured behavioural differentiation in risk and innovation.
- Innovativeness and risk orientation emerged independent of wealth status.

ARTICLE INFO

Keywords: Livelihood, Paddy farmers, Principal component analysis, Risk orientation, Innovativeness.

https://doi.org/10.48165/IJEE.2026.62211

Citation: Saha, S., Patra, A., Reddy, M. D., Prusty, A. K., & Ghose, B. (2026). Exploring Livelihood Structures of Paddy Farmers in Koraput District of Odisha. *Indian Journal of Extension Education*, *62*(2), 66-73. https://doi.org/10.48165/IJEE.2026.62211

ABSTRACT

Despite the economic centrality of paddy cultivation in tribal districts of Odisha, empirical understanding of the latent socio-economic structures shaping farmers' livelihoods remains limited, with most studies relying on descriptive profiling rather than multivariate dimensional analysis. The study addresses that gap by applying Principal Component Analysis (PCA) to primary data collected in 2025 from 120 paddy farmers across four blocks of Koraput district, Odisha. Thirteen continuous socio-economic variables and five categorical attributes were transformed through one-hot encoding and standardized prior to analysis. The first principal component (35.9% variance) revealed an experience–education gradient distinguishing older, highly experienced but less formally educated farmers from younger, more educated counterparts. The second component (17.0% variance) represented a wealth–resource axis defined by income, livestock holdings, and land size. These components explained 52.9% of total variance, while subsequent components captured behavioural heterogeneity in risk orientation, innovativeness, and social participation. The findings demonstrate that livelihood differentiation in tribal paddy systems is structured along distinct socio-economic and behavioural axes rather than being uniform. By empirically identifying these gradients, the study provides a robust analytical foundation for designing stratified extension, credit, and capacity-building interventions tailored to differentiated farmer typologies in vulnerable agrarian regions.

INTRODUCTION

Paddy cultivation is one of the most vital agricultural activities in the world, serving as a primary source of food, employment, and livelihood security for millions of people, particularly across Asia and in countries like India where it plays a central role in agrarian economies. The term "paddy" refers to two species: *Oryza glaberrima,* which has many cultivated variants in West Africa and *Oryza sativa*, which comprises all paddy variations in Asia, Europe and America (Manful & Graham-Acquaah, 2016; Bharath et al., 2024). Odisha's agrarian economy and rural livelihood are primarily

Received 17-02-2026; Accepted 08-03-2026

dependent on paddy agriculture. Rice or paddy occupies 45% of all farmed land and employs more than 60% of the state's labour force, demonstrating its supremacy as the staple cereal and a vital source of food (Rout et al., 2025).

Approximately 94% of the state's total grain output comes from the 4.4 million hectares of paddy farming in Odisha, which makes up 91% of the cereal land. Odisha contributes 5.5% of India's total rice production (Saha et al., 2005). The production choices of the farmers and their ability to adopt new technology are influenced by their socioeconomic factors. Education, landholding size, income, family structure, social participation, inventiveness and risk-taking are some of the elements that have a significant impact on access to resources and receptivity to extension programs (Nayak, 2025). According to empirical data, smallholders' poverty is frequently prolonged by low asset ownership, weak market ties and a lack of institutional support, particularly in rainfed and tribal areas (Birthal et al., 2014). Despite many governmental initiatives aimed at boosting agricultural growth and farmer welfare, Odisha's backward districts, such as Koraput, continue to exhibit lower production and greater livelihood risk (Gual & Das, 2025).

In fact, rice is the most prevalent crop in Koraput's Jeypore tract, accounting for more than 40% of the farmed area (Chatterjee et al., 2025). This illustrates the paddy agro-ecological suitability for the area as well as its importance for local livelihood, culture and food security. Furthermore, it highlights the need for ecological sustainability through sustainable agriculture and organic farming, which reduce chemical inputs and support long-term soil and ecosystem health (Singh et al., 2024; Thangjam & Jha, 2024). Farmers' lives and agricultural productivity are greatly influenced by their social status. Several socioeconomic factors, such as income level, landholding size, education and credit availability affects a household's capacity to invest in inputs and adopt improved practices (Touch et al., 2024; Yadav et al., 2025). By improving farmers' comprehension and use of contemporary methods, education plays an empowering role. Similarly, increasing farm resilience and productivity necessitates having access to institutional funding. The welfare of farmers and agricultural productivity are typically restricted by limited financial resources (Shitaye et al., 2024; Khemundu & Majhi, 2026). The limited access to credit and financial services in the rural areas of this region prevents farmers from investing in quality seeds, fertilisers and modern equipment, thereby reducing agricultural productivity and adversely affecting their overall socioeconomic wellbeing (Baliwada et al., 2017; Kumar et al., 2023; Ullah et al., 2024; Hiranya & Joshi, 2025).

METHODOLOGY

The study examined the multidimensional livelihood structure of paddy farmers in Koraput district of Odisha and was purposively selected due to its predominantly tribal population, high dependence on rainfed paddy cultivation and documented livelihood vulnerability despite significant agricultural potential. Out of fourteen blocks in the district, four blocks Jeypore, Koraput, Semiliguda and Lamtaput, were purposively chosen based on their substantial concentration of paddy farmers. Two villages from each block were selected where paddy farming is the primary occupation. From each village, 15 farmers were selected using proportionate random sampling, resulting in a total sample of 120 respondents across eight villages. Primary data were collected in 2025 using a structured interview schedule. Thirteen continuous variables (age, income, landholding, livestock holding, farming experience, social participation, innovativeness and risk orientation) and five categorical variables (education, occupation, family size, family type and housing type) were measured to capture the diverse dimensions of farmers' livelihoods.

Prior to conducting Principal Component Analysis (PCA), the suitability of the dataset was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The overall KMO value was 0.77 indicating good sample adequacies. Bartlett's test was statistically significant ($\chi^2 = 500.669$, $p < 0.001$), confirming that the correlation matrix was appropriate for factor extraction. These results justified the appropriateness of the proceeding with PCA in the present study. Nominal categorical variables were converted into binary indicator variables using one-hot encoding prior to PCA, ensuring appropriate numerical representation without imposing artificial ordinal assumptions in the analysis. The primary goal of Principal Component Analysis is to minimise the dimensionality of a set of data, especially for data sets with many variables that reside in two-dimensional subspaces (Abdi & Williams, 2010). PCA is used to evaluate a set of data representing observations specified by correlated dependent variables. The goal is to extract meaningful information from the data and display it as a set of new orthogonal variables known as Principal Components (Karamizadeh et al., 2013). Categorical variables were transformed using one-hot encoding, and all variables were standardised prior to analysis to ensure comparability across scales.This technique enhanced the research findings by offering a comprehensive data-driven knowledge of complicated linkages within the dataset (Greenacre et al., 2022).

RESULTS

The socioeconomic profile contained 120 farmer observations and 13 original variables that included both continuous and categorical elements. Continuous measurements were made of age, livestock holding (number of animals), annual income, landholding size, agricultural experience, social participation, innovativeness (4–20 scale), and risk orientation. Five categories–education (ordinal coding 0/1/2, reflecting increasing formal education), occupation (categories 3/4/5, representing distinct occupational groupings), family size (1 = smaller; 2 = larger), family type (1/2, commonly interpreted as nuclear versus joint), and house type (2/3, indicating comparatively different housing quality) were transformed using one-hot encoding prior to multivariate reduction.Following encoding, the analytical matrix contained 14 derived features. The dimensional reduction showed that variation among farmers was primarily shaped by three interconnected dimensions: generational experience, resource endowment and behavioural orientation. Age and farming experience aligned along one dominant axis, separating older and highly experienced farmers from relatively younger and more formally educated farmers. A second major dimension reflected disparities in income, livestock ownership and landholding size, indicating clear inequality in economic positioning within the district. Behavioural attributes such as innovativeness and risk orientation

formed an additional axis, suggesting that adaptive capacity and openness to change were distributed independently of resource ownership. The clustering patterns observed in the reduced component space further demonstrated that farmers were stratified into distinct livelihood groupings rather than forming a homogeneous population. These findings established that socio-economic differentiation in Koraput district was structured along identifiable gradients, providing empirical evidence of livelihood heterogeneity among paddy farmers.

Table 1 presented the explained variance and cumulative variance associated with each principal component. PC1 accounted for 0.359 (about 35.9%) of the total variance. Inclusion of PC2 increased the cumulative variance explained to 52.9%. PC3 contributed 0.097, raising the cumulative variance to 0.626 (62.6). Subsequent components contributed progressively smaller proportions of variance: PC4 accounted for 0.083 (70.9% cumulative), PC5 for 0.064 (77.3%) and later components added marginal increments. By the seventh component, cumulative variance reached 0.875 and beyond the eighth component, the increase became minimal, with the cumulative variance approaching 1.000 by the PC14. The Sharp decline in explained variance after the initial components suggested that most of the structural variation among respondents was captured within the first three to five principal components, whereas later components contributed only limited additional explanatory power.

Table 2 presented "Top loadings for the first five principal components". Loadings represented the relative contribution of each original variable to the respective component, with the sign indicating the direction of association and the magnitude reflecting the strength of influence. PC1 was primarily characterised by positive loadings on age (0.44) and farming experience (0.44) and a negative loading on education (-0.42). High score on PC1 were therefore associated with older farmers possessing greater farming experience but lower levels of education, whereas lower PC1 scores corresponded to relatively younger and more educated farmers. PC2 showed that strong positive loadings for income (0.62) and livestock holding (0.59), along with moderate loading for land size (0.28). High score on PC2 were associated with greater income, large landholdings and higher livestock ownership, indicating a resource or wealth dimension. PC3 was defined mainly by positive loadings on risk orientation (0.56) and innovativeness (0.49) with a smaller contribution from age (0.38). Higher PC3 score associated with more risk-oriented and innovative farmers. PC4 exhibited a positive loading on social participation (0.54) and negative loadings on risk orientation (-0.45) and income (-0.45). Higher PC4 score were associated with greater social engagement and comparatively lower income and risk orientation. PC5 was characterised by a strong positive loading on innovativeness (0.64) and negative loadings on land size (-0.55) and social participation (-0.31). Higher PC5 Scores were associated with innovative farmers possessing relatively smaller landholdings and lower levels of social participation (-0.31). Higher PC5 scores were associated with innovative farmers possessing relatively smaller landholdings and lower levels of social participation.

Table 3 presented the mean PC1 and PC2 scores across categorical variables, indicating the positioning of different socio-demographic groups along the first two principal components. PC1 represented the experience–education dimension, while PC2 reflected the resource dimension. For education, categories 0, 1 and 2 recorded mean PC1 scores of 1.79, –0.38 and –2.10 respectively, demonstrating that lower education levels were associated with higher PC1 scores (older and more experienced), whereas higher education levels were associated with negative PC1 scores. Mean PC2 scores across education categories (0.15, –0.04 and 0.17) showed minimal variation, suggesting limited differences in resource endowment by schooling level. Occupational categories (3, 4 and 5) recorded mean PC1 scores of 0.35, –0.71 and –0.27 and mean PC2 scores of 0.15, 0.25 and –0.52 respectively, indicating that category 4 farmers possessed relatively higher resource levels but lower experience scores, while category 5 farmers exhibited

Table 1. Explained variance of principal components

PC	Explained variance	Cumulative variance
PC1	0.359	0.359
PC2	0.170	0.529
PC3	0.097	0.626
PC4	0.083	0.709
PC5	0.064	0.773
PC6	0.054	0.827
PC7	0.048	0.875
PC8	0.038	0.913
PC9	0.027	0.940
PC10	0.017	0.957
PC11	0.016	0.972
PC12	0.013	0.985
PC13	0.009	0.994
PC14	0.006	1.000

Table 2. Top loading for the first five principal components

PC	Dominant variable	Interpretation
PC1	Age (0.44), Farming experience (0.44), Education (-0.42).	Opposes older, experienced farmers against more educated farmers. High PC1 scores correspond to older, less educated farmers with long farming experience.
PC2	Income (0.62), Animals (0.59), Land size (0.28)	Represents the wealth dimension, a higher PC2 score reflects higher income, more livestock and land holding.
PC3	Risk orientation (0.56), Innovativeness (0.49), Age (0.38)	Differentiates risk-oriented, innovative farmers from more conservative ones.
PC4	Social participation (0.54), Risk orientation (-0.54), Income (-0.40)	Contrasts social engagement with risk aversion and income socially active farmers score high, whereas wealthier and more risk-oriented farmers score low
PC5	Innovativeness (0.64), land size (-0.55), social participation (-0.31)	Highlights an innovativeness versus land size axis innovative farmers with smaller holdings and lower social participation have high PC5 scores.

Table 3. Mean PC1 and PC2 scores for categorical variables

Category	Code	Mean PC1	Mean PC2	Interpretation
Education	0,1,2	1.79, -0.38, -2.10	0.15, -0.04, 0.17	Low education (code 0) aligns with higher PC1 (older, experienced); high education (code 2) has strongly negative PC1 scores. PC2 varies little across education levels.
Occupation	3,4,5	0.35, -0.71, -0.27	0.15, - 0.4, -0.17	Category 3 farmers are older and wealthier (positive PCs), category 4 shows the highest wealth but lower experience, category 5has lower wealth (negative PC2)
Size of family	1 (small) 2 (large)	-0.71, 0.38	-0.78, 0.42	Larger families cluster with positive PC1/PC2, implying more resources and experience. Smaller families have negative scores on both axes.
Types of family	1,2	-0.40, 0.05	-0.66, 0.08	Type 2 families (likely joint or extended) have slightly positive scores on both PCs, while type 1 families are negative on both axes.
Types of house	2,3	0.84, -0.84	-0.21, 0.21	Housing quality aligns strongly with PC1: household coded 2 (better house) have high PC1, whereas code 3 (poorer houses) have negative PC1

comparatively lower resource positioning. Family size also showed differentiation, with small families (code 1) recording mean PC1 and PC2 scores of –0.71 and –0.78, whereas large families (code 2) recorded 0.38 and 0.42, suggesting greater experience and resource alignment among larger households. Family type showed modest differences, with type 1 families recording –0.40 (PC1) and –0.66 (PC2), while type 2 families recorded 0.05 and 0.08 respectively. Housing type exhibited clear separation along PC1, with type 2 households recording 0.84 and type 3 households recording –0.84, indicating differentiation along the experience–education dimension; however, PC2 values (–0.21 and 0.21) suggested only marginal variation in resource ownership across housing types. Overall, the categorical groups demonstrated structured alignment along the dominant livelihood dimensions identified in the analysis.

The scree plot showed two key pieces of information for every principal component (PC), Individual explained variance (blue bars) – how much of the total variability each PC captures on its own. Cumulative explained variance (red dashed line) – the running total of variance captured up to that component. From the plot, PC1 accounts for roughly 36% of the variance, and PC2 adds about 17%, meaning the first two components together explain over half the variability in the data. PC3 contributes another ~10%. After PC3, the bars get much smaller, indicating that PCs 4–14 explain progressively less variance. The cumulative curve rises steeply at first and then flattens out; this "elbow" around PC3/PC4 is a common heuristic for selecting how many components to retain.

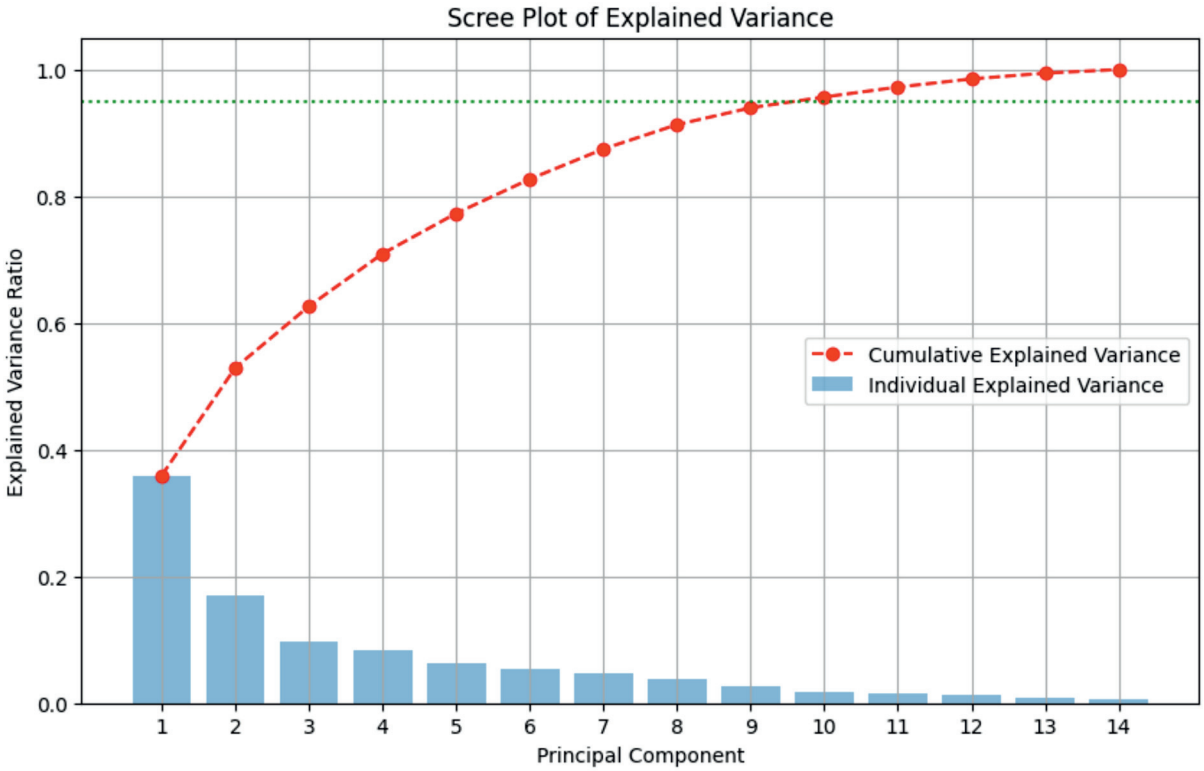

Figure 1. Scree plot of explained variance

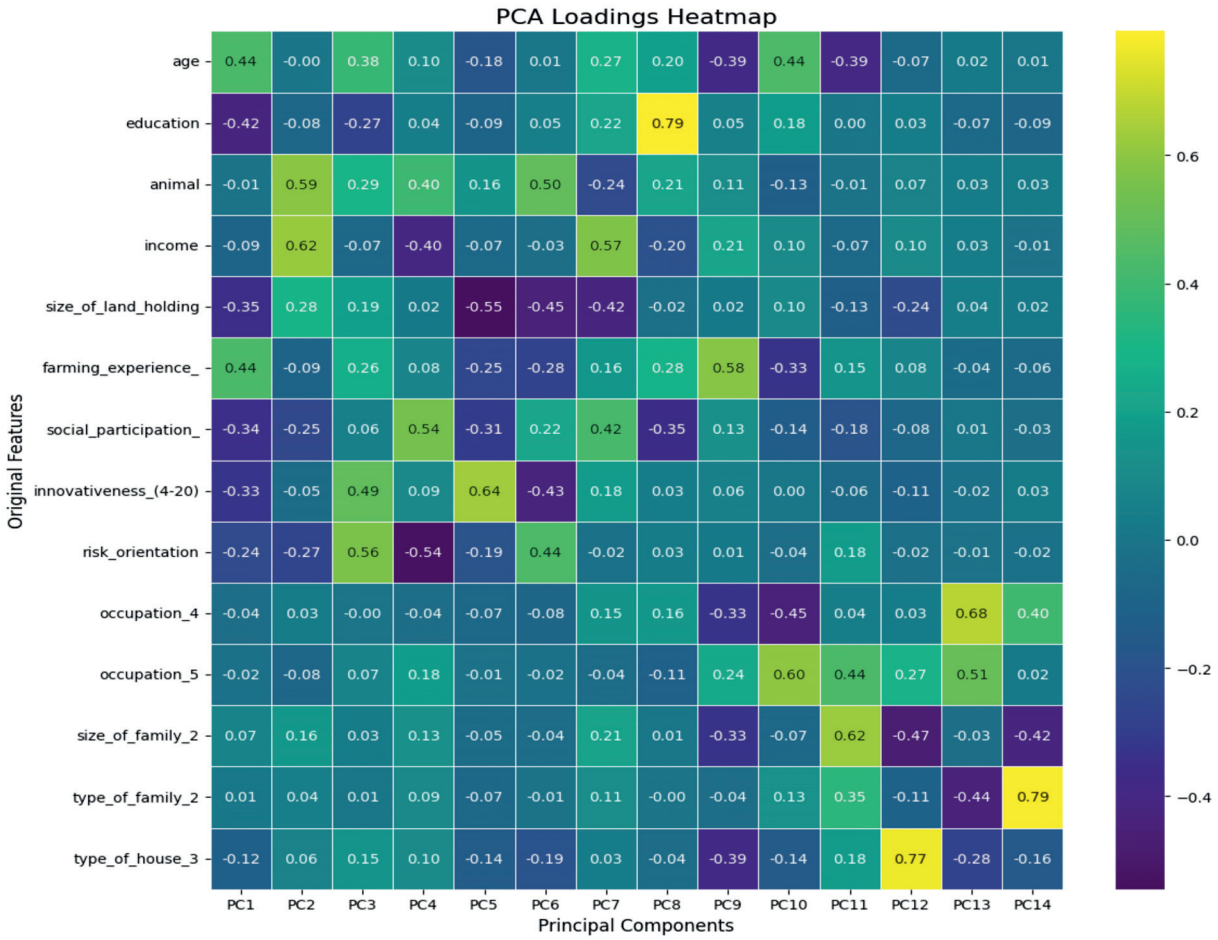

Figure 2. PCA Loadings heat map

By the time ten components are included, the cumulative variance exceeds 95/ %, but most of the structure is already captured in the first few.

The heat map displayed the loadings (weights) of each original variable on each principal component. Rows correspond to the original variables, and columns correspond to PCs. Colour intensity and sign convey the magnitude and direction of each loading (yellow/green for positive, blue for negative). PC1 has strong positive loadings on age and farming experience, and a strong negative loading on education. This confirms that PC1 contrasts older, experienced farmers with those who have more formal education. PC2 is dominated by income and animal, with smaller contributions from size of land holding. These positive loadings indicate that PC2 is essentially a wealth/resource axis.PC3 shows large positive loadings for risk orientation and innovativeness, distinguishing innovative, risk taking farmers from more conservative ones. Later components highlight more specialised patterns: for example, education loads heavily on PC12 (0.79), occupation_4 on PC13 (0.68) and type_of_family_2 on PC14 (0.79). These components capture variations specific to individual categories rather than broad socio economic trends. This heatmap also makes it clear that most categorical dummy variables contribute strongly to later PCs rather than to the first few, which is why the first components are driven largely by continuous socio economic variables.

The biplot overlays the scores of the observations (blue dots) onto the loading vectors (red arrows) for the first two principal components. It allows you to see how individuals cluster in the reduced space and how variables influence those positions. The horizontal axis (PC1) separates individuals by age/experience vs. education. Points to the right have higher age and farming experience and lower education; points to the left are more educated and often have poorer housing conditions (as indicated by the type of house arrow pointing left). The vertical axis (PC2) represents wealth and resources. Points higher up correspond to farmers with greater income, more animals and larger land holdings; points lower down have lower income and fewer resources. The arrows for income and animal are nearly vertical, indicating they load heavily on PC2 and minimally on PC1. The vector directions, arrows pointing in similar directions represent positively correlated variables. For example, income and animal arrows are close together, showing that these measures of wealth tend to increase simultaneously. Arrows pointing in opposite directions, such as age (right) and education (left), reflect negative correlations. Arrows at right angles (e.g., income vs. risk orientation) suggest little or no correlation between those variables in the original data. Most observations cluster around the origin, but there are notable groups: a right-hand cluster (older, less educated, more experienced farmers), an upper cluster (wealthier farmers with high income and livestock), and a lower-left cluster (more educated or smaller farmers with

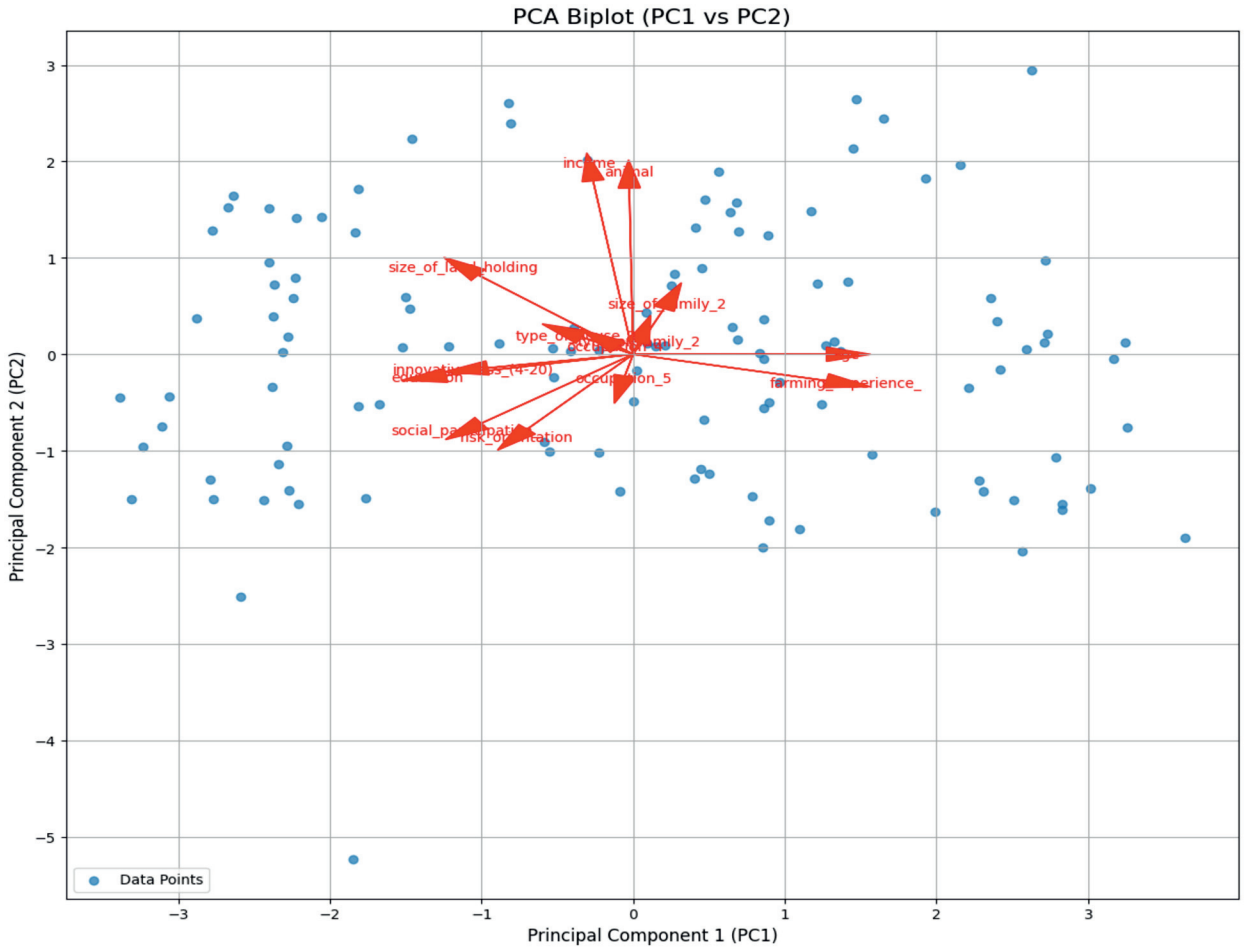

Figure 3. PCA Biplot

lower wealth). Outliers at the far right of the x axis correspond to farmers with very long experience and low formal education.

DISCUSSION

The present study, based on primary data collected from 120 paddy farmers in Koraput district, reveals that livelihood differentiation in this tribal agrarian region is socially structured rather than homogeneous. Although the first two principal components explained 52.9% of total variation, their importance lies in highlighting underlying socio-economic transitions within the district. The experience–education gradient reflects an ongoing generational shift in Koraput's farming communities. Older farmers, characterised by long farming experience but limited formal education, continue to depend largely on indigenous knowledge systems and traditional cultivation practices suited to rainfed conditions. Their decision-making is shaped by risk minimisation and ecological familiarity developed over decades. In contrast, younger farmers with comparatively higher formal education represent an emerging group exposed to modern information sources and institutional extension systems. However, many among them lack sufficient land and livestock assets. This generational divergence suggests a structural imbalance between experiential capital and formal human capital, influencing technology adoption patterns and engagement with government schemes.

The wealth–resource dimension identified through income, landholding and livestock ownership reflects economic stratification within tribal villages. In Koraput's predominantly rainfed and geographically remote blocks, asset ownership directly determines resilience against crop failure, price fluctuation and climatic variability. Farmers with larger landholdings and livestock possess greater livelihood security and diversification capacity, while small and marginal farmers remain vulnerable to indebtedness and seasonal income instability. These disparities are linked to broader structural constraints such as fragmented land inheritance, limited irrigation access and uneven penetration of institutional credit in tribal regions. Behavioural traits such as innovativeness and risk orientation further distinguish farmers beyond material resources. The presence of innovative and risk-taking individuals indicates latent entrepreneurial potential within the community. However, the observed contrast between social participation and economic strength suggests that wealthier or risk-oriented farmers may not necessarily be the most socially integrated. In tribal societies where collective norms, kinship networks and self-help groups influence agricultural decisions, weaker social engagement may restrict the diffusion of new practices. Strengthening farmer groups, cooperatives and village-level institutions therefore becomes critical to transform individual innovation into community-wide adoption. Family structure and housing conditions also reflect embedded socio-cultural realities.

Larger or joint families appear to have relatively stronger livelihood positioning, likely due to shared labour and pooled resources. Nuclear households, particularly younger ones, may face greater production risks and financial pressure. Housing quality acts as a visible indicator of socio-economic status and access to welfare schemes, reflecting uneven developmental outreach across remote villages.

Overall, the findings demonstrate that paddy farmers in Koraput cannot be approached as a uniform extension target group. Livelihood variation is shaped by generational transition, asset distribution and behavioural orientation within a tribal socio-cultural framework. Extension strategies must therefore be stratified and context-sensitive. Older farmers require participatory training that respects indigenous knowledge while introducing gradual technological improvement. Younger but resource-constrained farmers need credit linkage, market integration and entrepreneurship support. Innovative farmers can be mobilised as local opinion leaders to strengthen peer learning and horizontal knowledge exchange. By grounding multivariate evidence in the socio-economic realities of Koraput district, the study underscores the need for socially embedded, inclusive and differentiated extension approaches to strengthen paddy-based livelihoods in tribal regions.

CONCLUSION

The study reveals that paddy farmers in the Koraput district represent a socially and economically diverse community rather than a uniform group. Livelihood patterns are shaped by generational differences, unequal asset ownership and varying behavioural orientations. Older farmers rely strongly on experimental knowledge but have limited formal education, while younger farmers possess greater educational exposure yet often lack adequate productive resources. Economic disparities in landholding, livestock ownership and income significantly influence livelihood security in the districts' rainfed and tribal context. Behavioural traits such as innovativeness and risk orientation further differentiate adaptive capacity among farmers. These findings highlight the need for stratified and context-sensitive extension strategies. Programmes must combine indigenous knowledge strengthening for experienced farmers, institutional credit and market linkage support for resource-poor youth and leadership roles for innovative farmers to promote collective learning. Tailored interventions are essential for improving sustainable paddy-based livelihoods in Koraput and similar tribal regions.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection.

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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (74-78)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Small Tea Growers' Perception towards Pricing of Green Tea Leaves in Dibrugarh District of Assam

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HIGHLIGHTS

- 51.72% of small tea growers perceived pricing of tea leaves as unfair and 25.32% considered it highly unfair.
- Areas of cultivation and the number of selling options available to small tea growers have a significant positive correlation with their perception.
- Improved market infrastructure, automation of processing units, and regulation regarding the commission of tea agents may improve the pricing of green tea leaves.

ARTICLE INFO

Keywords: Tea pricing, Fairness, Perception, Small tea growers, Market infrastructure.

https://doi.org/10.48165/IJEE.2026.62212

Citation: Phukan, J., & Chakraborty, D. K. (2026) Small Tea Growers' Perception towards Pricing of Green Tea Leaves in Dibrugarh District of Assam. *Indian Journal of Extension Education*, *62*(2), 74-78. https://doi.org/10.48165/IJEE.2026.62212

ABSTRACT

Tea cultivation on a small scale plays a crucial role in employment generation in rural areas of Assam and has contributed a lion's share to the state's tea production. But the small tea growers (STGs) are facing many challenges, and a lack of fairness in the pricing of green tea leaves creates threats to their sustainability. The study assessed STGs' perception towards the pricing of green tea leaves in Dibrugarh district of Assam. 379 samples were selected purposively from 3 tea-producing blocks of the district, and data were collected using a structured interview schedule. STGs' perception towards pricing was examined with the help of a scale, calculated on the basis of 12 statements related to three approaches: distributive fairness, procedural fairness and interactional fairness. The market of green tea leaves was dominated by the buyers, where the STGs play a minimal role in price realisation.51.72% of STGs perceived the pricing of tea leaves as unfair, and 25.32% considered it highly unfair. Area of cultivation and the number of selling options were found to have a significant positive correlation with STGs' perception. Initiatives to improve market infrastructure and automation of processing units are needed to ensure a fair pricing mechanism.

INTRODUCTION

Tea cultivation on a small scale in Assam was introduced in 1978 and considered a prestigious source of livelihood in the rural areas (Gam & Deka, 2020). The Tea Board of India defines "a Small Tea Grower (STG) as a person who has a tea cultivation area of up to 25 acres or 10.2 hectares (ha)" (Sonowal, 2019). According to the Economic Survey, Assam (2024-25), there are 133,000 small tea growers in the year 2024 accounting for 295.35 million kg in production, which is almost 48% of the state's production. The tea cultivation in small scale covers 125802.83 ha of area under cultivation and provides direct and indirect employment to the rural areas of Assam. Dibrugarh district, also known as the tea city of Assam, has the highest number of small tea growers and contributes a major portion to the state's production. Despite the importance in the state's economy, the growers face many barriers (Panda et al., 2022). One of these barriers is a lack of a fair and remunerative pricing system. There are rapid price fluctuations of green tea leaves, and a significant gap exists between the price offered by the final consumers of tea and the price received by the growers (Das & Mishra, 2019). The real price of tea leaves begins to decrease with

Received 24-01-2026; Accepted 11-03-2026

periodic fluctuation due to low nominal price realization (Gam & Deka, 2020). The Tea Board of India had introduced a price- sharing formula that mandates the Bought Leaf Factories (BLFs) to allocate a fair price to STGs from the auction price of processed tea as per the prescribed 60:40 ratio to protect STGs, which was never implemented properly (Gogoi, 2023). A degree of monopsonistic exploitation of small tea growers by buyers of green tea leaves was observed (Das, 2019). The small tea growers have become passive price takers, as the price of green leaves is determined by BLFs, collection agents, and estate factories, leaving growers with little bargaining power (Kakoty & Kaurinta 2021).

But a fair and remunerative pricing is a necessary condition for the sustainability of farmers (Verma et al., 2025; Lahiri et al., 2024). Fairness in pricing is not only about the price of green tea leaves; it is associated with livelihood security, dignity and justice. Growers' positive perception regarding pricing is an essential determinant of the future of small tea cultivation in the study area. Hence, the perceptions and behavioural aspects of the small tea growers regarding the pricing of green tea leaves should be addressed. In this study, small tea farmers' perception towards the pricing of green tea leaves is assessed using the three approaches of fairness in pricing.

METHODOLOGY

The present study focused on assessing the perception of small tea growers towards the pricing of green tea leaf using three approaches of fairness in pricing. Dibrugarh district of Assam was selected because, according to the Tea Board of India, it is the top-most producer of tea in Assam and the highest numbers of registered small tea gardens (27347) were concentrated here, with 20572.52 ha, and small tea growers contributed 52% of total district production (Economic Survey, Assam, 2024-25). In July, 2024, data were collected using a multistage sampling technique. Among the 7 development blocks, 3 blocks – Lahowal, Panitola, and Tingkhong were selected purposively. Using the Krejcie and Morgan (1970) table for sample size determination, the sample size was determined to be 379. Sample sizes included 126 from Panitola, 126 from Lahowal, and 127 from Tingkhong. From each block, 12 tea-producing villages were taken randomly, and 10 to 15 samples were selected from each village at random. The survey was conducted by using a structured interview schedule. The STGs were asked to indicate their perception by giving scores accordingly: strongly agree = 5, agree = 4, neutral = 3, not agree = 2 and, strongly not agree = 1. STGs' perception towards pricing was examined by calculating a scale developed by Sarnaik et al. (2020) with a little modification to match the objective of the present study. The scale was calculated based on 12 statements constructed from three approaches to pricing fairness, i.e., distributive fairness, procedural fairness, and Interactional fairness (Machini et al., 2024). The internal consistency of these approaches was tested using Cronbach's Alpha. The obtained values (0.802, 0.841, and 0.847 respectively) were above the acceptable threshold of 0.70, indicating satisfactory reliability. A total score was calculated for each respondent, and based on the obtained score, the perception index was worked out with the help of the formula:

$$\text{Perception Index} = \frac{\text{Actual obtained perception score of respondent}}{\text{Maximum obtained perception score}} \times 100$$

The STGs were categorised into highly unfair, unfair, fair, and highly fair perceptions. The classification was carried out using the Cumulative Square Root Frequency (CSRF) method. 7 socio-economic variables were selected based on the relevance of these variables in the literature and growers' awareness, decision-making, and market participation. Pearson's simple correlation coefficient (r) was estimated to examine the direction of the relationship between STGs' perception and their socio-economic variables.

RESULTS

Socio-economic analysis revealed that 56.46% of respondents are in the 46-60 years age group. The majority of growers, i.e. 44.06% have studied to secondary level, and 45.38% STGs have a big family with 5-6 members. The results regarding farm activities showed that 78.62% of STGs have a tea cultivation area of less than 2 acres, and 32.45% growers earn 76-100% income from tea cultivation. 53.03 per cent of growers have above 20 years of experience in the said sector. The result of the post- harvesting operation revealed an interesting fact that, 53.03 per cent of the small tea growers have 1-2 selling options to sell their product

Small tea growers' perception towards the pricing of green tea leaves

In this study three approaches were used to understand STGs perception towards the fairness in pricing of green tea leaves (Table 1). These included distributive fairness, procedural fairness, and interactional fairness.

The analysis of the data in Table 1 indicated a significant lack of perceived distributive fairness among green tea leaf farmers, as all mean scores fell below the neutral midpoint of 3.0. The most critical finding was the very low mean of 1.84 regarding the price received compared to the final retail price, which suggested that farmers felt heavily exploited or undervalued within the broader supply chain. This sentiment was compounded by a lack of trust in quality-based price differentiation, with a mean of 2.12 and a shared belief that price risks were not equitably distributed among stakeholders, reflected by a mean 2.23. Furthermore, the results highlighted a precarious economic situation for the growers; the mean score for profit margin adequacy was 2.54, suggesting that earnings were often insufficient to cover cultivation costs or provide a decent living. The low mean score for price stability (2.25), combined with a low standard deviation (0.89), reflected a strong, consistent consensus that the market was unreliably volatile. Overall, the data on distributive fairness revealed a farming community that felt economically marginalised, bearing the highest burden of market risk while receiving the lowest share of the value created.

The results of perception of STGs on procedural fairness in the pricing of green tea leaves reflected a significant deficiency in procedural fairness in the pricing of green tea leaves. The four indicators, i.e. transparent price formula, documentation, voice, and grievance redressal, score poorly, which suggests a widespread issue rather than an isolated one. The result regarding the price-sharing

Table 1. STGs' perception on distributive, procedural and interactional fairness in tea leaf pricing

Approaches of fairness	Statements	Mean	Standard Deviation
Distributive fairness	The price I receive for green tea leaves is fair compared to the final retail price of the pack.	1.84	0.92
	My current profit margin is enough to cover the cost of cultivation and provide a decent living.	2.54	1.29
	The price risk is endured by all stakeholders of the supply value chain.	2.23	1.08
	The differentiated prices based on the quality of leaves are reasonable and fair.	2.12	1.02
	The price of green tea is stable and fluctuations can be predicted.	2.25	0.89
Procedural fairness	I always receive a formal written contract or document from the processing unit/tea agent regarding price and terms of payment.	2.17	1.34
	A clear and transparent price- sharing formula is practised.	1.86	0.90
	I feel I have a collective voice that helps me negotiate or bargain for a better price.	2.17	1.17
	I feel confident that if I file a grievance, it will be resolved fairly to resolve disputes.	2.16	1.16
Interactional fairness	The processing units/ Tea agents are honest and trustworthy.	3.14	1.46
	I receive timely and clear information about the price and the causes of fluctuation in price.	3.13	1.38
	Tea agents/ Factory staff treat me with respect and dignity	3.84	1.10

formula showed the lowest average score (1.865) and the lowest standard deviation (0.909), which suggested that most of the growers find it unclear and unfair. Another statement was regarding a formal, written contract for the price and payment terms, which also showed a negative perception with a mean of 2.174, indicating it as an unfair aspect, and the wide spread in responses, standard deviation value of 1.344, implied that some growers get contracts while many others do not. Growers also felt that they had less bargaining power when it came to negotiating a better price (2.172) and lacked confidence that any disputes would be resolved fairly (2.169).

The perception regarding interactional fairness in pricing of green tea leaves was better compared to distributive and procedural fairness. The sample STGs reported good treatment from the processing units and tea agents, with a mean of 3.84 above the neutral response. The results regarding informational fairness, i.e. clarity and timeliness of data and trustworthiness, were slightly positive above the neutral, with a mean of 3.13 and 3.14, respectively. But they had high dispersion values, i.e. 1.388 and 1.455, which indicated a lack of uniformity in the experience of interactional fairness in the study area. A perception score was calculated for each respondent and based on the obtained score, the perception index was worked out using the formula mentioned in the methodology. Here, the maximum obtained perception score is 60, minimum perception score is 12. After calculating the perception index for each respondent, the STGs are grouped into four categories on the basis of perception index using the Cumulative Square Root Frequency (CSRF) method shown in Table 2.

Table 3 showed that a significant portion of STGs, especially 51.72% perceived the pricing of green tea leaves as unfair, and 25.32% considered it highly unfair. Only 13.98% of the STGs perceived the pricing of green tea leaves as fair, and 8.97% judged it as highly fair.

Table 2. STGs' Perception towards fairness in the pricing of green tea leaves

Category	Strata	Frequency	Percentage
Highly Unfair	40-49	96	25.32
Unfair	50-59	196	51.72
Fair	60-69	53	13.98
Highly fair	70-above	34	8.97

Correlation between demographic and farm variables with perception of STGs towards fairness in pricing of green tea leaves

The correlation analysis was conducted to examine the relationship between selected demographic and farm characteristics of respondents and their perception towards fairness in tea leaf pricing to assess how individual and farm characteristics shape small tea growers' perception regarding pricing fairness. These included age, education, area of cultivation, selling options, income, family size, and years of experience. The selection of these variables was based on their relevance in literature and growers' awareness, decision-making, and market participation.

Table 3. Correlation between demographic and farm variables with perception of STGs towards fairness in pricing of green tea leaves

Demographic and farm variables of respondents	Correlation	P value
Age	-0.216	0.076
Education	-0.194	0.095
Area of cultivation	0.256	0.013*
Selling options	0.237	0.002*
Income	0.189	0.341
Family size	-0.312	0.156
Year of experience	-0.345	0.197

*Significant at the 0.05 level of probability

Area of cultivation and selling options exhibited a significant positive correlation with STGs' perception towards pricing of green tea leaves, with p value less than 0.05.

DISCUSSION

The results reveal a predominantly negative outlook on the pricing of green tea leaves. More than 75% of the growers consider the pricing process unfair. The STGs are not satisfied with the

distributive and procedural approaches of fairness compared to interactional fairness. The results are found to be fair in terms of interpersonal treatment, i.e. respect and dignity of growers in the process of pricing of green tea leaves. It is found that the market of the green tea leaves is dominated by the buyers, where the STGs play a minimal role. The cartel of processing units has a strong influence on the supply chain of green tea leaves. Though many of them do not have their own tea plantation, they can dictate the price. The results show that, they fix the price without a specific formula and are not transparent regarding the price formulation process. Kakoty and Kaurinta (2021) found similar result in their study that the pricing decision of green tea leaves is controlled by a cartel of BLFs, collection agents and large estate factories where the growers are considered as the price takers. Marchini et al. (2024); Hazari et al. (2023) pointed out that the weak position of farmers in the supply chain is a very crucial issue that prevents them from obtaining a good price for their product. Kagira et al. (2012) and Ghosh et al. (2017) also found that the small tea growers frequently receive prices lower than the justified market value and faced market vulnerabilities due to a lack of direct market access, limited institutional support, poor organisational strength, weak infrastructure, and insufficient transparency in the pricing process. According to Lahiri et al. (2025) small-scale production, lack of storage, and seasonal fluctuations are major constraints that reduce bargaining power. Mano Raj (2021) also found poor bargaining power as one of the factors that exacerbated STGs' market vulnerabilities.

The correlation of STGs' perception with area of cultivation is positive and significant. It indicates that with an increase in the area of cultivation, the growers perceive the pricing process as fairer compared with the growers with a relatively small area of cultivation. The growers with less area of cultivation are found to be less organised and confident, which makes their perception towards the pricing of green tea leaves unfair. Similarly, the growers having many selling options considered the pricing process fair. On the other hand, the growers with fewer selling options perceived the process as unfair. Das and Das (2022) also found that the small tea growers who have only a single sales option are exploited more by the buyers than those with multiple sales options of green tea leaves.

CONCLUSION

The present study reveals a predominantly negative perception towards the pricing of green tea leaves. The position of small tea growers is weaker in the supply value chain of tea compared to processing units and tea agents, and they need urgent attention from policymakers. Initiatives should be taken to improve market infrastructure, automation of processing units, and regulation regarding the commission of tea agents, which will reduce the dominance of buyers over small tea growers. Diversification of farms, establishment of co-operatives, and contract farming, help increase living income and strengthen the collective bargaining capacity of growers. The government should initiate a robust mechanism to align growers and processors for fair price realisation, and can also introduce a Minimum Support Price to protect the marginal growers from severe price fluctuations.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents and their organisations regarding the study during the course of the data collection.

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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (79-85)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Factors Influencing Agricultural Diversification: The Case of Northern Bangladesh

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HIGHLIGHTS

- Simpson's Index of Diversity showed that 85.1% of farmers in northern Bangladesh exhibited low to medium levels of agricultural diversification.
- Decision-making ability, risk orientation, credit-seeking behavior, extension media contact, and market accessibility positively influenced agricultural diversification.
- Farm size was the only factor found to have a significant negative influence on agricultural diversification.

ARTICLE INFO

Keywords: Simpson's index of diversity, Multiple linear regression, Smallholder farmers, Extension media contact, Market accessibility.

https://doi.org/10.48165/IJEE.2026.62213

Citation: Rashid, M. M., Mondol, M. A. S., Rahman, M. S., & Jackson, T. (2026). Factors Influencing Agricultural Diversification: The Case of Northern Bangladesh. *Indian Journal of Extension Education*, *62*(2), 79-85. https://doi.org/10.48165/IJEE.2026.62213

ABSTRACT

Agricultural diversification has significant positive impacts, including generating more rural employment and higher incomes, creating new market opportunities, improving nutritional standards, and empowering women. However, due to socio-economic, psychological, communicational, technological, infrastructural, and climate aspects, farmers' agricultural diversification decisions are poorly understood. The study aimed to measure the extent of agricultural diversification and the influence of selected factors on it in northern Bangladesh in 2024. A multi-stage sampling method was utilized to pick 348 participants from the northern districts of Kurigram, Thakurgaon, and Dinajpur in Bangladesh. Simpson's Index of Diversity results indicate that 85.1% of farmers had low to medium agricultural diversification, with the overall diversification level in northern Bangladesh ranging from 0.534 to 0.665. Multiple Linear Regression model reveals that decision-making ability, risk orientation, credit-seeking behavior, extension media contact, and market accessibility had a positive effect on agricultural diversification, whereas farm size was found to negatively influence the adoption of agricultural diversification. Based on these findings, it is recommended that extension agencies and policymakers consider these factors when designing and implementing agricultural diversification programs in northern Bangladesh. Further research is suggested to explore smallholder farmers' preferences for agricultural diversification in the region.

INTRODUCTION

Agriculture continues to play a central role in Bangladesh's rural economy by providing livelihoods, ensuring domestic food supply, supplying raw materials for agro-based industries, and generating rural employment (Australian Centre for International Agricultural Research [ACIAR], 2024; International Food Policy Research Institute [IFPRI], 2024). Nearly two-thirds of the rural population is directly engaged in agricultural production (World Bank, 2016), and farm households are commonly categorized as landless, marginal, small, medium, and large based on landholding status (Department of Agricultural Extension [DAE], 1999). Smallholders dominate the sector; about 84% of farming households cultivate less than one hectare and largely depend on rice-based

Received 04-02-2026; Accepted 11-03-2026

production systems (Islam et al., 2018; De Pinto et al., 2019). Although agriculture contributes only 11.61% to national GDP, it remains vital to rural livelihoods, supporting over 50% of employment and sustaining nearly 70% of households (Bangladesh Bureau of Statistics [BBS], 2023a; Imdad, 2021).

Bangladesh's agriculture is increasingly constrained by climate change–induced hazards and persistent socio-economic challenges that undermine productivity and threaten food security (Mondal, 2010; Ghose, 2014; Sheikh & Pervez, 2025). Erratic rainfall, droughts, heatwaves, floods, and riverbank erosion are particularly severe in northern Bangladesh, including the Barind Tract and the Tista and Jamuna–Brahmaputra basins. These vulnerabilities intensify production risks for smallholder farmers, contributing to persistent poverty and high food insecurity; the Rangpur Division reports approximately 29.98% of the population experiencing moderate or severe food insecurity (BBS, 2023b). In response, agricultural diversification has been promoted to enhance farm resilience, stabilize income, and improve rural livelihoods. The Government of Bangladesh emphasizes diversification through high-value crops, livestock, poultry, and fisheries, supported by improved seed systems, irrigation expansion, credit access, and extension services (Miah et al., 2013; De Pinto et al., 2019; United Nations Country Team, 2022; Nandi et al., 2024). Diversification reduces dependence on a single crop, expands income opportunities, and strengthens adaptive capacity under climatic and market uncertainties (Winters et al., 2006; Mastura et al., 2023). In Bangladesh, diversification typically involves a shift from rice monoculture toward non-rice crops, fruits and vegetables, and integrated crop–livestock–fisheries systems (Mastura et al., 2023).

Despite policy emphasis, rice dominates cropping systems, occupying about 75% of cropped land and over 80% of irrigated areas (Bangladesh Rice Research Institute [BRRI], 2023). In northern Bangladesh, Boro rice–Fallow–T. Aman rice rotations account for over half of cultivated land (International Rice Research Institute [IRRI], 2024). Nevertheless, diversification is gradually increasing, though trends fluctuate and vary spatially (Brown et al., 2023; Rashid et al., 2024; Nandi et al., 2025). Empirical evidence shows diversification can enhance farm income, employment, dietary diversity, food security, and women's economic participation (Joshi et al., 2004; Abro & Sadaqat, 2010; Islam et al., 2024; Nahar et al., 2024; Jannat et al., 2025). However, farmers' diversification decisions are shaped by socio-economic, psychological, institutional, and ecological factors, including age, education, farm size, irrigation access, labor, credit, markets, and extension services (Rashid et al., 2024; Nahar et al., 2025).

Although global studies on agricultural diversification are extensive (Rai, 2015; Bharadwaj, 2019; Kumari, 2021; Mukherjee, 2021; Dudhatara et al., 2022; Rathod, 2023; Nepali et al., 2024; Shekhar et al., 2024), evidence from Bangladesh, especially in agro-ecologically vulnerable riverine basins, remains limited. Most studies focus mainly on crop diversification, with less attention to integrated enterprises and drivers of farmers' decisions. Addressing this gap, the present study assesses the level of agricultural diversification among farm households in northern Bangladesh and identifies the key factors influencing diversification choices, with implications for extension strategies, policy interventions, and sustainable rural development.

METHODOLOGY

This study was conducted in the Kurigram, Thakurgaon, and Dinajpur districts, representing the three primary zones: Charland, Upland, and Barind Tract of northern Bangladesh. A multi-stage sampling method was applied to select 348 respondents using Yamane's (1967) formula. Data were collected via in-person interviews conducted by local enumerators from August to December 2024.

To assess agricultural diversification, which was the first objective, Simpson's index of diversity appeared to be an appropriate choice for this study because of its computational simplicity, robustness, and wider applicability (Dudhatara, 2021; Khatun & Roy, 2012). Therefore, this study employed the Simpson's Index of Diversity (SID) to assess the extent of agricultural diversification among the selected farm households in northern Bangladesh. According to Addisu (2017), the SID is influenced by both the number of income sources (richness) and the proportion of income from each source (evenness or balance). Considering this, the income of different agricultural activities was categorized into five (Cereals, field crops, horticulture crops, livestock, and fisheries) for computing agricultural diversification.

$$SID = 1 - \sum_{i=1}^{n} p_i^2$$

Where, SID is Simpson's Index of Diversity, n is the number of income sources, and p_i is the proportion of income coming from the i^{th} income source. Accordingly, Agricultural Diversity Index (ADI) was estimated using the equation as follows:

$$ADI = 1 - \sum_{i=1}^{N} \{(\frac{A}{Ti})^2 + (\frac{B}{Ti})^2 + (\frac{C}{Ti})^2 + (\frac{D}{Ti})^2 + (\frac{E}{Ti})^2\}$$

Where, Ti = Total household income, A = Income from cereal crops, B = Income from field crops, C = Income from horticulture crop, D= Income from livestock and E = Income from fisheries. ADI scores range between 0 and 1; a value of zero (0) denotes perfect specialization, while a value of one (1) denotes perfect agricultural diversification.

The second objective was to examine the influence of selected factors on agricultural diversification. Based on prior studies, 15 explanatory variables were hypothesized, categorized as: socioeconomic factors (age, education, family size, farm size, experience, non-agricultural income, irrigation intensity, mechanization), psychological factors (decision-making ability, risk orientation, attitude toward diversification), and institutional factors (social participation, credit-seeking behavior, extension media contact, market accessibility). The influence of these factors was explored in three steps: first, correlation analysis; second, the multiple linear regression; and finally, the stepwise multiple regression. The similar steps were followed by Mishra et al. (2025), Jayasingh and Mishra (2024), Rahman et al. (2024), and Shahin et al. (2024) to explore the influence of selected factors in their respective studies.

RESULTS

Extent of agricultural diversification practiced by farmers

The extent of agricultural diversification practiced by farmers in northern Bangladesh was measured using the Agricultural

Diversification Index (ADI), as presented in Table 1. The average ADI value across the three situations was 0.599, indicating a medium level of agricultural diversification in the study area.

Table 1. Distribution of the respondents according to their agricultural diversification index

Categories	Respondents (n=348)	
	Frequency	Percentage
Low diversification (≤0.533)	55	15.8
Medium diversification (0.534-0.665)	241	69.3
High diversification (>0.665)	52	14.9
Observed range	0.314-0.749	
Mean	0.599	
SD	0.066	

Table 2. Relationship of independent variables with agricultural diversification

Dependent variable / Independent variables	Coefficient of correlation (r)
Agricultural diversification	
Age (X_1)	0.058
Educational qualifications (X_2)	0.162**
Family size (X_3)	0.165**
Farm size (X_4)	-0.341**
Farming experience (X_5)	0.201**
Non-agricultural income (X_6)	-0.075
Irrigation intensity (X_7)	0.025
Farm mechanization (X_8)	-0.028
Decision making ability (X_9)	0.445**
Risk orientation (X_{10})	0.438**
Attitude towards agricultural diversification (X_{11})	0.188**
Social participation (X_{12})	0.178**
Credit seeking behavior(X_{13})	0.387**
Extension media contact (X_{14})	0.466**
Market accessibility (X_{15})	0.482**

** Significant at 0.01 level; tabulated value (r) = 0.138 & with 346 d.f

Table 1 also shows that 69.3 percent of farm families were classified as having medium agricultural diversification, followed by 15.8 percent with low diversification and 14.9 percent with high diversification. The probable reason for these findings might be that the farmers had small farm sizes, but they had adequate cropping intensity, which reflects the efficient use of farmland. It is also important because the majority of the respondents depend on farm produce to ensure household food security.

Factors influencing the agricultural diversification

The influence of selected factors on agricultural diversification was examined in three stages: correlation analysis, multiple linear regression, and stepwise multiple regression. Initially, Pearson's correlation coefficient (r) was estimated to test the null hypothesis regarding the relationships between agricultural diversification and the selected explanatory variables. The results of the correlation analysis indicate (Table 2) that, out of the fifteen variables considered, eleven were significantly correlated with agricultural diversification, namely educational qualification (r = 0.162), family size (r = 0.165), farm size (r = –0.341), farming experience (r = 0.201), decision-making ability (r = 0.445), risk orientation (r = 0.438), attitude towards agricultural diversification (r = 0.188), social participation (r = 0.178), credit-seeking behavior (r = 0.387), extension media contact (r = 0.466), and market accessibility (r = 0.482).

The correlation analysis can only show the direction of the relationships between variables; it is unable to highlight their influences (Sarmin & Hasan, 2019). So, these eleven variables were incorporated in multiple regression analysis (both enter and stepwise methods) to ascertain the extent to which various explanatory variables influenced agricultural diversification. The results of the multiple regression analysis are presented in Table 3. Prior to regression modelling, the Variance Inflation Factor (VIF) was employed to assess multicollinearity among the explanatory variables. The results indicated that multicollinearity was not a concern, as all VIF values were below 5.0 and tolerance values exceeded 0.25 (James et al., 2021).

Table 3. Multiple Linear Regression (MLR) with significant factors on agricultural diversification

Variable codes	Independent variables	Unstd. co-efficient B	Std. co-efficient Beta	t-values	Sig. level	Collinearity statistics	
						Tolerance	VIF
X_2	Educational qualifications	0.001	0.053	1.189	0.235	0.743	1.346
X_3	Family size	0.002	0.058	1.418	0.157	0.874	1.144
X_4	Farm size	-0.032	-0.210	-5.141	0.000	0.869	1.151
X_5	Farming experience	0.000	0.060	1.412	0.159	0.812	1.232
X_9	Decision making ability	0.003	0.244	5.932	0.000	0.861	1.161
X_{10}	Risk orientation	0.002	0.169	3.622	0.000	0.671	1.490
X_{11}	Attitude towards agricultural diversification	0.000	0.026	.613	0.541	0.793	1.261
X_{12}	Social participation	-0.002	-0.035	-.797	0.426	0.749	1.335
X_{13}	Credit seeking behavior	0.004	0.123	2.710	0.007	0.706	1.417
X_{14}	Extension media contact	0.003	0.153	3.216	0.001	0.645	1.551
X_{15}	Market accessibility	0.007	0.229	5.221	0.000	0.756	1.322

Constant = 0.344, R= 0.715, R^2 =0.512, Adjusted R^2 =0.496, F value=32.019, P= 0.000

Table 4. Step-wise multiple regression analysis showing contributing variables to agricultural diversification (n = 348)

Model	Independent variables (X)	Unstd. Coeff. (B)	Std. Coeff. (β)	R^2 change	t-value	Sig. F change
Constant+ X_{15}	Market accessibility (X_{15})	0.008	0.248	0.232	5.868	0.000
Constant+ X_{15}+X_9	Decision making ability (X_9)	0.003	0.240	0.121	5.885	0.000
Constant+ X_{15}+X_9+X_{14}	Extension media contact (X_{14})	0.004	0.175	0.069	3.869	0.000
Constant+ X_{15}+X_9+X_{14}+X_4	Farm size (X_4)	-0.031	-0.201	0.037	-5.090	0.000
Constant+ X_{15}+X_9+X_{14}+X_4+ X_{10}	Risk orientation (X_{10})	0.002	0.181	0.033	4.142	0.000
Constant+ X_{15}+X_9+X_{14}+X_4+ X_{10}+ X_{13}	Credit seeking behavior (X_{13})	0.004	0.122	0.012	2.818	0.000

Constant = .359, R= 0.709, R^2 = 0.503, F value= 57.522, P=0.000

The results of the multiple linear regression analysis indicate that only six variables farm size, decision-making ability, risk orientation, credit-seeking behavior, extension media contact, and market accessibility had a statistically significant influence on agricultural diversification in northern Bangladesh. The coefficient of determination (R^2) revealed that all independent variables together explained 51.2% of the variation in agricultural diversification. The adjusted R^2 value indicates that 49.6% of the variation in agricultural diversification is explained by the variables included in the model. The F-statistic (32.019) was significant at $p < 0.001$, confirming the overall significance of the regression model.

The results further suggest that farmers with smaller farm sizes and higher levels of decision-making ability, risk orientation, credit-seeking behavior, extension media contact, and market accessibility exhibited a greater extent of agricultural diversification. To assess the relative contribution of these significant predictors, the six variables (X_4, X_9, X_{10}, X_{13}, X_{14}, and X_{15}) were subsequently included in a stepwise regression analysis, and the results are presented in Table 4.

The stepwise regression analysis indicates that the farmers' market accessibility was found to have a great influence and accounted for 23.2% of the total variation in the extent of agricultural diversification. The other factors, in order of their extent of contribution, were decision-making ability (12.1%), extension media contact (6.9%), farm size (3.7%), risk orientation (3.3%), and credit-seeking behavior (1.2%).

DISCUSSION

The predominance of medium-level agricultural diversification observed in this study may be attributed to small landholdings, relatively high cropping intensity, efficient use of limited farm resources, and strong reliance on agriculture for household food security. Under such conditions, diversification functions mainly as a risk-management strategy rather than a pathway to specialization. Farmers' moderate to high levels of risk orientation, decision-making ability, and access to extension services, credit, and markets likely facilitated diversification. These findings align with earlier studies reporting a dominance of medium-level diversification (Miah et al., 2013; Rai, 2015; Bharadwaj, 2019; Kumari, 2021; Dudhatara et al., 2022; Rathod, 2023; Shitu et al., 2024). However, the results contrast with Bagri (2020), who reported that nearly half of the farmers in Panna district, Madhya Pradesh, belonged to the low diversification category. Such differences may reflect variations in agro-climatic conditions, institutional support, market access, and resource endowments. Recent studies from Bangladesh and the Eastern Gangetic Plains also report moderate diversification shaped by socio-economic and institutional factors (Nahar et al., 2024; Islam et al., 2024; Jackson et al., 2025; Nandi et al., 2025), underscoring the context-specific nature of diversification.

Among the explanatory variables, market accessibility exerted the strongest positive influence on agricultural diversification, accounting for approximately 23.2% of the variation. Improved rural infrastructure, transport facilities, and communication technologies in Bangladesh have increasingly connected farmers to markets, enabling better price realization, timely information flow, and access to diversified input–output channels. Similar positive relationships between market access and diversification have been documented by Jackson et al. (2025) and Reddy (2019) for livelihood diversity, Kavitha (2021) for integrated farming systems, Rehan (2020) for on-farm diversification, and Chowdhury (2017) for vertical crop diversification.

Farmers' decision-making ability was another significant determinant, contributing about 12.1% to diversification. This likely reflects improved access to information, education, farming experience, and exposure to new technologies, which facilitate informed production choices and encourage a shift from subsistence-oriented to market-oriented farming systems. Rahman (2008), Nain and Kumar (2010) similarly reported that education and farming experience enhance farmers' crop choice behavior, thereby supporting diversification and commercialization.

Regression results further revealed that extension media contact had a positive and statistically significant influence, explaining approximately 6.9% of the variation in diversification. This effect may be attributed to the sustained efforts of governmental and non-governmental organizations in disseminating agricultural information and advisory services. In Bangladesh, extension contact has been shown to play a crucial role in shaping farmers' production decisions and adoption of diversified practices (Rahman, 2009). Comparable findings have been reported in India by Rai (2015), Bharadwaj (2019), Bagri (2020), Kumari (2021), Dudhatara et al. (2022), and Rathod (2023). Recent evidence also highlights that frequent extension interactions enhance adoption of diversified and integrated farming systems (Islam et al., 2024; Nahar et al., 2024; Jackson et al., 2025).

In contrast, farm size had a significant negative effect on agricultural diversification, accounting for about 3.7% of the variance. Larger farms often concentrate on a limited number of high-yield or commercially profitable crops, whereas smaller farms diversify to reduce production risks, ensure household food security, and generate multiple income sources. This inverse relationship is supported by

studies from Bangladesh (Rahman, 2009; Islam & Hossain, 2017) and other contexts (Pfeifer et al., 2009; Kankwamba et al., 2018; Dudhatara et al., 2022; Kumari, 2021; Felix & Ramappa, 2023; Rathod, 2023). Similar patterns have also been observed in livelihood diversification studies (Pal et al., 2017; Nirmala et al., 2024).

Risk orientation positively and significantly influenced diversification, explaining approximately 3.3% of the variation. Farmers with higher risk tolerance are more willing to adopt diversified enterprises to cope with climate variability, income uncertainty, and food security challenges. Previous studies in Bangladesh and India also confirm the role of risk perception in shaping diversification decisions (Rahman, 2009; Islam et al., 2017; Rai, 2015; Bharadwaj, 2019; Bagri, 2020). Credit-seeking behavior likewise showed a positive, though smaller, contribution, reinforcing evidence that access to financial resources enables farmers to invest in diversified production systems (Rashid et al., 2024; Rai, 2015; Bagri, 2020; Rathod, 2023).

CONCLUSION

The extent of agricultural diversification in northern Bangladesh was moderate, with 85.1% of farmers exhibiting low to medium levels of diversification. Correlation analysis revealed that educational qualification, family size, farming experience, decision-making ability, risk orientation, attitude towards agricultural diversification, social participation, credit-seeking behavior, extension media contact, and market accessibility had significant positive relationships with agricultural diversification, while farm size showed a significant negative relationship. The multiple linear regression analysis further identified six key determinants-farm size, decision-making ability, risk orientation, credit-seeking behavior, extension media contact, and market accessibility as having a significant influence on diversification. Overall, higher diversification was associated with smaller farm size and stronger institutional and behavioral capacities. Therefore, extension agencies and policymakers should prioritize these factors with particular emphasis on smallholder farmers when designing and implementing agricultural diversification programs in northern Bangladesh and similar agro-ecological contexts.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents and their organisations regarding the study during the course of the data collection.

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.

Acknowledgement: The authors are grateful to the ACIAR-funded "Transforming Smallholder Food Systems in the Eastern Gangetic Plain (RUPANTAR) Project" for funding this PhD Fellowship. In addition to the project's financial support, the authors thank everyone who helped accomplish this research.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (86-93)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Bibliometric Analysis of Research Trends and Growth in Farm Media and Agricultural Journalism

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HIGHLIGHTS

- Farm media research grew steadily from 2005 to 2024, with accelerated growth after 2018 due to digitalization and sustainability concerns.
- The United States leads in output, Sweden in citation impact, with rising contributions from Nigeria and India.
- Key themes include digital media, ICT-enabled extension, environmental communication, and technology-driven agricultural knowledge exchange.

ARTICLE INFO

Keywords: Farm media, Agricultural journalism, Sustainability, Mass media, Bibliometric analysis, Agricultural communication.

https://doi.org/10.48165/IJEE.2026.62214

Citation: Khan, S., Khan, E. A., Verma, A., Begum, S., & Sonowal, R. R. (2026). Bibliometric Analysis of Research Trends and Growth in Farm Media and Agricultural Journalism. *Indian Journal of Extension Education*, *62*(2), 86-93. https://doi.org/10.48165/IJEE.2026.62214

ABSTRACT

Farm media encompasses multiple forms of mediation, representational, infrastructural, and elemental that shape the modern agriculture-food system. Although its relevance to sustainable agriculture and rural development is widely acknowledged, a comprehensive synthesis of scholarly contributions to farm media has remained limited. To fill this gap, a bibliometric analysis was carried out on publications from 2005 to 2024, using data from the Web of Science Core Collection and the Dimensions AI database. Data were cleaned and analysed using Biblioshiny and VOSviewer for science mapping. The study examined annual publication trends, citation patterns, journal productivity, keyword co-occurrence, and geographical distributions. Results indicate a sustained rise in publications, reflecting growing interest at the intersection of media, agriculture, and sustainability. The United States leads in output, while Sweden shows high citation impact, and contributions from Nigeria and European countries demonstrate expanding global participation. Keyword mapping identifies dominant and emerging themes in digital agriculture communication and sustainability-focused media practices. In India, where mass media play a crucial role in agricultural extension and rural livelihoods, the limited presence of high-impact studies highlights a significant research and visibility gap. The findings underscore the need for inclusive, collaborative, and context-specific research to strengthen agricultural communication systems globally.

INTRODUCTION

The intersection of agriculture and media, often called farm media, is an emerging field that examines how various communication channels shape farming practices, rural development, and knowledge exchange. In recent years, the concept of farm media has gained prominence. Recent scholarship highlights that modern farmers access information through a diverse mix of media, ranging

Received 23-02-2026; Accepted 12-03-2026

from traditional channels like radio and print to digital platforms, and social networks (Mittal & Mehar, 2016; Kish & Peters, 2023). Furthermore, digitalisation has transformed this landscape: mobile phones, internet platforms, and social media now enable two-way communication between extension agents and farmers (Aker, 2011). For example, smartphones provide direct market price feeds and weather alerts, while social networking platforms (e.g. WhatsApp, Facebook) facilitate peer-to-peer knowledge sharing among rural producers. These trends reflect global developments in agricultural innovation, where the adoption of technology and concerns about sustainability drive new communication needs (World Bank, 2011; Armenta-Medina et al., 2020; Khan et al., 2020).

Amid global pressures such as climate change, food security, and sustainability, the demand for effective agricultural journalism and communication has intensified (Khan et al., 2020; Kish & Peters, 2023). However, the circulation of agricultural knowledge remains uneven across media platforms. Evidence from India indicates that although agriculture underpins rural livelihoods, mainstream newspapers allocate limited coverage to agricultural issues, often prioritising national political and economic topics over farm-level concerns (Kumar et al., 2026). This imbalance raises critical questions about how far mass media truly serve the informational needs of farming communities.

Despite its importance, the scholarly landscape of agricultural communication has historically been fragmented across disciplines. Studies have explored media relations in agricultural extension (Ruth et al., 2005), climate change coverage in farm publications (Asplund et al., 2013), and the adoption of ICT in farming (Armenta-Medina et al., 2020). Collectively, this literature underscores the crucial role of media in disseminating agricultural knowledge and highlights the growing importance of new media forms (Khan et al., 2020). Nevertheless, a comprehensive understanding of how these diverse research strands converge under the concept of farm media remains limited.

To address this gap, the present study adopts a bibliometric analysis approach, which provides a systematic method for mapping research trends, identifying influential works, and visualising thematic networks (Donthu et al., 2021; Roy et al., 2024; Barman et al., 2026). Similar approaches in related domains (such as ICT in agriculture, digital platforms for rural knowledge transfer, workplace bullying, family farming, and precision farming) have revealed growth patterns and knowledge structures (Armenta-Medina et al., 2020; Dhillon, 2026; Suman et al., 2025; Vishwakarma et al., 2025). By applying this approach, the study synthesises two decades of scholarship (2005–2024) and situates farm media within broader communication and development discourse. The study aims to compile relevant publications, trace the evolution of scholarly output, and identify key authors, journals, countries, and thematic trends in agricultural media research. It integrates perspectives from agricultural journalism, farm media, and agricultural media reporting.

METHODOLOGY

This study employed a rigorous bibliometric methodology, retrieving data from two major academic databases, the Web of Science Core Collection and Dimensions AI database, both of which are known for their comprehensive coverage of peer-reviewed literature. Publications were limited to the period 2005–2024 and to English-language journal articles to ensure consistency and comparability. The search was conducted across titles, abstracts, and keywords using the Boolean string ("agricultural journalism" OR "farm journalism" OR "agricultural reporting" OR "farm media" OR "extension journalism" OR "agricultural media" OR "farm reporting"). This search initially yielded 126 records. Non-qualifying document types such as conference papers, book chapters, reviews, and editorials were excluded. The remaining records were then refined through a PRISMA-inspired screening process (Figure 1), which involved the removal of duplicates and irrelevant items. After the screening and eligibility assessment, a final sample of 22 articles was retained that directly addressed the interface between mass media and agricultural extension. Although the final dataset is modest in size, it reflects the emerging and niche character of research linking mass media with agricultural extension, where only a limited number of studies explicitly address this intersection. Therefore, the dataset is considered adequate for exploratory bibliometric mapping and trend identification. The bibliographic data of these selected records were exported in tab-delimited and BibTeX formats and analyzed using two complementary tools: VOSviewer and the Biblioshiny interface of the Bibliometrix package in R. These tools facilitated the construction and visualization of bibliometric networks, as well as the generation of statistical summaries, trend analyses, and science mapping outputs. These included author collaboration patterns, keyword co-occurrence structures, citation relationships, annual publication trends, growth rates, and the identification of leading authors, journals, countries, and highly cited works. All data processing and visualization procedures followed established bibliometric protocols to ensure accuracy and robustness. The combined use of both tools enhanced the validity of the findings by integrating network-based clustering with temporal and descriptive analytical perspectives.

RESULTS

Table 1 below summarizes the key features of the bibliometric dataset from 2005 to 2024. The final collection includes 22 journal articles from 17 different journals (as shown in Figure 1). This focused data set reflects a highly specialized research field. The annual growth rate was 5.95%, indicating sustained interest. On average, each article was cited 5.5 times, showing moderate scholarly influence. The

Table 1. Main Information of the Bibliometric Dataset

Main information	Timespan	2005:2024
	Sources (journals)	17
	Documents	22
	Annual growth rate %	5.95
	Document average age	4.95
	Average citations per doc	5.5
Authors	Authors	61
	Authors of single-authored docs	6
	Author's keywords (de)	104
Authors collaboration	Co-authors per doc	2.82
	International co-authorships %	13.64
Document types	Article	22

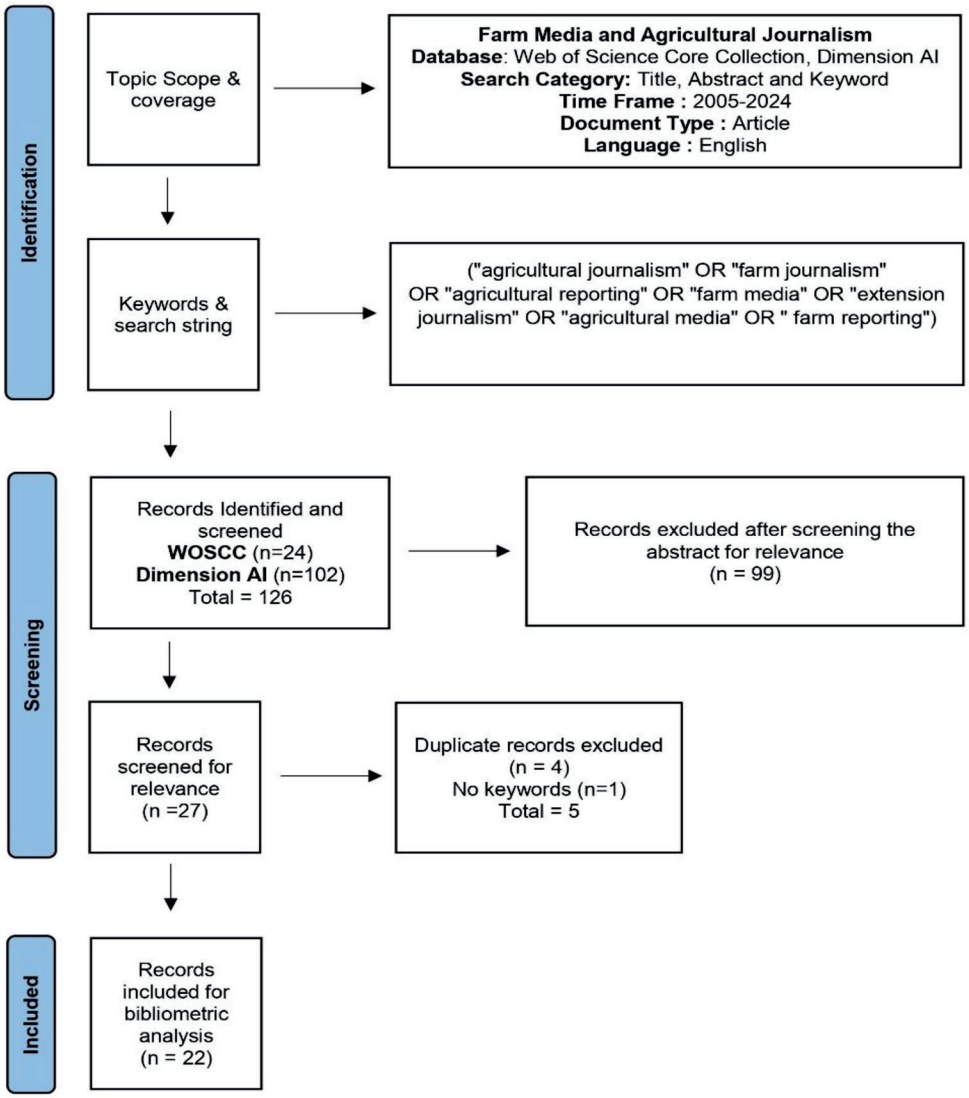

Figure 1. PRISMA 2020 Framework

average document age was around 5 years, indicating most output is relatively recent. These numbers suggest a niche but active research area. In total, 61 authors contributed to the 22 articles, demonstrating broad participation across the field. Most papers were co-authored: the average of 2.82 authors per paper suggests collaboration, though 6 articles were authored by a single person. International collaborations, in which authors have different country affiliations, were reported in about 13.6% of papers, suggesting some cross-border research but still limited global teamwork.

Publication Trend

The annual publication trend (Figure 2) shows a steady rise since 2018, following a period of sporadic output. Between 2005 and 2014, only occasional papers appeared (notably one in 2005, 2012, 2013). This sparse early activity suggests limited academic attention at a time when the field was in its infancy. Starting in 2018, we observe a clearer growth trajectory, with 1–3 papers per year, peaking in 2023 with eight articles, and a slight drop to 3 articles in 2024. The observed upward trend indicates increasing scholarly interest. The surge in the late 2010s and early 2020s may be driven by global challenges: climate change, digital transformation, and sustainable development agendas have brought agricultural media into focus. The COVID-19 pandemic may also have highlighted the importance of resilient information channels in rural communities. Overall, the transition from scattered early contributions to a more robust research phase suggests that farm media is becoming an established topic. If current trends continue, we can expect further growth, especially as younger scholars adopt bibliometric tools to navigate this interdisciplinary area.

Top Cited Works

A citation analysis reveals the foundational and influential studies in farm media research (Table 2). The most cited article is Asplund, Hjerpe, and Wibeck (2013), which has garnered 47 citations. This paper examines climate change framing in Swedish farming magazines, exemplifying how the media shape environmental communication in agriculture. Next are Amu and Agwu (2012) (12 citations), who surveyed Nigerian agricultural journalists on climate change reporting, and Ruth et al. (2005) (10 citations), who explored media relations training for agricultural scientists. These early works underscore the field's strong focus on climate and media relations in its roots.

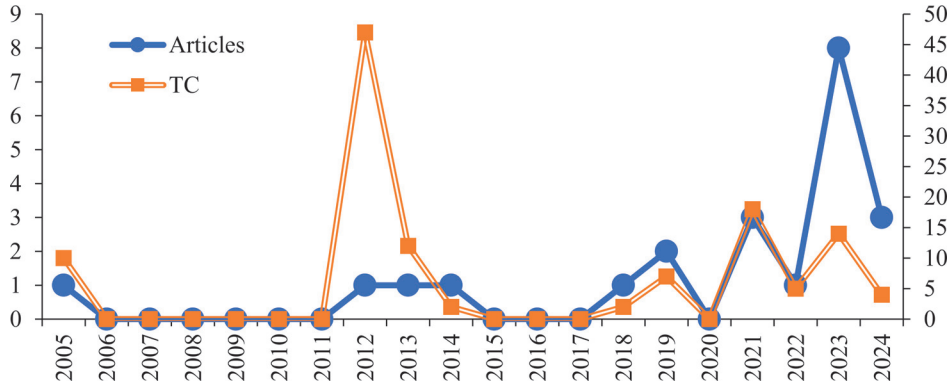

Figure 2. Annual Publication Trend and Total Citation per Year

More recent high-impact studies include Fischer and Hess (2021) (9 citations), which investigated farmers' perspectives in the Swedish GMO debate, and Carolan (2023) (5 citations), analysing the *affective politics* of farming media in *New Media & Society*. Notably, Kish and Peters' (2023) conceptual introduction to farm media is among the most highly cited works. These newer publications reflect an expanding thematic range from technological issues, such as ICT adoption in fish farming (Oke et al., 2021), to the sociocultural dimensions of rural television (Fountaine, 2020) highlighting the growing diversity in topics and methods.

This citation distribution indicates that seminal topics (climate communication, media training) have a lasting influence, while emerging issues (digital media, sustainability, rural journalism) are gaining traction. The presence of several *New Media & Society* articles among the most cited suggests that farm media research is increasingly recognised in mainstream communication journals.

Most Prolific Journals

The 22 articles appeared in a mix of communication and agricultural journals, reflecting the field's interdisciplinary nature. In Table 3, New Media & Society published five of the 22 papers, making it the most prolific outlet for farm media research. This prominence highlights how agricultural topics are increasingly being incorporated into broader media and technology discussions. Other

Table 2. Most Cited Articles on Farm Media and Agricultural Journalism

Article	DOI	Total Citations
Asplund, T., Hjerpe, M. & Wibeck, V. (2013) Framings and coverage of climate change in Swedish specialized farming magazines. Climatic Change 117, 197–209.	https://doi.org/10.1007/S10584-012-0535-0	47
Amu, C.J., & Agwu, A.E. (2012). Attitude and Knowledge of Print Media Journalists towards Reporting of Climate Change News in Nigeria. The Journal of Agricultural Extension, 16, 52-67.	https://doi.org/10.4314/JAE.V16I2.5	12
Ruth, A., Lundy, L., Telg, R., & Irani, T. (2005). Trying to Relate: Media Relations Training Needs of Agricultural Scientists. Science Communication, 27(1), 127-145.	https://doi.org/10.1177/1075547005278347	10
Fischer, K., & Hess, S. (2021). The Swedish Media Debate on GMO Between 1994 and 2018: What Attention was Given to Farmers' Perspectives? Environmental Communication, 16(1), 43–62.	https://doi.org/10.1080/17524032.2021.1960406	9
Oke, F. O., Olorunsogo, G. O., Akerele, D. (2021). Impact of Information Communication Technology (ICT) and mass media usage on technical efficiency of fish farming in Ogun State, Nigeria. J. Agribus. Rural Dev., 2(60), 143–15.	https://doi.org/10.17306/J.JARD.2021.01378	8
Fountaine, S. (2019). Themes of connection and progress in rural television: New Zealand's Country Calendar 1990–2015. Media International Australia, 174(1), 109-124.	https://doi.org/10.1177/1329878X19873930	7
Artner-Nehls, A., Uthes, S., Zscheischler, J., & Feindt, P. H. (2022). How the Agricultural Press Addresses the Slurry–Water Nexus: A Text Mining Analysis. Sustainability, 14(16), 10002.	https://doi.org/10.3390/SU141610002	5
Carolan, M. (2023). The perilous promise of productivity: Affective politics of farming media and its consequences for the future of agriculture. New Media & Society, 25(8), 1913-1934.	https://doi.org/10.1177/14614448231174521	5
Kish, Z., & Peters, B. (2023). Farm media: An introduction. New Media & Society, 25(8), 1827-1841.	https://doi.org/10.1177/14614448231174522	2
Obweger, A., Mitter, H. & Schmid, E. (2024) Framing the CAP reform 2013 in Austria's agricultural media. Agric Hum Values 41, 1393–1415.	https://doi.org/10.1007/s10460-024-10554-7	2

active journals included the Asian Journal of Agricultural Extension, Economics & Sociology (with two articles), and specialised titles such as Agriculture and Human Values, Climatic Change, and Environmental Communication (each hosting 1–2 articles). The diversity of journals, ranging from sociological to agricultural economics outlets, demonstrates how agricultural media issues transcend traditional disciplinary boundaries.

In terms of authorship, no single author dominates the field. Table 4 shows the top contributors; the only author with more than one publication is Peters B (2 articles). All other identified authors (Adeeb H, Adnan H, Agwu A, Akerele D, etc.) have published one work each. This pattern suggests a decentralised and emerging scholarly community. The widespread authorship indicates that many researchers are entering the field; however, a small core of authors has established a significant presence. The average of 2.82 co-authors per paper and an international collaboration rate of 13.64% also indicate collaborative networks that are still maturing. As the domain grows, new clusters of co-authors may form, and prolific researchers will emerge.

Table 3. Most Prolific Journals Based on Publication Count

Journal	No. of Articles
New Media & Society	5
Asian Journal of Agricultural Extension, Economics & Sociology	2
Agriculture and Human Values	1
Climatic Change	1
Environmental Communication	1

Table 4. Most Prolific Authors Based on Publication Count

Authors	Articles
Peters B	2
Adeeb H	1
Adnan H	1
Agwu A	1
Akerele D	1

Most Prolific Countries

Figure 3 illustrates the country affiliations of all contributing authors (Table 5). The United States leads in output with seven publications, indicating strong institutional capacity and interest in agricultural communication. In contrast, Sweden stands out in terms of impact rather than count, accounting for 47 citations, all from Asplund et al. (2013). This single highly cited paper amplifies Sweden's influence in the citation metric. Nigeria has three publications (22 citations), reflecting the growing research in developing regions that focuses on local extension and climate issues. Other contributing countries (India, Malaysia, Ghana, etc.) each had 1–2 publications, showing an increasingly global reach.

The international collaboration rate is modest (13.64%), but the data suggest a shift toward more global engagement. While early research was regionally concentrated, increasing contributions from Asia and Africa suggest that agricultural media is of worldwide relevance. However, regional disparities persist: Western countries (the USA, Sweden, and Germany) currently generate the most

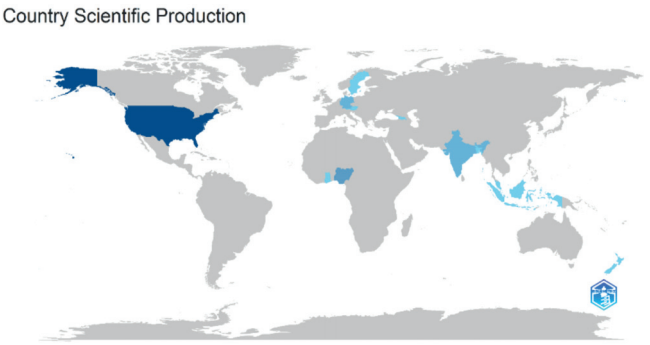

Figure 3. World Map Top Contributing Countries

Table 5. Top Contributing Countries (authors' affiliations)

Country	No of publication	Total Citation
USA	7	23
Nigeria	3	22
India	2	1
Germany	2	14
Sweden	1	47
Austria	1	2
Bangladesh	1	0
Indonesia	1	1
Malaysia	1	2
Georgia	1	0
Ghana	1	2
New Zealand	1	7

output and citations, likely due to their resource advantages. As the field matures, broader collaboration could arise, enriching the scholarship with diverse perspectives.

Keyword and Thematic Analysis

A co-occurrence analysis of author keywords was conducted to identify core themes. Across the 22 articles, 96 unique keywords were identified. Figure 4 (a word cloud) highlights the most frequent terms. Figure 5 illustrates that the top keyword is "farm media" (4 occurrences), followed by "agriculture" (3) and "environmental media" (3). These high-frequency terms underscore the central focus on agricultural communication and environmental issues. Other recurring keywords (each with 2 occurrences) include "agricultural media," "content analysis," "development communication," "Nigerian newspapers," "discourse," and "precision agriculture." This mix suggests that methodological approaches (e.g., content analysis) and diverse contexts (e.g., media in Nigeria) are present.

Notably, terms like "digital media," "information communication technology (ICT)," "extension journalism," and "environmental communication" also appear frequently. It indicates that digitalisation and sustainability are prominent research directions. The presence of ICT and digital media terms aligns with broader trends in which mobile and online platforms are transforming the agricultural sector. In summary, the keyword map suggests that farm media research is grounded in agricultural extension and environmental discourse, while also integrating perspectives on technology and development.

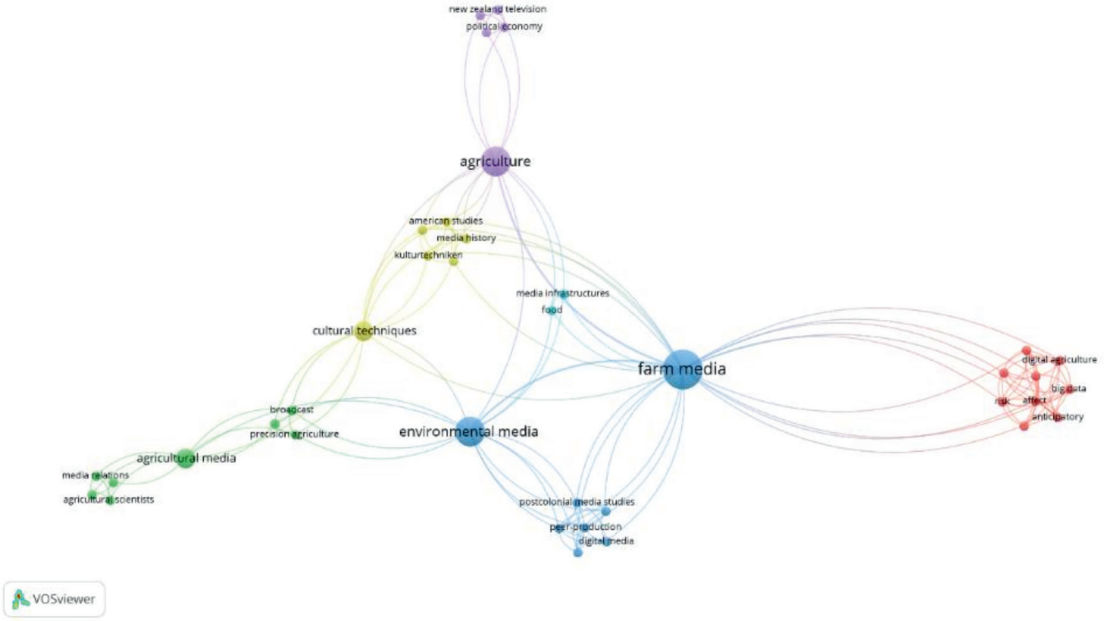

Figure 4. Word Cloud of Top Keywords

Figure 5. Co-Occurrence Analysis of Author Keywords

DISCUSSION

The bibliometric findings suggest that farm media and agricultural journalism are emerging as an interdisciplinary research field that has experienced steady growth between 2005 and 2024, with an annual publication increase of 5.95%. Although the overall number of publications remains relatively modest, the upward trend indicates growing scholarly recognition of the important role media plays in agricultural knowledge exchange and rural development communication (Donthu et al., 2021). The noticeable increase in publications after 2018 coincides with expanding global attention to digital agriculture, climate change adaptation, and sustainable food systems. Earlier research between 2005 and 2014 primarily addressed foundational communication needs, such as improving scientists' engagement with the media and strengthening the role of agricultural journalism in enhancing public understanding of farming-related issues (Ruth et al., 2005). More recent studies emphasize how digital communication technologies including mobile platforms, social media, and data-driven information systems are transforming the dissemination of agricultural knowledge and reshaping communication among farmers, extension services, and research institutions (Klerkx et al., 2019). From an analytical perspective, this shift indicates that farm media is no longer confined to traditional journalism but has become part of a broader "media ecology," where multiple communication platforms from broadcast media to networked and algorithmic technologies shape knowledge flows within agricultural systems (Carolan, 2023).

Authorship patterns indicate that the field is still in an early stage of intellectual consolidation. Contributions come from diverse disciplinary backgrounds, including communication studies, rural sociology, agricultural economics, and information science. The average of 2.82 authors per article and the presence of 13.6% international co-authorship suggest moderate collaboration. However, the absence of a dominant research leader, along with the presence of single-authored publications, indicates that farm media research is

largely driven by individual scholarly initiatives rather than coordinated research networks. Geographically, the United States emerges as the most productive contributor, reflecting its established institutional infrastructure in agricultural extension, land-grant universities, and communication research. Sweden shows notable citation impact due to the highly cited study by Asplund et al. (2013), demonstrating how influential publications can shape national research visibility. The dataset also reveals participation from developing countries, particularly Nigeria and India, where studies often focus on climate change communication, rural media systems, and agricultural extension services. Nigeria's publications and citations indicate growing engagement with local agricultural communication challenges. However, India's comparatively lower citation visibility despite its extensive agricultural sector and reliance on media for extension communication suggests structural disparities in global research visibility, possibly influenced by differences in research infrastructure, funding, and publication access.

Journal distribution further highlights the interdisciplinary nature of farm media research. *New Media & Society*, with five articles, leads in publication output, demonstrating the integration of agricultural topics into broader digital media scholarship. Research also appears in journals related to rural studies, environmental communication, and agricultural sociology, reflecting multiple disciplinary entry points. This distribution shows how agricultural communication is increasingly connected with broader debates on sustainability, technological innovation, and socio-ecological transformation (Carolan, 2023). Keyword co-occurrence analysis further supports these developments. Core terms such as "farm media" and "environmental media" anchor the literature within an agro-environmental communication framework, while the prominence of "digital media" and "ICT" signals a transition toward technology-driven communication platforms. These trends reflect broader transformations in agricultural extension systems, where ICT-enabled tools including mobile applications, online advisory services, and social media networks facilitate more interactive knowledge exchange between farmers, researchers, and policymakers (Klerkx et al., 2019). Overall, the findings suggest that farm media and agricultural journalism are evolving as important components of sustainable development communication, integrating traditional communication approaches with emerging digital technologies to support innovation and knowledge transfer in agricultural systems.

CONCLUSION

This bibliometric study reviews two decades of research on farm media and agricultural journalism, demonstrating a steadily expanding and increasingly diverse field. Publications from 2005 to 2024 show consistent growth, with a significant rise after 2018 driven by digitalisation, climate change, and food security challenges. The field has progressed from scattered early contributions to a recognised interdisciplinary domain, reflected in leading journals such as *New Media & Society* and themes including climate communication, ICT adoption, and media influence in agriculture. Research is increasingly global. While the United States leads in output, Sweden's influence is notable due to a highly cited study, and growing contributions from Nigeria and India highlight widening international relevance despite citation disparities. Mass media are increasingly recognised as critical tools in agricultural extension and rural knowledge dissemination. Overall, farm media research is emerging as a dynamic field shaping farmer awareness, innovation adoption, and public discourse on agriculture.

DECLARATIONS

Ethics approval and consent to participate: This study uses a bibliometric design based on publications indexed in the Web of Science and Dimensions AI databases, accessed through MANUU, Hyderabad. Documents were selected using predefined inclusion and exclusion criteria. As only secondary bibliographic data were used, ethical approval and informed consent were not required.

Conflict of interest: The authors confirm that there are no commercial or financial relationships that could be interpreted as a potential conflict of interest.

Author contributions: The author conducted the literature search, analysis, and interpretation, and prepared, revised, and finalized the manuscript.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (94-100)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

From Innovation to Implementation: A Qualitative Study of Kushinagar District Sugarcane Farmers' Technological Experiences

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HIGHLIGHTS

- Research-driven technical advancements and the real-world experiences of sugarcane farmers differ significantly.
- Because of poor digital literacy and inadequate extension assistance, the advantages of digital tools which have increased efficiency and transparency remain unequal.
- Local agroclimatic, irrigation, and farm-size realities are not taken into account by universally applicable research solutions.
- Sustainable sugarcane development requires research that is context-specific, participatory, and has stronger institutional and feedback links.

ARTICLE INFO

Keywords: Sugarcane farming, Agricultural management, Technical innovations, Smallholder farmers.

https://doi.org/10.48165/IJEE.2026.62215

Citation: From Innovation to Implementation: A Qualitative Study of Kushinagar District Sugarcane Farmers' Technological Experiences
Chaturvedi P., & Vatta, L. (2026). *Indian Journal of Extension Education*, *62*(2), 94-100.https://doi.org/10.48165/IJEE.2026.62215

ABSTRACT

As information and communication technologies and precision agriculture instruments are integrated, agricultural management techniques are being enhanced. Through improved input applications, communication across various hardware and datasets, and reduced production costs, this integration intends to improve the sustainability of the sugarcane crop production system. Many sugarcane farmers, especially smallholders, continue to face low profitability, increased input prices, labour shortages, and limited benefits from institutional and digital innovations despite consistent research investment and technical advancements. The research tried to understand sugarcane-growing farmers' viewpoints and experiences about digitalization and challenges in sugarcane farming. In the Kushinagar district of Uttar Pradesh, exploratory-descriptive qualitative research was carried out at the Deoria Sugarcane Committee's Jaura Bazar Centre "A" between October 2023 and January 2025. A pre-tested semi-structured guide was used to conduct in-depth, in-person interviews with purposively recruited twenty-four sugarcane producers. Interviews were audio recorded, verbatim transcribed, and subjected to thematic analysis using NVivo 15. Results show significant discrepancies between farmers' lived experiences, extension services, and agricultural research. Technical innovations like online slip generation, digital payment systems, and digitization have increased operational efficiency and transparency. Adoption was hampered by low digital literacy, limited access to advanced technology, insufficient extension assistance, and poor institutional coordination.

INTRODUCTION

The cultivation of sugarcane has changed significantly in recent decades as a result of institutional, technological, and economic advancements. Sugarcane continues to be one of India's most significant commercial crops and is essential to rural lives and agro-based businesses, especially in the state of Uttar Pradesh. To improve agricultural operations and marketing procedures, tools

Received 25-02-2026; Accepted 13-03-2026

including mobile phones, digital advising platforms, online cane slips, and direct bank payment methods have been implemented. ICT is crucial to modern agriculture, according to Devi et al. (2025), since it gives farmers fast and precise information that improves production, farm management, market access, price, and income while lowering agricultural hazards. Mukhamedova et al. (2022) state that modern digital information systems are necessary for the effective use of precision farming, particularly when utilising complete Farm Management Information Systems. However, the use of digital technology in agriculture is still unequal, especially among small and marginal farmers who frequently encounter issues with infrastructure, financial resources, and digital literacy. Udisha et al. (2023) discovered issues such as a lack of understanding regarding digital agriculture, a lack of enabling legislation, and poor internet connectivity. The authors recommend creating supportive laws, increasing digital literacy, and modernizing infrastructure to promote the use of digital agriculture. Awan et al. (2019) claim that the lack of local information centers and the high percentage of illiteracy are the primary barriers keeping farmers from utilizing modern information systems. Due to their limited exposure to modern technology, many farmers still employ traditional methods and lack familiarity with contemporary agricultural practices. Information and communication technologies have become a crucial part of contemporary agricultural extension operations. Farmers are using ICT tools like smartphones, social media, and digital advisory services more frequently to get timely agricultural information, weather forecasts, and market updates (Mukherjee & Jha, 2024). Singh and Mathur (2024) found that ICT platforms offer tremendously more potential for providing rural communities with agricultural information and enhancing farmers' ability to manage their farms more effectively. According to the report, farmers are depending more and more on ICT tools to get crop-related information, advisory services, and technology advancements that help them make agricultural decisions. Increasing use of digital devices, such cellphones, in obtaining agricultural information has also been highlighted by recent study. According to a research by Singh et al. (2025), most farmers utilized cellphones to get information about market pricing, pest control, and weather predictions. However, the study also showed that farmers' use of advanced digital services is still modest and is impacted by variables including knowledge level, landholding size, and education level. Research has shown how crucial it is to increase farmers' access to and understanding of ICT for successful digital agriculture. According to Kumar (2025), even though farmers are becoming more aware of the advantages of ICT tools, the majority of farmers still only have a medium level of ICT understanding. This suggests that more digital literacy and extension help are necessary to increase technology adoption.

METHODOLOGY

This study used an exploratory-descriptive qualitative research technique to give a thorough understanding of farmers' perspectives, challenges, and experiences with digitalization and technological transformation in sugarcane farming. The study was guided by the Consolidated Criteria for Reporting Qualitative Research) checklist Tong et al. (2007) to ensure methodological quality, rigor, and transparency. Between October 2023 and January 2025, in depth, face-to-face interviews were carried out at participants' homes or farms, based on their preferences. The research team adhered to the COREQ standards in order to ensure the transparency, validity, and dependability of the qualitative data. Since the Jaura Bazar Center "A" within the Deoria Sugarcane Development Committee in Kushinagar district had the greatest sugarcane output under the Cooperative Sugarcane Development Committee Limited, Deoria, the current study was purposefully carried out there in 2024. According to government statistics, Kushinagar district has become one of Uttar Pradesh's top producers of sugarcane. Approximately 3.62 million metric tons of sugarcane were grown on 68,739 hectares, yielding roughly 52.69 quintals per hectare (KVK Kushinagar). Twenty-four sugarcane growers participated in the study. Three participants were selected by each of the eight villages out of sixteen villages. An appropriate sample size for qualitative analysis was maintained while balanced geographic representation was ensured by choosing three farmers every village. Participants were chosen on the basis of their willingness to take part in the study, marketing their crop through the sugar mill system, and having at least five years of experience growing sugarcane. Farmers from a variety of age groups between 31 and 40, between 41 and 50, and above 50 were included in the sample. Capturing intergenerational disparities in opinions toward the adoption of digital technology in agriculture was made easier by include a variety of age groups, levels of education (from primary school to higher secondary and graduate school). This variance made it easier to comprehend how farmers' knowledge and use of digital agricultural technology are influenced by their level of education. Farm sizes (less than two hectares, two to four hectares, and more than four hectares). This classification made it easier to examine how the availability of resources affects the use of technology in sugarcane growing. With the participants' informed consent, the interviews were audio recorded, lasted 30 to 40 minutes, and were conducted in Hindi, the native language. Coded labels (R-1, R-2, etc) were used to identify the respondents and to protect participant privacy. Data saturation was reached at 14 interviews. In order to preserve sample uniformity throughout the chosen villages and to strengthen the reliability and credibility of the results, the researchers still carried out all 24 scheduled interviews. Following Braun et al. (2022) six-step methodology (Familiarization with the data, generating initial codes, Searching for themes, Reviewing themes, Defining and naming themes, Reporting the findings) thematic analysis has been used to analyze the data Ahmed et al. (2025). NVivo version 15 was used to manage, code, and arrange the qualitative data. Themes were cross-checked against raw data to verify consistency and reliability, and coding selections were revisited frequently to improve rigor.

RESULTS

Theme and sub-theme based on the interview questionnaire as per the responses

Theme 1- *Changing sugarcane production techniques*

Farmers claim that chemical-based farming practices have definitely replaced traditional organic farming methods. In order to meet manpower limits and meet production demands, the prior

reliance on organic fertilizer has progressively been replaced with chemical fertilizers. Similar changes have been observed in the expanding sugarcane systems of northern India, where productivity demands are driving an increase in the usage of external inputs. Adopting better planting techniques, especially trench sowing, was generally considered as beneficial due to wider spacing, moisture retention, and higher yields, supporting research indicating improved agronomic approaches raise sugarcane output under smallholder settings.

Shift from traditional to chemical-based farming

Instead of employing organic manures like cow dung, farmers reported using chemical fertilizers. Rather than being a decision, this shift was a response to the growing need for higher yields, shorter crop cycles, and the paucity of organic inputs. While chemical fertilizers boosted yield, farmers expressed worries about rising costs and declining soil health. "When chemical fertilizers were not available, we used to cultivate sugarcane by adding cow dung manure. Gradually, developed chemical fertilizers came." (R-5)

Adoption of improved planting methods

Improved planting techniques, particularly trench sowing, were viewed by farmers as a significant advancement. Farmers highlighted greater moisture retention, better plant spacing, and observable production enhancement, which promoted wider implementation of this technique despite the need for initial technical support. "Now the same is being sown at a distance of one foot by trench method, and the yield is good." (R-7)

Theme 2- *Economic stress and inequitable allocation of resources*

Respondents commonly cited rising input costs as their primary concern. Fertilizers, pesticides, manpower, and mechanization have all contributed to a sharp increase in agricultural costs, which has reduced profit margins. These rising costs disproportionately affected small and marginal farms, expanding the gap between resource-rich and resource-poor farmers. This trend is in line with other studies showing that larger farmers often benefit more from capital-intensive agriculture than smallholders.

Increasing cost of cultivation

Farmers stated a significant rise in the cost of inputs, such as labour, machinery, herbicides, and fertilizers. Although sugarcane is still grown, producers are increasingly susceptible to institutional and market delays since the profit margins are decreasing. "The cost of sugarcane inputs has increased. Earlier the cost was not so much, therefore there was inclination towards sugarcane cultivation." (R-12)

Resource disparity among farmers

Inequality in access to machinery, quality inputs, and digital services was frequently highlighted. Farmers with better financial resources were able to adopt modern technologies, while small and marginal farmers struggled to keep pace, leading to unequal benefits from technological progress. The only farmers who can benefit from new technologies are still farmers with adequate resources. Those with limited resources can't even access or use 10% of these facilities. (R-2).

Theme 3- *Farmers' experiences with agricultural digitalization*

Digital initiatives such as online slips and direct bank payments are well received by farmers. Digital technology improved payment process transparency, reduced the need for intermediaries, and reduced in-person visits to government offices. These findings support other studies that demonstrate how digitalization enhances the efficacy, accountability, and confidence of agricultural marketing systems.

Access to digital information and online slips

Farmers admitted that their reliance on intermediaries and frequent visits to organization offices has decreased, "thanks to digital technologies like online slips". These methods made it easier to obtain timely information on cane supply management and harvesting schedules. Harvesting programs used to be manually organized by supervisors, and farmers had to visit the society office frequently. Thanks to developments in online technology, this process is now more effective and requires less frequent physical coordination. (R-2)

Digital transactions and financial transparency

Direct bank payments or digitalization of payments were viewed as a major improvement as it ensure timely and transparent transactions. Farmers appreciated reduced corruption and easier payment processing, which boosted their trust in governmental procedures. "Now the bank has made the payment, the money in the account will go to the farmer's account, he will be able to withdraw his money easily." (R-10)

Theme 4- *Digital divide and limited access to technology*

Despite technological developments, there is still a significant digital divide. Low digital literacy hindered the efficient use of mobile phones and applications, particularly among older and less educated farmers. Additionally, most farmers said they had limited firsthand experience with cutting-edge technologies like drones. This unequal access reflects broader concerns in the literature on the uneven adoption of digital agriculture technologies in rural areas.

Limited digital literacy

According to some of the respondents, older and less educated farmers found it difficult to use mobile devices and apps. Due to their lack of digital literacy, farmers were more reliant on others and had less trust in their ability to adopt new technologies. "Many farmers do not know how to use a mobile because old farmers are not educated, so they have to face problems." (R-12)

Lack of exposure to advanced technology

Farmers claimed to have little to no familiarity with advanced machinery such as drones. Lack of training, demonstrations, and local availability hampered the adoption and understanding of precision technology. Farmers said they had little to no direct

experience with advanced agricultural technologies, such as GPS-enabled tractors, sensor-based soil testing devices, automated irrigation systems (drip and sprinkler systems with digital controllers), drones for crop monitoring and spraying, and mobile-based decision support apps. The lack of field demonstrations, training programs, and local availability of these technologies limited farmers' awareness and practical comprehension of precision agricultural equipment. "I have not seen a drone. There is no drone here in our area. We have not seen how a drone works." (R-8). "Drones are not available or demonstrated locally; we have only heard about them and have not seen any in our area." Precision sprayers, digital crop monitoring tools, sensor-based irrigation systems, drones, and other cutting-edge technologies are not available or demonstrated locally. They have just heard about these technologies, they haven't really seen or used them locally. (R-14)

Theme 5- *Crop shift and economic dependence on sugarcane*

This theme captures the broader structural transformation of regional agricultural systems, as livelihood possibilities are more influenced by market integration and institutional frameworks rather than agronomic variation. Sugarcane's growing dominance is a reflection of farmers' alignment with crops connected to legitimate procurement channels and trustworthy payment mechanisms. This change, which has reoriented farming toward income stability and commercial production while simultaneously decreasing crop choice flexibility and increasing reliance on sugar mills and legal frameworks, has made farm households more vulnerable to institutional disruptions.

Shift from food crops to sugarcane

The switch to sugarcane is an example of farmers' adaptive reaction to market risk and economic uncertainty. Sugarcane is viewed as a more reliable source of revenue due to its well-organized procurement system and more steady profits. This shift implies a decrease in agricultural diversity and an increase in commercialization, which might improve short-term income stability but also increase reliance on institutional arrangements and susceptibility to changes in the market and in policy. "In the past, the area's main crops were wheat and mustard, but over time, farmers have increasingly switched to sugarcane cultivation." (R-1)

Sugarcane as a cash crop

Due to guaranteed procurement and consistent payments from sugar mills, sugarcane was widely acknowledged as a reliable cash crop, making it essential to household financial planning. "Sugarcane is a cash crop; the factory gets its bundle made and gives us cash for it." (R-3)

Theme 6- *Improved productivity and emerging production risks*

This theme highlights the growing discrepancy between the long-term durability of intensive agricultural methods and sugarcane production systems. Even while technological developments have altered production results, farmers still have to deal with increasing uncertainty regarding crop performance and input efficacy. These problems point to structural weaknesses in input control, agronomic support, and sustainability planning, suggesting that output growth alone cannot ensure stability or reduce risk in sugarcane production.

Yield improvement through technology

Farmers observed notable yield improvements through methods such as trench planting and improved land preparation. These benefits reinforced positive attitudes toward technological interventions. "We had grown more sugarcane by the Trench method; we had bought it one year. We had grown a lot of sugarcane." (R-5)

Pest, disease, and inputs quality issues

Farmers voiced grave worries about insect infestations, disease outbreaks, and poor crop protection inputs despite output increases. Production hazards were increased by a lack of timely and efficient responses. "Sometimes we face huge loss because crops are get affected from diseases… But there is no cure for it." (R-11)

Theme 7- *Institutional and policy related constraints*

One significant limiting element was found to be an organizational challenge. Farmers complained about stringent subsidy requirements, ongoing middlemen's participation, and factory delays in sugarcane procurement, which resulted in financial losses. These limitations have been well documented as obstacles to the development of inclusive agriculture.

Subsidy restrictions and middlemen

Farmers expressed dissatisfaction about restrictive subsidy conditions and the continued involvement of intermediaries, which restricted their access to government assistance and increased their reliance. "This year they have also put a binding that means only the sugarcane of those who have sown sugarcane variety 9301 will be sown and subsidy will be given to that sugarcane only." (R-2)

Procurement Delays in Sugar Mills

Delays in procurement by sugar mills were a major problem that often led to production loss, quality degradation, and financial pressure. "Many time factory does not take the sugarcane on time, then the farmer suffers a loss." (R-3)

Inadequate extension support

Farmers frequently said that their capacity to implement and oversee new technologies in sugarcane production was hampered by a lack of field-level support, technical advice, and extension services. In contrast, frequent field demonstrations, seasonal training programs, pest advisories, soil health services, and mobile-based information via Krishi Vigyan Kendras and state agencies were seen as more systematic forms of extension support for food crops like rice and wheat. Farmers pointed out that sugarcane does not have the same emphasis on crop-specific expansion. Regular field inspections, stage-by-stage technical recommendations, mechanization demonstrations, and prompt assistance with pest and disease control were all anticipated. "The government does not provide us with sufficient assistance. We are compelled to handle everything ourselves without institutional support, and there are no observable advantages. (R-3)

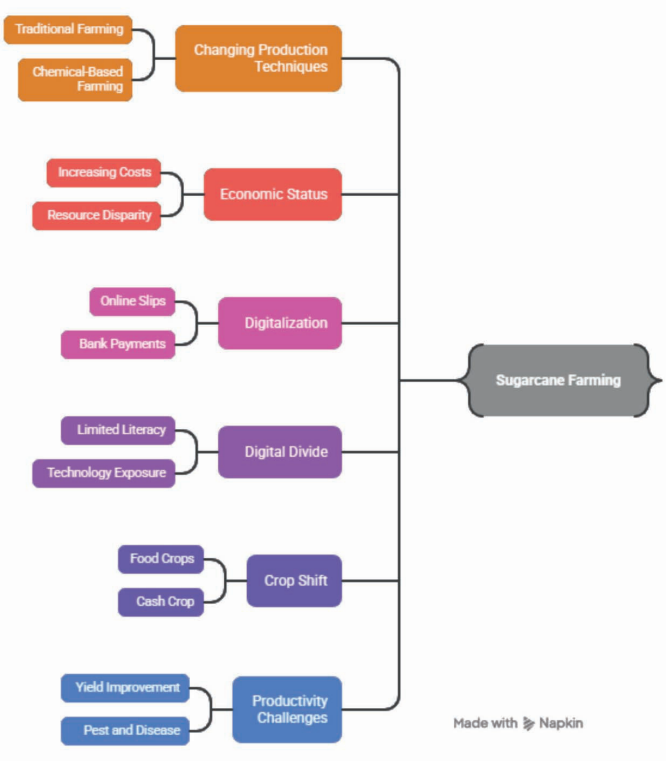

Figure 1. Challenges and opportunities in sugarcane farming

Water scarcity and irrigation issues

The absence of a steady supply of water throughout critical growth phases was highlighted by farmers, and irrigation seemed to be a major barrier. Water scarcity was considered a major obstacle to crop survival and productivity. "There is a need for improvement in water availability by the government, suppose we plant sugarcane in 5 acres, now if water is not available in May, June, then everything will become useless." (R-5)

DISCUSSION

The study's conclusions are consistent with larger structural changes in Indian sugarcane farming, where middle-aged and smallholder farmers continue to be the key players influencing production choices. The prevalence of smallholder profiles in cane belts is reinforced by empirical data that sugarcane producers frequently operate on tiny landholdings with restricted access to finance and credit (Singh, 2025). Across agro-ecological areas, national trends of small-scale farming and land fragmentation continue to limit production and the uptake of new technologies (Roy et al., 2020). According to socioeconomic studies conducted in Uttar Pradesh, the majority of farm households are small and marginal farmers, and land fragmentation affects agricultural methods and livelihood strategies (Kashyap et al., 2022). The respondents' preference for chemical fertilizers over organic inputs is consistent with earlier studies that demonstrate commercial crop agricultural intensification. This intensification has led to short-term improvements in output, but it has also increased cultivation costs and caused problems with soil, particularly for smallholders (Pingali, 2012; Jat et al., 2016). Farmers viewed digital interventions favourably because they increased transparency and decreased reliance on middlemen, especially online slips and direct bank payments. Studies looking at digital governance and mobile-based services in agriculture have shown similar results, emphasizing improvements in efficiency and confidence in institutional systems (Aker, 2011; Fabregas et al., 2019). Kremer and Houngbo's (2021) claims on the transformative possibilities of digital agriculture are supported by the substantial improvements in information availability, transparency, and fraud reduction brought about by digital interventions like online slips, mobile phones, and direct bank payments. Farmers' assessments of reduced dependency on intermediaries and greater payment predictability imply positive institutional change. However, the unequal distribution of these advantages as a result of low digital literacy is consistent with research on rural technology adoption, which warns that if capacity building is insufficient, digitalization may worsen inequality (Trendov et al., 2019; Emeana et al., 2020). Satapathy et al. (2024) reported that lack of ICT knowledge, financial support, and reliance on traditional information sources significantly restricted ICT adoption in Odisha. While basic ICT tools like televisions and cell phones were widely available, their use for informed farm decision-making remained superficial (Panda et al., 2019; Singh & Mathur, 2024). The analysis reveals a significant digital disparity despite these advancements. The wider advantages of digitalization are limited by poor exposure to cutting-edge technology like drones, insufficient knowledge of agricultural uses, and limited digital literacy. This result is consistent with the observations of Harris and Achora (2018) and Emeana et al. (2020) that uneven access to digital tools may exacerbate rather than lessen already-existing inequities. Insufficient exposure to cutting-edge technologies, such as drones, exposes persistent shortcomings in prolonged efforts and localized demonstrations. Research on smart and precision agriculture often shows that without strong extension assistance, smallholders cannot access new technologies (Wolfert et al., 2017; Shitu et al., 2018; Klerkx et al., 2019). Organisational obstacles, including strict subsidy rules, delayed sugar mill procurement, and poor extension services, continue to erode farmers' faith. Furthermore, the argument that technical adoption alone is insufficient in the absence of suitable physical infrastructure and climate-resilient planning is supported by irrigation-related challenges and water scarcity (Shirsath et al., 2017: Barman et al., 2026).

CONCLUSION

The study highlights that while mechanization and digitalization have increased the production, efficiency, and transparency of sugarcane cultivation, their benefits are still not equitably distributed. For small and marginal farmers, issues including rising input costs, limited access to cutting-edge technologies, insufficient extension services, and water shortages persist. If digital agriculture is to significantly contribute to inclusive rural development, technological innovation must be combined with targeted policy changes, more institutional support, and investments in irrigation and digital literacy. Technology integration with equitable governance frameworks is necessary to achieve sustainable sugarcane development. Even while farmers utilize chemical fertilizers, trench sowing, mechanized ploughing,

smartphones, online slips, and direct bank payments more regularly, access to state-of-the-art technology such as drones, soil testing facilities, and agricultural mobile applications is still uneven. Small and marginal farmers in particular confront a number of obstacles, including rising input costs, labor shortages, water scarcity, limited extension services, and restricted access to subsidized machinery.

DECLARATION

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding: The researchers did not apply for any funding; therefore, no financial support was available for the study.

Authors contribution: The study was conceptualized by PC, who also created the research design, carried out fieldwork, gathered qualitative data, completed data transcription and theme analysis, and wrote the initial report. In addition, she was in charge of creating tables and integrating the results with relevant research. LV oversaw the whole academic program, helped create the interview guide and study strategy, and critically examined and updated the work for intellectual substance. The final draft of the paper was read and authorized by both writers, who both agreed to take full responsibility for the work.

Acknowledgments: The authors are grateful to all the participants who took part in the study. The farmers of Kushinagar, Uttar Pradesh, deserve heartfelt appreciation for generously sharing their time and knowledge, providing us with vital data and insights that made our research possible. Their willingness to participate in surveys and interviews was crucial to the research outcomes. For providing relevant reports and statistical data that greatly improved the study, the Uttar Pradesh Agricultural Department deserve special gratitude.

Competing interests: The authors declare no competing interests.

Ethical consideration and consent to participate: Informed consent of the participants.

Conflicts of interest: The authors declare no conflicts of interest.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (101-106)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Social Capital of Rice Farmers in Andhra Pradesh and Kerala: A Social Network Analysis

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HIGHLIGHTS

- Rice farmers of Kerala had higher social capital than those of Andhra Pradesh, specifically in bridging and linking capital
- Bonding capital across both regions was low, indicating a lack of peer-to-peer interactions
- Andhra Pradesh farmers sourced information heavily from input dealers, while Kerala farmers relied on government institutional sources

ARTICLE INFO

Keywords: Social network analysis, Social capital, Information networks, Rice farmers, Climate resilience.

https://doi.org/10.48165/IJEE.2026.62216

Citation: Reddy, S. M. K., Bonny, B. P., Radhakrishnan, A., & Hema, M. (2026). Social Capital of Rice Farmers in Andhra Pradesh and Kerala: A Social Network Analysis. *Indian Journal of Extension Education*, *62*(2), 101-106. https://doi.org/10.48165/IJEE.2026.62216

ABSTRACT

The study explored the social capital among the rice farming communities, which is crucial in the context of climate change for building their resilience. The study was conducted in the South Indian states of Andhra Pradesh (AP) and Kerala during 2023. Primary data were collected from 120 farmers using a pretested schedule. Three social capital measures, viz., bonding capital, bridging capital, and linking capital, were analysed using social network analysis of the information sourcing and support networks of farmers. The results revealed relatively higher social capital among the farmers of Kerala than those of AP. Networks of both states had lower bonding capital, explained by lower density, moderate closeness centrality, and moderate modularity values. In the case of bridging and linking capital, Kerala regions had relatively higher levels than AP, explained by their in-degree centrality and betweenness centrality. The network maps also revealed greater reliance on input dealers for information in AP regions, whereas Kerala farmers relied on institutional sources. The results call for improving the bonding capital of all regions and the bridging and linking capital of AP farmers to expand their overall resilience.

INTRODUCTION

Agri-food systems involve complex interactions throughout the series of activities such as production, processing, retailing, and consuming, along with environmental and societal contexts under which all the activities occur (Ingram, 2011). All such interactions involve and lead to the building of social capital of the communities, which is defined as the "features of social organisation, such as trust, norms, and networks, that can improve the efficiency of society by facilitating coordinated actions" (Putnam, 2000). With climate change affecting agri-food systems all over the world, the concept of enhancing resilience has gained prominence as a policy tool both at national and international levels (European Commission, 2020). Enhancing the resilience of farming systems is featured in six out of the seventeen Sustainable Development Goals of the United Nations that are targeted to be achieved by 2030.

In the context of enhancing resilience, the sustainable livelihood framework emphasises the pentagon of assets, natural, human, physical, social, and financial (DFID, 1999). Social capital, however, plays a higher role as it influences the circulation and accumulation of all the other assets. Social networks, which constitute social capital, play varied positive roles in enhancing and building the

Received 17-02-2026; Accepted 16-03-2026

resilience of communities (Aldrich, 2012; Jordan, 2015; Cui & Li, 2020; Chaudhuri et al., 2021). Social networks among farmers were found to be beneficial in developing countries where rural education and extension services have yet to reach the last mile (Ma et al., 2014). They increased farmers' access to information on sustainable agricultural practices (Niranjan et al., 2023) and helped the extension agents to transfer the information to the entire network. Social networks of the farming communities enable knowledge diffusion and resource sharing, facilitate collective action, and improve social support, which altogether strengthen the capacity to cope with any challenges (Esparcia, 2014; Henry & Vollan, 2014; Rockenbauch & Sakdapolrak, 2017; Chapman et al., 2018; Nain et al., 2019).

In India, rice is the single largest crop grown with around 46 million hectares (GoI, 2023), underlining the importance of ensuring resilience among rice farming communities. India also occupies a vital role in the global rice supply chain by contributing around 40 per cent to the global rice exports. While existing research evidence highlights the important role of social capital in agriculture, gaps prevail in mapping the underlying structures and understanding the flow of resources among the farming communities. Informal social connections and their interplay with formal connections are vital in agriculture for technology dissemination, adoption and diffusion. Thereby, this study attempts to address these gaps by mapping the structure of rice farmer social networks and understanding its dynamics to leverage the networks to improve the resilience of farmers.

METHODOLOGY

The research was conducted in the South Indian states of Kerala and Andhra Pradesh (AP) during 2023. Within the selected states, districts were chosen based on the criteria of natural disaster proneness and area under rice cultivation (Rao et al., 2019). Accordingly, districts with a high risk of flooding (East Godavari, Thrissur) and drought (Kurnool, Palakkad) were purposively selected for the study. Villages with the highest area under rice in all four districts were taken for the study. As these villages are majorly dependent on rice farming, they have established information and support networks and study of such villages allows for scaling and replicating of interventions in other rice growing regions. Random sampling was used in selection of 30 farmers from each village and they were surveyed using a semi-structured interview schedule, making a total sample of 120 farmers. Also, given the relatively homogenous farming communities, the sample of 30 farmers per village gives a statistically representative cross-section of the village networks while also allowing for gaining comprehensive qualitative insights. The schedule included questions related to information sourcing networks and emotional support networks of farmers. The data was generated through the name generator technique, where each farmer can recall and list down the individuals they approached for accessing information and the persons from whom they seek emotional support without any limit of number of names since the preceding two cropping seasons. (Hampton, 2011). GEPHI software with version 0.10.1 202301172018 was used for the analysis and mapping of the data collected. Maps were developed using the ForceAtlas 2 layout format in the software.

Social capital was assessed using the framework developed by Aldrich (2012) that measures resilience in terms of bonding, bridging, and linking social capital. Bonding social capital represents close-knit ties between people similar in terms of socio-economic characteristics, attitudes, and resources living in close proximity (family, friends) (Putnam, 2000). Weak formal connections that link different communities or groups, providing access to external resources and knowledge beyond the immediate community, relate to the bridging social capital (Cofré-Bravo et al., 2019). Linking social capital provides access to resources and information unavailable through inside channels through formal connections with powerful institutions or individuals. It is often seen as a vertical link between a network and some form of authority or influence in the social context (Szreter, 2004; Aldrich, 2012). Communities with higher levels of bonding, bridging, and linking social capital are assumed to be more resilient than those with only one type of social capital or none (Woolcock & Narayan, 2000; Elliott et al., 2010; Aldrich, 2012).

In measuring the social capital, various SNA metrics were used. Density is the ratio between the total number of actual ties and potential ties in a network. High density in the network was found increase the chances of collaboration among the actors of community (Olsson et al., 2004; Luthe et al., 2012), increase the access to information sources and its spread and has a positive influence on social support and strengthens the trust among the actors in the network (Granovetter, 1973; Pretty & Ward, 2001). Closeness centrality is the reciprocal of the geodesic distance of a node to other nodes in the network (Golbeck, 2013). Closeness in a network influences the speed of information spread and also the efficiency in the spread of information (Elkady et al., 2023). Modularity is the strength of network division into different clusters (Prokhorenkova et al., 2016). Clusters, when present, can hinder the aspects of collaboration, dividing the network into many subgroups (Granovetter, 1973; Bodin et al., 2006). All three measures, density, closeness centrality, and modularity, are widely used in assessing the bonding capital of networks (Putnam, 2000; Woolcock & Narayan, 2000).

Betweenness centrality is the frequency with which a node lies in the geodesic path between two other nodes in a network (Perez & Germon, 2016). It is used in the identification of important actors and actors that may hinder the capacities of the network (Green et al., 2012). It also indicates bridges whose absence can disrupt the whole network and maintains heterogeneity in communities to avoid redundancy (Borgatti, 2003; Elkady et al., 2023). In-degree centrality is the total number of all the inward ties linked to an actor from other actors in the network (Guzman et al., 2014). In-degree value reveals the influential actors in the network (Srinivas & Velusamy, 2015), also facilitates coordinated action among central actors. However, it can also result in uneven distribution and influence on the network (Luthe et al., 2012). Granovetter (1973) and Lin (2002) describe betweenness centrality and in-degree centrality as measures for assessing the bridging capital in networks.

Linking capital was assessed by using the presence of various vertically linking actors such as formal institutions, political leaders, and other formal organisations (Woolcock & Narayan, 2000)

RESULTS

Information networks of rice farming systems

Figure 1 reveals the information networks of rice farmers in selected study locations. The maps were created using the in-degree centrality metric, and the size of the circles was scaled proportionally to their respective in-degree values.

In the information networks of Kerala regions, the panchayat-level government agricultural office, Krishi Bhavan, emerged as the primary information source with the highest in-degree values of 50. Other institutional actors that played significant roles are Kerala Agricultural University (KAU) with an in-degree of 23 and Krishi Vigyan Kendra (KVK) with an in-degree of 17. Along with these institutional actors, input dealers with an in-degree of 16 and a few farmers were the other critical actors in the network. Farmers with anonymized ID numbers 133, 105, 101, 10, and 47 emerged as influential actors with in-degree values more than 5. In-degree threshold of 5 was chosen as it allows for isolating the most sought-after actors from the average actors. Silva (2023) also emphasised the presence and importance of such opinion leaders in farmers networks for information sourcing.

In the regions of AP, input dealers emerged as the primary information source with an in-degree value of 27. Following input dealers, Rythu Bharosa Khendra (RBK), a government agricultural office, had a higher in-degree value of 16. Other prominent actors in the AP region are the National Disaster Management Authority (NDMA) with value 11 and the Reliance Group with value 5 provided information to farmers through mass media, specifically SMS and direct farmer calls respectively. Farmer with ID number 105 was found as an opinion leader with an in-degree value of 5.

Emotional support networks of rice farming systems

Figure 2 shows the emotional support networks of both states, which play a critical role in the farmers' community resilience, especially during natural hazards. It could be observed from the figure that in both regions, family followed by friends are the principal supporting actors. In AP, the family had an in-degree of 44, followed by friends with in-degree of 28. RBK with value 13 and landlords with value 5 were other important supporting actors to farmers. In Kerala, family had a value of 29, followed by friends with value 24. However, the Kerala network also had the presence of other actors such as Padashekaram members (21), Krishi Bhavan

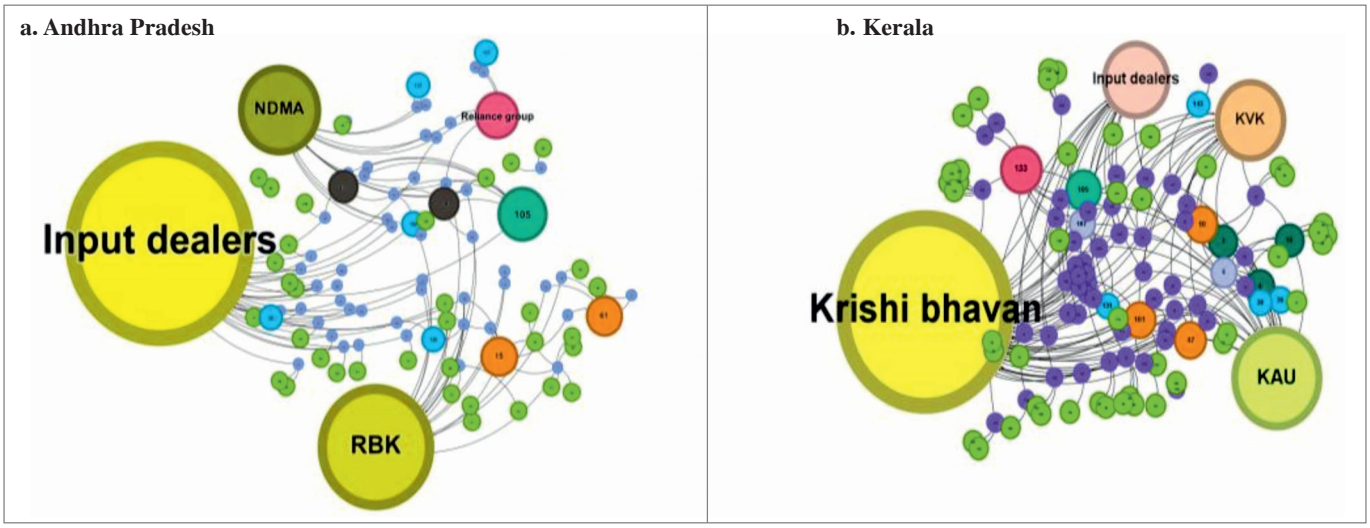

Figure 1. Information sourcing network map of rice farmers of Andhra Pradesh and Kerala regions

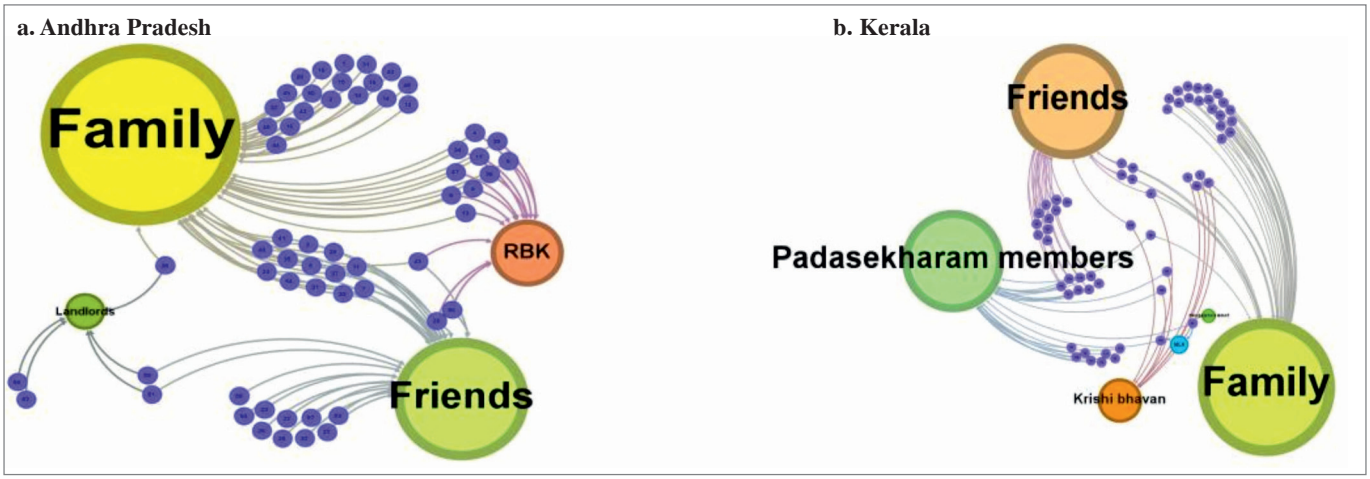

Figure 2. Emotional support network map of rice farmers of AP and Kerala regions

(8), MLA (2) and Panchayat President (1). Results show that farmers in Kerala relied on diverse set of actors while AP farmers relied heavily on a close-knit family and friends for support.

Social capital of the rice farming systems

The network linkages between actors and the centrality measures derived from SNA were used to categorise the social capital into three levels: bonding, bridging, and linking capital.

Table 1. Network properties of information networks of AP and Kerala rice farming systems (n=120)

Network properties	Andhra Pradesh	Kerala
Density	0.012	0.016
Closeness centrality	0.538	0.463
Modularity	0.629	0.398
In-degree centrality	1.215	1.80
Betweenness centrality	2.04	1.377

Network properties of the information networks of rice farmers of both states are represented in Table 1. Bonding capital of the networks was assessed based on the measures of density, closeness centrality, and modularity. Kerala network had a relatively higher density value of 0.016 than the AP network, which had a value of 0.012. Both the networks had less than two per cent of the total possible connections, indicating the presence of scarce connections among the farmers. In closeness centrality, both the regions had moderate closeness with values 0.538 and 0.463, respectively in the AP and Kerala regions. Moderate closeness implies the possibility of a delay that may occur in information dissemination. In modularity, AP had a higher value of 0.629, while Kerala network had a value of 0.398, indicating less fragmented networks than AP networks. The AP network had relatively higher cliques that interact more among themselves and less with other cliques, which could also be the reason for less density.

The bridging capital of the communities was assessed using the in-degree centrality and betweenness centrality measures. In in-degree centrality, the Kerala region had a higher value of 1.8 than the AP region, with a value of 1.215, indicating that the Kerala region had more influential actors. The results indicate that farmers in the Kerala network had multiple actors whom they could rely on for any need, while AP farmers relied on a few influential actors. In the case of betweenness centrality, the AP region had a higher value of 2.04, while the Kerala region had a value of 1.377. A higher value of AP indicates higher dependence on a few actors for information flow, who can act as gatekeepers of information.

Linking capital was assessed based on the number of linking actors present in both regions, both in information and emotional support networks. Institutional actors present in the Kerala region were KVK, KAU, Krishi Bhavan, MLA, and Panchayat President. In the case of AP regions, RBK, NDMA, and the Reliance group were the only prominent linking actors. Based on the in-degree values of institutional actors, Kerala network exhibited stronger links with a total of 93 ties, while AP had only 32 such ties. A higher number of ties ensures that information, even if not reached through a specific actor, will arrive through the other actors. Such a wide association with formal institutions can assist the governments in understanding the local capacities of communities to deal with any stresses and their further needs to increase their resilience (Carmen et al., 2022).

DISCUSSION

The study reveals key differences in the rice farmers social networks between the both states of AP and Kerala. Kerala farmers preferred government agencies for information due to their long-established trust and the presence of Padasekhara Samithies that brokered institutional ties through various meetings. The results of Kadeejabanu and Vishnupriya (2021) also revealed that 98 per cent of the farmers visited Krishibhavans to source information. However, in AP, the absence of agricultural government agencies at the village level till the recent establishment of RBK's in 2020 pushed the farmers to rely more on input dealers. In support networks, family and friends were the primary actors in both regions due to their physical proximity and everyday interactions. However, in Kerala, there is a wider presence of other institutional actors, which is limited in AP regions. The presence of MLA and Panchayat President as actors in the networks of Kerala was due to the presence of Padasekhara Samithies, whose leaders were acting as bridges connecting farmers. Such links connect the in the AP region, the presence of landlords in the network is due to the prevailing nature of tenant farming in the region of East Godavari (Revathi, 2014). Tenant farmers, being resource-poor, source financial and other resources from landlords.

Social capital assessed using SNA metrics shows relatively higher levels in Kerala than in AP farmers. However, the bonding capital of both the regions was found to be less, primarily due to fewer interactions between the farmers and presence of cliques. Dense connections within the network reportedly increase the social support available to all the members and also increase their adaptation levels to extreme weather events (Cassidy & Barnes, 2012; Béné et al., 2016; Yadav & Ghosh, 2023). Thereby, increasing connections by organising of farmers into groups and increasing their interactions through regular meetings is essential. In the case of betweenness centrality, network in which actors have higher betweenness centrality values can exert control over the information content and its flow (Elkady et al., 2023). Such control when exerted significantly by profit seeking actors such as input dealers, can be harmful. It is essential to increase the reach of governmental institutions in AP regions to serve the needs of farmers. Also, there was higher presence of opinion leaders in Kerala regions which lacked in AP regions. This can be attributed to the presence of Padasekharam Samithies, which facilitates the emergence of leadership among farmers. These opinion leaders improve the interconnections in the network by acting as bridges for information dissemination (Centola, 2010; Singh et al., 2023). Lack of such farmer groups and opinion leaders in AP region hinders them from forming consistent connections with formal institutions and leaders, leading to their lower linking capital.

While the study reveals critical insights into the social capital of rice farmers, certain limitations should be acknowledged. As the data was collected at a single point of time, only a cross-sectional representation of networks were captured. However, social networks are dynamic and evolve over time. RBKs of AP will likely

expand their reach to farmers, which could be effectively captured using longitudinal research. Also, the study was based on self-reported and recall data, which could have caused under-representation of infrequent ties.

CONCLUSION

The study was conducted to explore into the social capital of rice farmers. Results revealed that the regions of Kerala had relatively higher levels of social capital, compared to those of AP. While bonding capital was low in both regions, Kerala networks showed stronger bridging and linking capital through the presence of multiple opinion leaders and institutional actors. The difference can be attributed to the wider presence of Krishi Bhavans and Padasekharam Samithies, which together fostered the emergence of opinion leaders and created a platform for linking farmers with government leaders and institutions. In AP, a higher reliance on few key actors, particularly input dealers, and less presence of institutional actors limited their social capital. Organising AP into farmer-producer groups and facilitating the emergence of leadership could enhance their social capital. Also, RBKs need to increase their rapport with farmers and increase their role in information dissemination. Wider presence of input dealers in the farmer networks could be effectively leveraged for providing advisory services by training them to become para-professionals.

DECLARATION

Competing interests: The authors declare no competing interests.

Ethical consideration and consent to participate: Informed consent of the participants.

Conflicts of interest: The authors declare no conflicts of interest.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (107-111)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Participation and Constraints Faced by Rural Women in Agricultural Activities in Amethi District

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HIGHLIGHTS

- Rural women's participation was centered in labour intensive and post-harvest activities, reflecting limited access to resources.
- Among the three crops (rice, wheat, and potato), the highest participation was in potato-related activities.
- Low wages and dual responsibilities at farm and home were major constraints for rural women in participation.

ARTICLE INFO

Keywords: Rural women, Agricultural activities, Participation, Kruskal Wallis, Low wages.

https://doi.org/10.48165/IJEE.2026.62217

Citation: Maurya, T. S., Yadav, R. N., Yadav, R., Singh, S., & Singh, G. (2026). Participation and Constraints Faced by Rural Women in Agricultural Activities in Amethi District. *Indian Journal of Extension Education*, *62*(2), 107-111. https://doi.org/10.48165/IJEE.2026.62217

ABSTRACT

The study conducted examines the participation of rural women in various agricultural activities in Amethi district of Uttar Pradesh. A total of 80 respondents were selected using a multistage sampling technique from eight villages. Data were collected during 2022–2023 through a pre-tested and structured interview schedule to assess the level of their participation. The result indicated that the majority of rural women always participated in different agricultural activities. However, there was not much involvement in technically demanding activities like irrigation and plant protection management. Kruskal-Wallis H test revealed that among the three crops the maximum participation was in the potato crop, and the difference was significant. The overall participation index revealed that a medium level of participation, 61.25% of the respondents fell into the medium level of participation category. Coefficient correlation revealed a significant positive relation with age, information seeking behaviour, social participation, land holding and annual income, while education showed significant negative correlation; higher education reduced the participation in agricultural activities. Garrett's ranking reflects that low wages were the major constraint for low participation in agricultural activities.

INTRODUCTION

In India, agriculture forms the backbone of the rural economy and supports the livelihoods of a large majority of the population. Rural women are essential to this industry, yet their contributions often get neglected. Through their participation in post-harvest operations, livestock management, crop cultivation, and related fields, women make important contributions to agricultural production systems (Nishi et al., 2019). Women play an unquestionable role in the agricultural sector; they actively participate in the production of major field crops, and the extent of their involvement is associated with their age, social class, and the type of crop being grown (Kaur et al., 2016). Rural women work for nearly 12 to 15 hours a day and remain heavily engaged in their responsibilities, especially during the sowing and harvesting periods of the farming system (Ishaq & Memon, 2016). They are involved in nearly every step of the agricultural process, from planting and transplanting to weeding, harvesting, storing, and processing. Although they make an important contribution, still the work of women in agriculture is usually ignored (Shamna et al.,

Received 17-02-2026; Accepted 16-03-2026

2021). For rural women, limited access to advanced agricultural technologies, finance facilities, high-quality inputs, and land ownership continued to be an important constraint (Kumari et al., 2025). As farmers and agricultural labourers, women are the backbone of India's rural agricultural economy yet they also continue to be one of the most vulnerable demographics. Only 13 per cent of rural Indian women own land despite the fact that women have accounted for more than 60% of workers engaged in agriculture (Annual report for MoA and FW 2024–25) whereas 8.92 per cent of women in Uttar Pradesh own land (Census of Agriculture, 2020-21). In Uttar Pradesh only, 8.00% of women have control over agricultural revenue, 4.00% have access to institutional financing and less than 1.00% engage in government training programmes. In rural areas, the main source of income for 80% of economically active women is agriculture and allied sectors, out of which 33.00% are employed in the agriculture industry and 48.00% are independent farmers (Gupta et al., 2024). To enhance agricultural output, rural women are engaged at every stage of the agricultural value chain, including production, pre-harvest activities, post-harvest processing, packaging, and marketing. The technology may not work well enough to be motivated to persevere when unforeseen problems arise during the initial adoption of a publicly developed technology, and the key stakeholders may not know enough about the new technology for this learning selection to improve the fitness of the new technology (Nain et al., 2012). Pingali et al. (2019) reported that the proportion of women relative to men employed in the agricultural sector has increased over time and has made a notable contribution to GDP per capita. Projections by FAO (2011) indicate that women-focused reforms ensuring equal access to resources, skill development, and opportunities in agriculture could increase agricultural production by approximately 2.50 to 4.00% in developing countries.

METHODOLOGY

The study was undertaken during 2022-23 to investigate the participation of rural women in the agricultural activities of specific crops in Amethi district of Uttar Pradesh. A multistage sampling method was used to collect the data. Out of 13 blocks, two blocks were purposively selected on the basis of higher production of three major crops, namely rice, wheat, and potato. From these two blocks, four villages were randomly selected from each block, resulting in a total of eight villages. From each village, 10 respondents were randomly selected, making a total sample size of 80 respondents. A pre-tested structured interview schedule was used to collect primary data, and it was undertaken in person. The schedule included questions regarding socio-economic variables. The level of participation of rural women was measured by frequency with which they participate in agricultural activities. A three-point continuum was used for this purpose i.e. always (3), sometimes (2) and never (1). The highest attainable score was 63 (21 multiplied by 3). A participation index was developed.

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

To compare the participation of respondents among the crops Kruskal Wallis test (H) was used. It is a non-parametric test used to compare three or more independent groups. It determines whether variations in ranked or ordinal data between groups are statistically significant. To examine the relationship in participation of rural women across different socio-economic groups coefficient correlation was used. It allowed to identify significant relationship in participation frequencies across various demographic groups. To analyse the constraints faced by rural women in participation of different agricultural activities garrett ranking was used.

RESULTS

The extent of participation of rural women across different crops and agricultural activities varied, which is clearly reflected in the participation index (Table 1). In rice crop transplanting was found to have the highest participation index (81.60), reflecting that transplanting in rice is mostly dominated by women because in the research area, mostly farmers are marginal and cannot afford mechanical tools for transplanting and men were engaged in other activities. Harvesting (87.91) and post-harvest activities (85.00) came next, indicating women's greater participation in labour-intensive and post-production activities. On the other hand, due to a lack of knowledge, the participation index for irrigation management (72.91) and plant protection (74.58) was relatively lower, revealing that women were not as involved in resource-controlled and technically challenging activities.

Table 1. Participation of rural women in agricultural activities in different crops

S.N.	Activities	Participation index	Rank	Overall participation index	Rank
1	Rice				
	Nursery raising	76.25	V		
	Transplanting	91.66	I		
	Weed management	82.91	IV		
	Irrigation management	72.91	VII	81.60	II
	Plant protection	74.58	VI		
	Harvesting	87.91	II		
	Post-harvest activities	85.00	III		
2	Wheat				
	Seed preparation	77.91	IV		
	Seed sowing	71.25	VI		
	Weed management	80.41	III	76.25	III
	Irrigation management	75.41	V		
	Plant protection management	61.66	VII		
	Harvesting	82.08	II		
	Post-harvest activities	85.00	I		
3	Potato				
	Seed preparation	84.16	IV		
	Sowing	82.91	V	83.82	I
	Earthing up	85.00	III		
	Manual weeding	78.75	VI		
	Plant protection management	73.33	VII		
	Potato digging	90.41	II		
	Post-harvest activities	92.50	I		

In the wheat crop, women's participation was high in post-harvest activities (85.00) and harvesting (82.08), they were engaged in post-harvest activities like cleaning and winnowing. Due to small land holding, manual harvesting was dominant in the area. In the weed control, the participation index was (80.41), which revealed that due to financial constraints, manual weeding was preferred. The lowest participation index was found in activities like seed sowing (71.25) and plant protection management (61.66), which revealed that the participation of women primarily focused on manual and post-harvest activities rather than input-intensive activities.

Similarly, in the potato crop, the highest participation of rural women was in post-harvest activities (92.50) and potato digging (9041), emphasising their critical role in harvesting and post-harvest handling of tuber crops. Cleaning, sorting, grading and storing are directly related to household management responsibilities that are typically carried out by women, which allows them to do more. In the same way, the potato digging is manual in the study area, which invites more women's participation. Participation index of earthing up (85.00) and seed preparation (84.16) was relatively high because they do not require any expensive equipment and women are familiar with these operations from frequent seasonal engagement. Meanwhile manual weeding (78.75) and plant protection management (73.33) had lower participation index due to lack of information and safety concerns about plant protection chemicals.

According to the overall participation index, rural women were most actively involved in the potato-related activities (83.82), rice (81.60) and wheat (76.25), respectively. Higher engagement in potato linked to labour-intensive activities like digging, sorting, grading, which is traditionally done by women. Rice-based activities ranked second, reflecting that transplanting, harvesting and post-harvest management are mainly dominated by women, whereas lower participation in wheat reflects increased mechanisation and less involvement of women in technically demanding operations.

The Kruskal Wallis H test proved that the participation of rural women significantly varied across crops (H=12.47, df=2, p=0.002) (Table 2). Potato based activities had the highest mean rank (176.95) and mean participation score (2.78) of all the crops, indicating a relatively higher level of women participation. Rice came next mean rank (152.38) and mean score (2.64). on the other hand, wheat had the lowest mean rank (123.67) and mean score (2.41), indicating comparatively lesser participation. These variations could be explained by variations in different agricultural operations, with lower participation in mechanized and technically demanding activities and higher participation in labour-intensive and post-harvest activities.

Table 2. Crop-wise comparison of rural women's participation in agricultural activities using Kruskal–Wallis test

Crop	Mean participation score	Mean rank
Rice	2.64	152.38
Wheat	2.41	123.67
potato	2.78	176.95
Kruskal–Wallis H value	12.47	
Degrees of freedom (df)	2	
p-value	0.002	

The results indicate that a majority (61.25%) of rural women grouped into medium category of participation (Table 3), reflecting regular engagement in specific agricultural practices especially in labour intensive and post-harvest activities. Total engagement was hampered by low participation in technically challenging tasks like irrigation and plant protection. About 22.50 percent women were grouped into low category of participation which could be explained by sociocultural limitations, domestic responsibilities and restricted access to farm resources. Only 16.25 percent of rural women reported high participation which is a reflection of more experience, family support and an active role in agricultural decision making.

Table 3. Distribution of respondents on overall participation of rural women in agricultural activities

Category	Percentage
Low Participation (less than 46.26)	22.50
Medium participation (46.26-56.58)	61.25
High participation (more than 56.58)	16.25
Total	100.00

Mean=51.42; S.D.=5.16

The correlation between age as well as participation was positive and significant (r = 0.246*) (Table 4), suggesting that engagement increased slightly as age increased due to greater experience in agricultural activities. There was a negative correlation between education and involvement (r = -0.536), indicating that lower participation is linked to greater educational status. This could be explained by educated people looking for non-agricultural or alternative sources of income. The correlation between information-seeking behaviour and participation was positive and significant (r = 0.475**), suggesting that respondents who actively look for information are more likely to act successfully. Similarly, social participation was highly correlated (r = 0.399**), indicating that social networks and group involvement are important factors in increasing participation. Strong positive and very significant correlations were also found between landholding (r = 0.515**) and annual income (r = 0.515**), suggesting that respondents with higher resource are more likely to participate. Overall, the findings highlight how socioeconomic and communication-related factors are crucial in influencing rural women.

Low wages emerge as the most severe constraints (Table 5) with the highest mean Garrett score (65.46), demonstrating that inadequate payment remained a substantial disincentive to continued engagement and economic motivation. The dual role at farm and

Table 4. Relationship between socio-economic variables and participation of rural women in agricultural activities

Independent variables	Correlation coefficient (r)
Age	0.246*
Education	-0.536**
Information-seeking behavior	0.475**
Social participation	0.399**
Landholding	0.515**
Annual income	0.515**

* Significant at 5% level, ** Significant at 1% level

Table 5. Constraints faced by rural women in participation in agricultural activities

S.N.	Constraints	Mean Garrett score	Rank
1.	Low wages	65.46	I
2.	Dual role at farm and home	55.15	II
3.	Health problems	51.15	III
4.	Household responsibilities	42.54	IV
5.	Social and cultural norms	33.70	V

home ranked second (mean Garrett score 55.15), illustrating the struggle of managing profitable agricultural activity with family responsibilities. This combined burden frequently affects efficiency in farm-related task and restricts time availability. Health problems ranked third (mean Garrett score 51.15). Fourth place was taken by household responsibilities (mean score = 42.54), which restricted time for productive activities. Social and cultural norms got the fifth rank (mean score = 33.70), indicating a relatively smaller influence. In general, socio-cultural considerations were less important in limiting involvement than economic and role-related limitations.

DISCUSSION

The study clearly shows that rural women play a significant role in agricultural activities, particularly in labour-intensive and post-harvest operations. The findings indicate that the majority of rural women had a medium level of participation in agricultural activities, with the highest involvement observed in transplanting and post-harvest tasks. These results are in line with the findings reported by Nain and Kumar (2010), Afzal et al. (2010), Chayal et al. (2010), Nazir et al. (2013), Singh et al. (2018), and Vijayan et al. (2025). The lowest level of participation was observed in technically demanding activities such as irrigation and plant protection management. This may be attributed to factors such as lower levels of education, limited technical knowledge, less exposure to modern practices, and restricted access to farm resources. Similar findings were reported by Sowjanya et al. (2016). Among the three crops studied, rice, wheat, and potato, the highest level of participation of rural women was found in potato-related activities. This is mainly because potato cultivation involves several labour-intensive operations, including cleaning, grading, and sorting, which are traditionally performed by women. However, women's involvement in wheat farming seems to have decreased as a result of increased mechanisation in wheat, which raises concerns that technological advancements without gender inclusion may further minimise women farmers. Age, information-seeking behaviour, social participation, landholding, and annual income all had positive correlations with participation, demonstrating that women's participation in agriculture is increased by experience, knowledge access, and resource ownership, but education had a negative correlation, indicating that educated women were more likely to diversify into non-farm livelihoods, illustrating low agricultural economic returns and structural barriers. The main obstacles preventing women from effectively participating in agricultural activities were found to be low wages and combined farm-household responsibilities.

CONCLUSION

The study arrives at the conclusion that rural women perform an important yet unrecognised role in agricultural activities, especially in labour-intensive and post-harvest operations. Despite their active participation in all major crops, women are still under-represented in technical and decision-making roles. Socioeconomic and information-related factors had a considerable impact on participation levels, but greater involvement was limited by low pay and several responsibilities. To increase women's engagement, productivity, and empowerment in agriculture and support inclusive and sustainable rural development, it is crucial to strengthen gender-sensitive extension strategies, expand access to skill-based training, and promote women-friendly technologies.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection.

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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (112-116)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

A Comparative Study on the Understanding of Food Labels Among Young Adults (18–25 Years) in Varanasi and Delhi

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HIGHLIGHTS

- Food labels serve as a crucial source of information regarding the constituents of food products, informing consumers about the contents and quantities of what they consume.
- The importance of understanding food labels has become increasingly critical in the context of rising lifestyle-related disorders.
- The consumption of unhealthy food and lack of physical activity are predominant issues.

ARTICLE INFO

Keywords: Awareness, Food labels, Pre-packed foods, Students, Varanasi, Delhi.

https://doi.org/10.48165/IJEE.2026.62218

Citation: Gautam, A., & Vatta, L. (2026). A Comparative Study on the Understanding of Food Labels Among Young Adults (18–25 Years) in Varanasi and Delhi. *Indian Journal of Extension Education*, *62*(2), 112-116. https://doi.org/10.48165/IJEE.2026.62218

ABSTRACT

With the rise in processed food consumption and the spread of non-communicable diseases, the importance of food labels has grown to help prevent these issues and inform consumers about their dietary choices and their effects. A food label on pre-packed food products is very significant. It provides information on what we should eat or purchase. Label literacy means a person's ability to understand, comprehend and utilise this information while purchasing pre-packed food items. In the modern world, people are so occupied with their lives that they often lack the time to eat, leading to a growing demand for packaged food products. This research was conducted to assess the level of understanding of food labels among individuals aged 18-25 in Delhi and Varanasi during August 2025. The study employed a survey method, gathering data through purposive sampling techniques. Data analysis was conducted using Excel. Findings reveal that most participants from both locations read nutritional labels easily, indicating understanding. A significant number of respondents say that the lack of time was the main challenge, while most approved nutritional labels are warning labels on food packets.

INTRODUCTION

Consuming nutritious food is vital for preventing non-communicable diseases (NCDs). Yet, in India, dietary habits are shifting due to evolving food preferences, with processed and ultra-processed foods becoming more prevalent in daily meals (Doshi et al., 2025). The growing presence and intake of these foods pose a major public health issue. Excessive consumption of energy-dense, high-fat, sugar, and salt (HFSS) ultra-processed foods can elevate the risk of obesity and associated health issues at a younger age. Thus, it is crucial to oversee the availability of these foods in both home and school settings to prevent them from replacing nutritious home-cooked meals (Jain & Mathur, 2020). Moreover, concerning health trends have emerged among children and adolescents: about one in ten school children is prediabetic, 5% of teenagers have hypertension, and roughly 7% are at risk of developing chronic kidney disease (Gupta & Suchdev, 2022). A 2020 study by the Food Safety and Standards Authority of India (FSSAI) found that only 4.4% of 1300 sampled packaged food products adhered to the World Health Organisation's recommended limits for fat, sugar, and salt. This means that 95.6% of the products surpassed at least one of these critical nutrient thresholds. The WHO's nutrient limits are used to identify products that should feature front-of-pack labelling (FoPL) warnings, aimed at reducing the intake of HFSS

Received 22-01-2026; Accepted 18-03-2026

foods and preventing overweight, obesity, and other diet-related diseases. At the same time, young adults often encounter conflicting or inaccurate nutrition information due to their extensive use of digital media. To effectively interpret and critically assess such information, sufficient nutrition literacy is necessary (Vrinten et al., 2023). In India, the Food Safety and Standards Authority of India (FSSAI) oversee the labelling of pre-packaged foods to ensure safety, protect consumers, and promote transparency (FSSAI, 2025).

Food labels serve as an essential and direct means of conveying information to consumers, hypothetically influencing their purchasing decisions. Such labels enable individuals to avoid products that are high in energy yet deficient in essential nutrients. Food labelling is recognized as a significant public health strategy, offering consumers information that may impact their buying choices. Labels that are comprehensive, accurate, reliable, and precise reflect the true nature and characteristics of food products, thereby empowering consumers to make informed and health-conscious decisions (Kodali & Telaprolu, 2018).

These labels aim to assist consumers in making well-informed dietary decisions and encourage healthier eating practices. Nonetheless, the success of food labels is largely contingent upon the consumer's capability to read, understand, and utilize the information they present, a skill commonly known as label literacy. The study aims to understand the food labels among young adults from Varanasi and Delhi.

METHODOLOGY

Delhi, as a major metropolitan area, exhibits a high availability of packaged snacks, fast-food chains, and sugary beverages, facilitated by the presence of numerous malls, restaurants, and international food brands. This abundance has led to an increased consumption of high-fat, sugar, and salt (HFSS) foods, particularly among adolescents and working professionals. In contrast, while fast food is accessible in Varanasi, traditional home-cooked meals and local street foods predominate. Consequently, the overall exposure to highly processed HFSS foods remains comparatively low.

A cross-sectional study was conducted among consumers of pre-packed foods in Delhi and Varanasi, India, to check the understanding of food labels among respondents from these two cities. The study focused on young adults aged 18–25 years who were pursuing graduation, master's degrees, or preparing for competitive examinations. Participants belonged to different income groups, including high, middle, and low-income categories. A total of 400 respondents participated in the study, consisting of 200 males and 200 females from the two regions. Participants were selected from Delhi and Varanasi using a purposive sampling technique. The sample included individuals who consumed pre-packaged foods several times a week. Data were collected using a self-structured bilingual questionnaire designed to gather information about consumers' understanding of food labelling. The questionnaire was divided into several sections: (a) demographic profile, (b) comprehension of food labels, (c) significance of food labels, and (d) types of food labels preferred by consumers. Before completing the questionnaire, informed consent was obtained from all participants, and they were assured that their responses would remain confidential and that the data would not be accessible to anyone else. The collected data was analysed using Microsoft Excel software. Responses to multiple-choice questions were analysed and presented in terms of frequency and percentage.

RESULTS

The Table 1 represents data on how easily residents from Delhi and Varanasi understand food labels printed on pre-packed foods. Out of a total of 400 respondents, 265 (66.25%) respondents find food labels to be comprehensible. This indicates that for many individuals, the information provided, such as ingredients, nutritional content, and expiration dates, is clear and accessible. Among them, 153 (38.25%) were from Delhi and 112 (28%) from Varanasi. Meanwhile, 39 (9.75%) respondents said they could not understand the labels. The remaining (24%) respondents categorized as Sometimes constitute a moderate segment of the data. This suggests that some individuals occasionally encounter difficulties in understanding food labels. Their confusion may be contingent upon the type of product, the manner in which the information is presented, or the specific terminology employed on the label. Finally, the smallest group of respondents, 'No' represents those who consistently find food labels challenging to comprehend. Although this group is small, it underscores the necessity for clearer labelling formats and enhanced consumer education to facilitate informed food choices for all individuals. Overall, Delhi had 210 respondents, and Varanasi had 190. The majority in both cities reported that they could understand food labels, though a notable portion especially in Varanasi, expressed occasional or no understanding. This suggests that while food labelling is generally effective, there may still be room for improvement in clarity or accessibility, particularly for certain groups. Similar research has been conducted to assess the ability to interpret nutrition labels, revealing that respondents struggle to understand them (Doshi et al., 2025; Aggarwal et al*.,* 2025).

Table 1. Distribution of respondents on the basis of residence and their understanding about food labelling

Understand food labels easily printed on pre-packed foods	Respondents (N=400)		Total
	Delhi (%)	Varanasi (%)	
Yes	38.25	28	66.25
No	4	5.75	9.75
Sometimes	10.25	13.75	24
Total	52.5	47.5	100

Table 2 indicates that more than quarter of the male respondents (35%) said "Yes", indicating they do avoid such purchases, while a significantly higher (45.75%) of females responded "Yes", showing a stronger tendency among women to avoid unlabelled food items. Only 5% of males and 12% of females said "No", which means they do not avoid buying food without labels. A smaller portion, 2.25% of males and 7.25% of females, responded "Sometimes", suggesting occasional caution. Overall, the data suggests that female respondents are more likely than male respondents to consistently avoid purchasing pre-packed food items

Table 2. Distribution of respondents on the basis of gender and their avoidance food item which don't have food labelling

Avoid purchasing pre-packed food items that don't have food labels	Gender of respondents (N=400)		Total
	Male (%)	Female (%)	
Yes	35	45.75	80.75
No	7	5	12
Sometimes	5	2.25	7.25
Total	47	53	100

that lack proper labelling, reflecting perhaps a greater concern for food safety or nutritional information among women. This behaviour might suggest that women have a heightened awareness and concern about food safety, nutritional details, ingredient transparency, and product quality. Given that women frequently play a crucial role in purchasing food for the household and preparing meals, they may be more attentive to labelling information that ensures the safety and health of their family members.

Table 3 illustrates that a substantial proportion of respondents (47.25%) feel they lack sufficient time to read or interpret labels while shopping, suggesting that the shopping environment or consumer behaviour may not facilitate detailed decision-making. over a quarter of the respondents (43%) expressed concerns regarding font size. Nearly half of the participants perceive the font as too small, which impedes their ability to read the information effectively. This underscores the necessity for more consumer-friendly packaging standards featuring legible print. A notable percentage of individuals (14%) question the credibility or accuracy of the data presented on labels because they agreed that they don't trust the information printed on the food labels. This scepticism may stem from misleading marketing, confusing claims, or previous experiences. A smaller yet significant percentage of consumers (5%) encounter challenges due to language barriers, particularly among multilingual or immigrant populations, where labels may not be in a familiar language. A lesser number of respondents continue to struggle with understanding food labels due to a lack of nutrition knowledge or overly technical information. Moreira et al. (2019) conducted a similar study, finding that consumers acknowledged both a lack of time to read nutritional labels and difficulty in understanding them. Study conduced by Patel & Nagar (2025) explains that consumers don't understand food labels and agreed that they don't have time to read because of a language barrier.

Table 3. Distribution of respondents based on residence and their challenges while reading nutritional labels

Challenges faced while reading nutritional labels	Residents of the respondents (N=400)		Total
	Delhi (%)	Varanasi (%)	
Lack of time	29.5	14.25	47.25
Font size	18	16	42.5
Don't trust the information	6	8	14
Language-related barrier	1.5	3.5	5
Unable to understand food labels	1.5	1.75	3.25
Total	56.5	43.5	100

The Table 4 depicts that more than a quarter of the respondents (38%) consider food labels "very important," reflecting that approximately more than a quarter of the population is highly conscious of checking label information before buying food products. Additionally, less than quarter of the participants (27%) view labels as "important," showing that a sizable portion still values this information, though perhaps with slightly less intensity. Meanwhile, 26% of participants remain neutral, neither actively valuing nor disregarding food labels. This segment could be influenced through targeted education and awareness campaigns to better understand the relevance of food labelling. On the other end of the spectrum, only 2% of respondents believe food labels are "unimportant," and 7% consider them "very unimportant." Combined, this 9% represents a small minority of consumers; maybe they are uninformed or indifferent to the role of food labels in guiding healthy choices. Overall, the table reflects a strongly positive consumer attitude, with a total of 65% (38% + 27%) acknowledging the importance of food labels. This reinforces the idea that food labelling is a vital part of consumer decision-making and health consciousness. Hassan and Dimassi (2017) explored the use and comprehension of food labels among Lebanese shoppers, with respondents agreeing on the importance of food labels.

Table 4. Distribution of participants on the basis of their gender and the importance of nutrition labels

The importance of the nutritional label	Gender of the respondents (N=400)		Total
	Male (%)	Female (%)	
Very unimportant	3	4	7
Unimportant	1.25	1	2.25
Neutral	16.5	9.5	26
Important	15	11.75	26.75
Very important	15.75	22.25	38
Total	51.5	48.5	100

Figure 1 depicts that Warning labels are the most supported, with approximately 65% of respondents preferring them. This suggests that consumers want clear, direct indicators of potentially harmful ingredients (e.g., high sugar, salt, or fat content). Health Star Rating System is supported by about 50%, indicating moderate Favor toward simplified summary formats that quickly inform

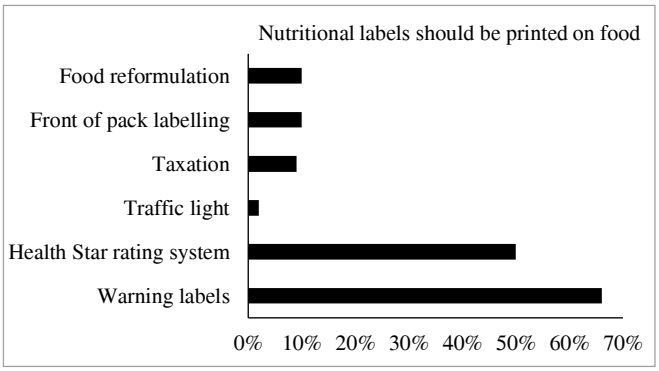

Figure 1. Distribution of respondents on the basis of their perception about kind of food labels printed on pre-packed items

buyers about the overall healthiness of the food. Support for the Traffic Light system (which uses red, amber, and green colour codes) is very low, below 5%, indicating it may be confusing or less trusted by consumers. Other options like Taxation, Front-of-pack labelling, and Food reformulation each receive around 10% or slightly more. These have minimal support compared to warning labels, possibly because they are indirect or harder for consumers to understand or control. Consumers strongly prefer simple, clear, and direct labelling formats like warning labels, while more technical or indirect methods (e.g., food reformulation or taxation) are less favoured. The low support for the traffic light system may point to a need for better education or a shift toward more intuitive labelling systems.

DISCUSSION

This study aimed to assess the comprehension of food labels on pre-packaged food items among individuals aged 18–25 years residing in Delhi and Varanasi. India is currently witnessing an increase in noncommunicable diseases, with young adults being particularly susceptible. This susceptibility is attributed to their relocation for educational purposes, often residing in hostels or as paying guests, where they encounter nutritional deficiencies due to factors such as time constraints, the unavailability of affordable, healthy foods, and a lack of awareness regarding health and nutrition. Compared to Varanasi, most respondents from Delhi reported greater ease in understanding food labels. Notably, over a quarter of female respondents indicated that they avoided purchasing food items lacking labels, suggesting an awareness of the significance of nutritional information. However, the majority of respondents from Delhi cited a lack of time to read nutritional labels, while participants from both Delhi and Varanasi acknowledged difficulties in reading labels due to font size. More than a quarter of respondents (38%), comprising both males and females, recognized the importance of nutritional labels when purchasing pre-packaged food items. Additionally, more than half of the respondents advocated for the inclusion of warning labels on food products. A similar study was conducted to determine the perception and practices of food labels among students in Bangalore; the study showed that although students have knowledge that food labels are helpful while purchasing food items, they were not reading them adequately (Kaviya et al., 2025). In contrast, in this study, respondents agreed that food labels are very important, but they did not have time to read them and faced many challenges in doing so. A study conducted to explore the influence of food labels among students found that nearly half of the students did not understand the food labels, and more than half of the students stated that they never changed their eating behaviour because of food labels (Verma et al., 2023). A similar study to the current study by Bhattacharya et al. (2022) stated that warning labels were the most preferred food label, followed by the traffic light system. Individuals with lifestyle diseases employed a two-day dietary record method. The findings indicated that the participants were experiencing lifestyle disorders due to poor dietary habits and a sedentary lifestyle. Additionally, the study revealed that these individuals were overconsuming nutrients, largely due to a lack of awareness regarding the detrimental effects of such consumption. (Yadav & Singh, 2022). A similar study about nutritional status and requirements was conducted in rural Tamil Nadu, finding deficiencies like underweight children (28% boys, 21.66% girls) and anaemia. Extension approaches improved knowledge (53.37%) and skills (56.67%) on balanced diets, iron-rich foods, and millet-based products among women and children. This study focuses on creating nutrition awareness among rural children (including potential adolescents) to address deficiencies (Rani, 2018). Analysed food patterns and nutritional status in Uttar Pradesh villages, noting medium awareness levels about food nutrition among school children (58.34%) and farm women (65%). Low prevalence of underweight/obesity, with emphasis on promoting nutritious food for security. Relevance: Directly addresses awareness about food nutrition among school children in rural India (Kumbhare et al., 2023). The study was conducted among a limited sample of young adults from only two cities, Delhi and Varanasi, which may limit the generalizability of the results to other regions of India. The study focused only on individuals aged 18–25 years, and therefore the findings may not represent the perceptions and practices of other age groups. Future study suggests with larger and more diverse populations, as well as longitudinal research designs, would provide a more comprehensive understanding of food label usage and its influence on dietary behaviour

CONCLUSION

This research examines understanding of food labels among young adults aged 18–25 living in Delhi and Varanasi. The results show that while many participants acknowledge the significance of food labels on packaged foods, their actual use is limited. Respondents from Delhi found it somewhat easier to comprehend food labels compared to those from Varanasi; however, a lack of time was cited as a primary obstacle to reading nutritional information. Additionally, participants from both cities reported that small font sizes made reading labels difficult, diminishing the effectiveness of food labelling. The study also found that a significant number of female participants refrained from buying products without labels, indicating a higher level of understanding and concern about nutritional details. Despite this understanding, fewer than half of the respondents actively considered nutritional labels when purchasing food. Moreover, more than half of the participants favoured the addition of warning labels on food products, reflecting a desire for clearer and more accessible labelling systems.

DECLARATIONS

Source of funding: None

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

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

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (117-122)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Community-Based Social Marketing for Self-Orientation Change in Extension Education

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HIGHLIGHTS

- Community-based social marketing operates as a participatory extension approach
- Self-orientation change precedes observable behavioural transformation
- Integrated 4Ps design strengthens identity formation and sustained commitment
- This study employs a qualitative case study to examine community-based social marketing practices

ARTICLE INFO

Keywords: Community-based extension, Professional mothers, Change in self-orientation, Participatory learning, Family development.

https://doi.org/10.48165/IJEE.2026.62219

Citation: Wisataone, V., Untari, D. W., & Andarwati, S. (2026). Community-Based Social Marketing for Self-Orientation Change in Extension Education. *Indian Journal of Extension Education*, *62*(2), 117-122. https://doi.org/10.48165/IJEE.2026.62219

ABSTRACT

Most social marketing practices focus on measurable behaviour change, but few examine self-orientation as the foundation of social change. This research was conducted in 2025 to analyse how the Professional Mother community uses social marketing as a developmental communication strategy to encourage changes in maternal self-orientation before behavioural changes occur. This research employs a qualitative case study design, including in-depth interviews with 5 informants from national and regional administrators, participatory observation of online and offline learning activities, and analysis of organisational documents. The results show that the social marketing mix is carried out in an integrated manner through segmentation based on life phases and learning needs, social products in the form of self-orientation towards the "best version of oneself", social pricing in the form of non-material commitments, distribution through multi-channel communication ecosystems, and promotion through value framing, role model, member participation, and public event space. This approach fosters reflective awareness and identity, enabling behaviour change to occur gradually and sustainably. These findings highlight that social marketing as a participatory extension model can enhance sustainable behavioural change through self-orientation and identity formation.

INTRODUCTION

The family is a fundamental social institution that determines the quality of a nation's human resources. Beyond serving as a domestic space, the family is the initial arena for the formation of an individual's values, capacities, and social orientation (Masten & Monn, 2015). In this context, mothers hold a central position in strengthening family resilience and contributing to sustainable development (Nomaguchi & Milkie, 2020; Nur et al., 2025; Schmidt et al., 2023). This demonstrates that mothers' influence extends far beyond the confines of their homes (Kumari et al., 2024), yet their role is still perceived narrowly as solely domestic (Devy & Firdaus, 2019), without recognition of its strategic dimension in social transformation.

In response to this phenomenon, the Professional Mothers community has emerged in Indonesia, aiming to revitalise the

Received 03-03-2026; Accepted 19-03-2026

meaning of motherhood and encourage women to contribute to building a nation within the family (Ibu Profesional, 2024). The community operates through a structured learning ecosystem designed to transform mothers' orientations, enabling them to construct identity. Therefore, the community can be understood as a form of community-based extension model in which learning occurs through participatory and dialogical processes among members. This aligns with extension education principles that emphasise contextual, learner-centred communication in facilitating sustainable behavioural change.

The community's approach to fostering this change can be analysed through the framework of social marketing as a planned development communication strategy (Kotler & Zaltman, 1971; van den Ban & Hawkins, 1996). Unlike commercial marketing, social marketing focuses on the adoption of values, ideas, and practices perceived to bring collective benefit. In contemporary extension practice, social marketing has become a crucial instrument for facilitating social change through audience segmentation, contextual message design, and adaptive message distribution systems (Rehman et al., 2022).

Numerous studies have shown that social marketing strategies are effective for specific behavioural changes related to health or environmental issues (Brennan et al., 2014; Vilmar, 2023). However, most studies position social marketing as a technical, measurable tool for specific behavioural campaigns. There are still limited studies exploring how the social marketing mix is implemented in an integrated manner within the community ecosystem to encourage more fundamental changes, namely changes in self-orientation, as the foundation for behavioural change.

Within the framework of planned behaviour theory, stable behavioural changes are preceded by behavioural changes at the cognitive and affective levels (Ajzen, 1991; Bandura, 1986). In line with the participatory development communication paradigm (Servaes, 2014), the transformation of individual consciousness is an important prerequisite for contextual and sustainable social change. Therefore, an analysis of the implementation of social marketing in the community as a learning-based extension model is relevant to expand the understanding of development communication strategies.

This study aims to analyse the implementation of the social marketing mix in encouraging changes in maternal self-orientation in the Professional Mothers community. Specifically, it addresses how the elements of product, price, place, and promotion are designed and implemented to facilitate self-orientation change as the foundation of behaviour transformation.

METHODOLOGY

This study used a qualitative case study approach to analyse the implementation of development communication using a social marketing approach with Professional Mothers (IP) to change members' self-orientation. The research has been conducted in both online and offline modes, involving central and regional administrators. This combination of online and offline approaches allows researchers to get a more comprehensive picture of the implementation of social marketing in Professional Mothers, both in terms of central and regional management.

Informants were selected using purposive sampling, considering their roles, active participation in the community learning programme, and experience in receiving or running social marketing communications in this community. The study involved 5 informants: 1 Secretary General, 1 National Creative Media Manager, 1 Regional Coordinator, 1 Regional Creative Media Manager, and 1 Coordinator of Learning Programme. Before the research took place, the author had read and provided a consent form to be an informant in the research. With the informant's consent, to protect the participant's privacy, a pseudonym was used instead of the participant's real name.

Data collection was conducted through semi-structured in-depth interviews with 5 informants, participatory observation of online and offline learning activities, and analysis of organisational documents, including programme modules, digital communication content, and community publications. Online observation included interactions within 5 WhatsApp community groups (1 regional, 2 learning classes, and 2 small discussion groups), 1 community learning class in the Learning Management System (LMS), 8 Zoom learning sessions, and official social media platforms such as Instagram and Facebook. Offline observations were conducted during 2 community meetings, 1 reflection session, and 2 public community events organised by the Professional Mothers community. Field notes were systematically compiled to record patterns of interaction, message framing, and member engagement.

Data analysis followed the steps outlined by Miles et al. (2014), which include: data collection, data reduction, data display, and conclusion drawing or verification. The analysis focused on identifying how elements of the social marketing mix (4Ps) are designed and implemented to support members' self-orientation changes. In this study, the social marketing mix refers to the application of four elements: product, price, place, and promotion, in community learning activities designed to facilitate change in members' self-orientation (Kotler & Zaltman, 1971). Data triangulation was conducted by comparing information obtained from interviews, observations, and documents to enhance the credibility and validity of the findings.

RESULTS

The findings showed that the Professional Mothers community implemented social marketing through a structured and integrated approach to facilitate change in members' self-orientation. Before developing the marketing mix, the Professional Mother community conducted audience segmentation to ensure that messages were aligned with the needs of the target groups. Segmentation was not limited to demographic characteristics but was based on members' life phases and learning needs. The diversity of members' backgrounds and corresponding learning needs was presented in Table 1. This segmentation enabled the design of communication messages that were adjusted to contextual differences among members.

The implementation of the social marketing mix (product, price, place, and promotion) operated as an interrelated system rather than as isolated technical components. Each element contributed to a continuous process of transformation within the community. The social products identified in this study were the

Table 1. Audience segmentation based on life phases and learning needs

Segment Category	Characteristics	Implication for Learning Needs
Unmarried women	Women not yet married	Focus on self-development and identity formation
Married without children	Newly married women without parenting experience	Preparation for parenting roles and family management
Mothers with children (infancy to adulthood)	Mothers at different child-rearing stages	Parenting skills, emotional support, and adaptive learning
Single mothers	Mothers raising children independently	Emotional resilience, social support, and self-capacity strengthening
Mothers in domestic roles	Focus on household and caregiving responsibilities	Time management, self-actualisation, and value internalisation
Mothers in public professions	Engaged in professional or career roles	Work-life balance and identity negotiation
Survivors of domestic violence	Mothers with vulnerable social experiences	Psychological recovery, empowerment, and a safe learning space

change in self-orientation toward the "best version of oneself". Members were positioned as active participants in a safe learning space, where they could understand, experiment with, and adapt community values to their personal and family contexts. According to the Secretary General of IP, the founding figure of the community did not set a standard for all members to follow:

"So Mrs. Septi mapped out what the pattern was like, then we were told to try. The goal was for us to find our own pattern. To be the best version of ourselves!" (Lihada, Secretary General of IP, 2025)

The statement illustrated that members were not instructed to imitate the founders or facilitators directly, but were encouraged to explore and adapt values independently through the learning process in the community. Learning was organised in tiered programmes designed to support gradual internalisation of values. These programmes functioned as platforms for members to understand, reflect upon, and practice community values in daily life. They also provided opportunities to share experiences, receive emotional support, and observe valuable practices demonstrated by other members and community administrators. The findings further showed that various obstacles emerged during the learning process, which were experienced as sacrifices required to achieve self-change. The dimensions of social price identified in this study are presented in Table 2.

The social price was identified in four main dimensions: time and energy, psychological sacrifices, relational sacrifices, and long-term commitments. Time and energy investment emerged as a primary social cost influencing the sustainability of change adoption. Participation in tiered classes and community programmes required significant time for learning, discussion, and reflection. For members with substantial domestic and parenting responsibilities, maintaining engagement over months of structured class demanded deliberate scheduling and sustained effort. Psychological sacrifice involved members' willingness to engage in deep, ongoing self-reflection. Members evaluated previously formed habits, perspectives, and self-identity, which required acknowledging personal limitations and opening space for change. Relational sacrifices referred to potential tensions within the family or social environment, including disagreements among family members about participation in community activities. Long-term commitment was reflected in the consistency required to internalise values and to maintain the self-orientation developed beyond formal community programmes. Members were expected to sustain discipline even when not directly involved in structured activities. These findings indicate that social price is not merely a barrier, but also a process that supports the internalisation of values and the sustainability of behaviour change. The place referred to the system of distributing learning messages within the community. The findings showed that the community implemented a multi-channel distribution design that combined online and offline platforms (Table 3).

Online media were the most widely used channel. Platforms such as the Learning Management System (LMS), WhatsApp Groups, YouTube, and Zoom functioned as primary channels for delivering learning materials and disseminating community values. These platforms provided flexible access for members with limited time and mobility. Social media platforms, including Instagram and Facebook Groups, supported the learning channels by expanding message reach. Offline meetings also played an important role. Activities such as playdates, grand graduations, regional meetings, and community celebrations created opportunities for direct interaction. These meetings facilitated more personal communication

Table 2. Dimension of social price in behaviour change

Dimension of Social Price	Description	Implication for Behaviour Change
Time and energy	Significant time investment in learning, discussion, and reflection activities	Influences the consistency and sustainability of participation
Psychological sacrifice	Engagement in deep self-reflection and evaluation of habits, perspectives, and self-identity	Encourages awareness and openness to change
Relational sacrifice	Potential tensions within the family or social environment, including disagreement about participation	Requires negotiation and social adaptation
Long-term commitment	Continuous effort to internalise values and maintain self-orientation beyond formal programmes	Support sustained behavioural change.

Table 3. Professional mother's message distribution channel

Channel Type	Channel Shape	Main Functions
Online Media	WhatsApp Groups (WAG) Pendopo, LMS, Zoom, official social media (Instagram, Facebook, and YouTube), Website, Podcast, and other digital broadcasts.	Access to learning materials and modules, distribution of values, reinforcement of reflection and support, dissemination of information, inspiration, and education
Offline Media	Playdate, Grand Graduation (reflection), Celebration, Community Meeting	Strengthening of social relationships, affective experiences, and internalisation of values

and strengthened social bonds among members. In this medium, there was a more expressive and meaningful exchange of messages, with facial expressions and body language. Through this activity, members were able to build stronger social relationships directly. The presence of facial expressions, gestures, and voice intonation enabled emotional expression and deeper interpersonal exchange. The findings also indicated that the community reduced participation barriers through flexible access and varied learning formats. Learning materials were available in synchronous and asynchronous modes, allowing members who were unable to attend live sessions to access content at alternative times.

Promotion within the community did not aim to standardise behaviour. Instead, it focused on reframing women's self-orientation towards maternal roles and strengthening personal capacity. The narrative of being "the best version of oneself" emerged as the central promotional message communicated consistently across various community platforms and activities. The findings showed that promotion strategies were organised into four main forms: (1) values and identity framing, (2) role models, (3) participatory promotion based on reflection and testimonials, and (4) public events as an identity reinforcement space (Figure 1).

Promotion was implemented through interconnected strategies that reinforced the narrative of self-orientation change. Value framing emphasised the reinterpretation of motherhood through the message of becoming the "best version of oneself", which was communicated consistently across classes, digital content, and community forums. This narrative was further strengthened through role modelling as founders, administrators, facilitators, and active members demonstrated community values in their daily practices, providing observable references for others during the learning process. Participatory promotion also occurred through member testimonials

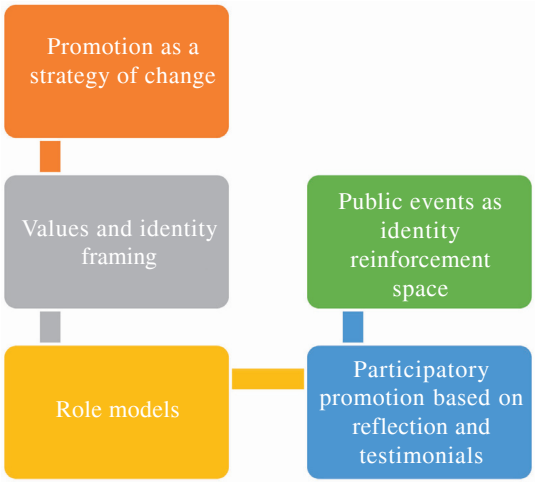

Figure 1. Social marketing promotion strategies

and reflection notes, in which participants voluntarily shared their learning experiences and personal journeys, expanding the meaning of self-orientation change grounded in lived realities. In addition, public events, from informal gatherings to national-level activities, served as broader social spaces that reinforced collective identity and strengthened shared learning experiences among members. Overall, the implementation of the social marketing mix operated as an interconnected system that supported gradual change in members' self-orientation within a community-based learning environment.

DISCUSSION

The findings of this study indicate that the implementation of social marketing in the Professional Mother community represents a participatory and contextual model of community-based extension. The practices identified reflect a dialogical learning process that encourages gradual reflection and internalisation of values (Rogers, 1973; Badri, 2016). From the perspective of modern extension, this process aligns with an empowerment approach that positions members as active subjects in shaping change rather than passive recipients of information. Audience segmentation based on life phase and learning needs aligns with the extension principle of contextual relevance. Messages designed according to these conditions increase the chances of acceptance and internalisation of values. Evidence suggests that interventions tailored to individual circumstances, such as life phases, enhance the probability of sustainable behaviour change (Zhu et al., 2024). This reinforces the view that social change requires adaptation to social diversity and individual experiences (Bartolucci et al., 2023).

This study further shows that the social marketing approach was not merely used as a promotional tool, but as a mechanism for transforming consciousness through changes in the mother's self-orientation. Within the framework of social cognitive theory (Bandura, 1986), stable behavioural changes begin with changes at the cognitive and affective levels. Therefore, the community positions the change in self-orientation toward the "best version of oneself" as its core social product, reflecting shifts in self-interpretation, maternal roles, personal capacity, and the strengthening of identity as a development actor within the family. This finding is consistent with the human development perspective that emphasises the transformation of individual consciousness and capability.

In the social marketing literature, the element of price refers to the cost the audience must bear to adopt a new behaviour, such as investing time, energy, psychological discomfort, relational sacrifice, and long-term commitment. This finding confirms that behavioural change within community-based learning environments entails both tangible and intangible social costs that must be

addressed strategically so that the benefits outweigh these costs (Banu & Özdemir, 2014; Ismail et al., 2022). To maximise the dissemination of social products, the community creates an integrated learning media ecosystem tailored to members' needs. Learning media is an element of distribution channels, both online and offline, as a tool to convey development messages (Rakic & Rakic, 2014) and enabling directed learning exchanges (Ravikumar et al., 2015; Shanmuka et al., 2022). Digital media is both an asset and an opportunity for communicating current developments, enhancing information exchange, and fostering community involvement in agriculture (Panda et al., 2019; Kumar, 2025). Thus, the digital ecosystem operates not only as a communication tool but also as a participatory learning environment.

The promotion of self-orientation change is supported through the framing of values, role models, member participation, and public events that expand the social reach of messages. Message framing combined with multi-channel communication increases audience engagement (Domegan, 2021), while role models strengthen self-efficacy through social learning processes (Nowiñski et al., 2019; Nain et al., 2019). The use of public spaces and member testimonials reflects participatory development communication (Servaes, 2014), where members act as both recipients and producers of meaning, reinforcing collective identity. These findings expand understanding of the social marketing mix in extension contexts, where product, price, place, and promotion are integrated to design a learning environment that supports value internalisation. In this community-based extension setting, the product is reflected in changes in self-orientation, prices in the social and psychological sacrifices required, a place in integrated learning platforms, and promotion through participatory communication practices. Theoretically, this study contributes to the extension education literature by positioning self-orientation transformation as a foundational mechanism for sustainable behavioural change in community-based social marketing strategies.

CONCLUSION

This study confirms that community-based social marketing functions as an effective development communication strategy when it prioritises self-orientation transformation before promoting sustainable behaviour change. The social marketing mix operates as an integrated system in which self-orientation toward the "best version of oneself" becomes the core social product. The social price reflects the psychological, relational, and temporal commitments required to adopt new values, while place serves as a multi-channel distribution system that facilitates flexible access to learning. Promotion reinforces change through value framing, role models, participatory reflection, and public events that extend the message into the broader social sphere. These interconnected elements strengthen participatory and contextual extension practices, positioning self-orientation change as a foundation for long-term and sustainable behavioural development.

DECLARATIONS

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

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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Acknowledgment: The authors would like to thank the Professional Mothers community for allowing us to conduct the research. The authors also received financial support from the Indonesian Education Scholarship (BPI), the Centre for Higher Education Funding and Assessment (PPAPT), the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, and the Indonesia Endowment Fund for Education (LPDP) for the Doctoral scholarship conferred upon awardee (BPI. 202209090879).

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (123-128)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Comparing the Yield and Knowledge Level of Cluster Frontline Demonstration (CFLD) Beneficiaries and Non-Beneficiaries

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HIGHLIGHT

- CFLD significantly increased the mustard yield, with a 32.93% increase from non-beneficiaries to beneficiaries.
- Knowledge gains were highest in seed-related practices because of direct input support and technical guidance.
- Minimum knowledge levels in plant protection reveal a critical gap and suggests the need for more targeted training.
- Kruskal-Wallis and Mann-Whitney tests confirmed a significant difference in knowledge across all groups.

ARTICLE INFO

Keywords: Demonstration, Knowledge, Mustard, Oilseed, Evaluation.

https://doi.org/10.48165/IJEE.2026.62220

Citation: Yadav, R., Singh, L. B., Harsha, Singh, S., Pandey, M. K., Kumar, M., Kumar, A., Amogh, C. N., & Prajapati, C. S. (2026). Comparing the Yield and Knowledge Level of Cluster Frontline Demonstration (CFLD) Beneficiaries and Non-Beneficiaries. *Indian Journal of Extension Education*, *62*(2), 123-128. https://doi.org/10.48165/IJEE.2026.62220

ABSTRACT

The research was conducted during 2024-25, aimed to assess the benefits of the Cluster Frontline Demonstration (CFLD) programme on mustard cultivation knowledge and yield among farmers in Uttar Pradesh (UP). By employing the quasi-experimental design, comparing non-beneficiaries (B_0), previous beneficiaries 2021–2024 (B_1) and current beneficiaries 2024-25 (B_2) with 120 participants each and a total sample size of 360, across three Krishi Vigyan Kendras (KVKs) of UP. The data was collected through a personal interview. Knowledge scores (% correct) and yield (q ha^{-1}) were measured and compared by using Kruskal-Wallis and Mann-Whitney U tests. Results showed a significant difference in yield, i.e. 14.00 q ha^{-1} (B_0) and 18.61 q ha^{-1} (B_2), and median knowledge increased significantly in variety (27.27% to 63.64%) and harvesting and threshing (50.00% to 100.00%) across three groups. All practices show a significant difference ($p < 0.00625$), with effect sizes up to 0.293. Results show that the CFLD programme significantly increases knowledge and yields, due to targeted training and resource support. Non-significant initial differences in some practices suggested overcoming barriers with sustained participation.

INTRODUCTION

The Indian Council of Agricultural Research (ICAR) has established various Krishi Vigyan Kendras (KVKs) across India as an institutional innovation to facilitate the application of agricultural technologies at farmers' fields, with a multidisciplinary team of agricultural scientists (Sahoo et al., 2021; Kumar et al., 2024). One of the important functions of KVKs for technology transfer is the Cluster Frontline Demonstration (CFLD) programme, implemented under the *national food security mission*, which serves as a long-

Received 09-03-2026; Accepted 19-03-2026

term educational initiative. This programme conducts systematic demonstrations on farmers' fields under the close supervision of scientists to showcase the efficiency of recommended practices and technologies (Bhowmik & Biswas, 2024; Lahiri et al., 2025). CFDLs promote a scientific Package of Practices (PoP), like high-yielding varieties, integrated pest management, and balanced fertilizer on farmers' fields. This approach increases farmers' knowledge regarding recommended PoP, allowing real-time feedback, encourages farmer-scientist interactions and supports localised adoption and increases the adoption of improved agricultural technologies (Kumar et al., 2023).

Oilseeds have been considered as one of the oldest cultivated plants in human civilisation (Kalia et al., 2021). Mustard crop in India is grown in diverse agro-climatic conditions ranging from north-eastern /north –western hills to down south under irrigated / rainfed timely / late sown, saline and mixed cropping conditions (Gupta et al., 2020). It significantly contributes to edible oil production and food security, particularly in northern states like Uttar Pradesh and produces approximately 20% of the country's oilseed production (Sachan et al., 2024). Though mustard is a traditional crop, from the health and economic point of view, its demand will always remain same (Kumar et al., 2022). Despite its economic importance, mustard yields remain suboptimal due to the limited adoption of the recommended package of practices (PoP) like land preparation, variety selection, seed treatment, irrigation, fertiliser application, intercultural practices, plant protection, and harvesting techniques. The low yield is often due to inadequate knowledge, resource constraints, and limited access to extension services, which together make it difficult for farmers to implement these practices effectively (Giordano et al., 2012 and Raj, 2013; Nain et al., 2014; Nain et al., 2015; Lahiri et al., 2020). To address these challenges, the CFLD programme, initiated by the ICAR and implemented through KVKs, provides farmers with training, quality inputs (e.g., seed and fertiliser), and on-farm demonstrations to promote the adoption of recommended PoP. Implemented in high-potential regions like the Indo-Gangetic Plains, CFLDs aim to increase farmers' knowledge and yields. However, the long-term effects of CFLDs on farmers' knowledge, particularly when comparing current participants, past participants and non-participants, remain underexplored, highlighting a gap in the literature and research. The study pursues two primary objectives: (1) to compare knowledge levels of recommended PoPs across the three groups and (2) to identify specific parameters where significant knowledge differences exist. By addressing these objectives, the research seeks to provide evidence-based insights for refining extension strategies, thereby informing policy to improve mustard productivity and enhance farmer livelihoods in India.

METHODOLOGY

The study was conducted during 2024-25 in KVKs under Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (SVPUA&T). Three KVKs, namely Meerut, Shahjahanpur and Muzaffarnagar, were selected purposively on the basis of the highest CFLDs conducted on mustard during 2021–22, 2022–23 and 2023–24. The study adopted a quasi-experimental design with a mixed-methods approach to linking quantitative outcomes (e.g., yield) and qualitative insights (e.g., Knowledge gained) to evaluate the CFLD programme's effectiveness in technology diffusion among mustard farmers. The research is based on Bennett's Hierarchy of Programme Evaluation (Bennett, 1975) and Diffusion of Innovations Theory (Rogers, 2003).

The CFLD programme, implemented by Krishi Vigyan Kendras (KVKs) under Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUA&T), Meerut, provides training, seed provision (2.5 kg to each farmer for 0.4 ha), sulphur inputs and on-farm demonstrations to enhance knowledge of improved mustard package of practices. The study compared three independent groups: non-beneficiaries (B_0), previous CFLD beneficiaries (2022–2024, B_1) and current CFLD beneficiaries (2025, B_2). Knowledge was assessed across eight parameters selected on the basis of recommendations of ICAR-Indian Institute of Rapeseed-Mustard Research and Experts in KVKs i.e. Land Preparation (K_1), Variety (K_2), Seed Rate and Treatment (K_3), Irrigation and Sowing (K_4), Fertiliser Application (K_5), Intercultural Practices (K_6), Plant Protection (K_7) and Harvesting and Threshing (K_8), consisting of 6, 11, 4, 10, 6, 11, 15 and 2 questions respectively. Each question was multiple choice and scored binarily (1 for correct, 0 for incorrect), with per cent correct calculated as [{(number of correct answers)/(total questions)} × 100], without partial credit. The questionnaire was pre-tested on 30 farmers, with revisions. Personal interviews were conducted for data collection. Quantitative knowledge scores were complemented by qualitative insights from focus group discussions (FGDs) to explore adoption constraints, such as non-availability of recommended varieties and high input costs.

The stratified sampling technique was used, and three strata/ independent groups were made, i.e. non-beneficiaries (B_0). Out of 627 mustard growers, 120 (40 per KVK) were selected from the villages within a 10 km radius of the selected KVKs. Out of 940 previous beneficiaries of CFLD from 2021–22 to 2023–24 (2021–2024) (B_1), 120 were selected (40 per KVK), and (2024-25) (B_2). Out of 580 current beneficiaries of CFLD in 2024–25, 120 were selected (40 per KVK). Data were tabulated and analysed using SPSS and Excel. Mean and % increase over B_0 were reported in the descriptive statistics. Due to non-normal distribution (Shapiro-Wilk and Kolmogorov-Smirnov $p < 0.001$, $K_8 = 0.538$), Kruskal-Wallis tests were used to compare median per cent correct scores across groups with Bonferroni-adjusted ($\alpha = 0.05 \div 8 = 0.00625$). Post-hoc pair-wise Mann-Whitney U tests were conducted with manual Bonferroni correction ($\alpha = 0.05 \div 3 = 0.0167$).

RESULTS

It can be observed from Table 1 that the average yield and knowledge over 8 practices differ significantly across three groups: non-beneficiaries (B_0), previous beneficiaries (B_1, 2021–2024) and current beneficiaries (B_2, 2024–2025). It can also be observed that the yield and knowledge were highest in B_2 and were lowest in B_0 across all parameters. Average yield increased from 14.00 q ha^{-1} in B_0 to 15.78 q ha^{-1} in B_1 and 18.61 q ha^{-1} in B_2, resulted in a 32.93% increase from B_0 to B_2, which suggest that CFLD helps in increasing productivity. The highest increase (112.73%) in knowledge over B_0 was seen in seed rate and seed treatment (K_3), followed by plant

protection (K_7), which rose from 22.17 in B_0 to 43.39 in B_2 (95.74% over B_0), and variety (K_2) increased from 30.45 in B_0 to 56.14 in B_2 (84.33% over B_0). While the lowest increase (16.67) was observed in land preparation (K_1), followed by 20.31% increase over B_0 in harvesting and threshing (K_8), which was already high in B_0. This means farmers were already familiar with those practices. In other practices, i.e. irrigation and sowing (K_4), fertiliser application (K_5) and intercultural practices (K_6), knowledge level was also higher among B_2 respondents as compared to B_0. These results suggest the CFLD training helped farmers improve their knowledge in all areas. As for B_1 respondents, regardless of prior training under CFLD through KVKs, their knowledge and yield were less than those of the B_2 respondents, but yet higher than those of the B_0 respondents.

The Kruskal-Wallis test results (Table 2) reveal that there was a significant difference in median knowledge scores (% correct) across the three groups for all eight mustard cultivation practices. The median scores and interquartile ranges (IQRs) show differences in knowledge levels across the group with the Bonferroni-adjusted significance threshold ($p < 0.00625$). Among all the practices, the median knowledge and IQR were higher in B_2 as compared to B_0, with a different effect size. Variety (0.293), plant protection (0.211), irrigation and sowing (0.153), Seed rate and seed treatment (0.152), intercultural practices (0.141) shows a significant difference in median knowledge level regarding recommended mustard cultivation practices across groups with a large effect size, indicating a strong influence of CFLD interventions on knowledge level of beneficiaries (B_1 and B_2) regarding these practices. Whereas fertiliser application (0.138), harvesting and threshing (0.096), and land preparation (0.069) show significant differences in median knowledge level regarding recommended mustard cultivation practices across the group with moderate effect size, due to farmers' pre-existing familiarity with these practices. The effect sizes (η^2) indicate that respondents (B_0, B_1, B_2) explains a significant portion of variance in knowledge scores, with large effect sizes ($\eta^2 \geq 0.14$) for K_2, K_3, K_4, K_6 and K_7 showing a strong influence and moderate effect sizes ($\eta^2 = 0.06$–0.14) for K_1, K_5 and K_8 shows a noticeable influence.

Mann-Whitney U Test (Table 3) shows detailed post-hoc pairwise comparisons of B_0, B_1 and B_2 for K_1–K_8. It reveals that there was a significant difference across groups, all comparisons were significant ($p < 0.0167$, Bonferroni-adjusted $\alpha = 0.05 \div 3$) except K1 (B_0 vs. B_1, $p = 0.075$), K6 (B_1vs B_2, $p = 0.030$) and K_8 (B_0 vs. B_1, $p = 0.123$), confirming the Kruskal-Wallis findings of overall significance. Comparison of knowledge regarding land preparation (K1) between B_0 and B_1 was not significant ($p = 0.075$, $r = -0.14$), but significant difference was observed between B_0 and B_2 ($p = 0.000$, $r = -0.33$) and B_1 vs B_2 ($p = 0.036$, $r = -0.16$), indicating a delayed but moderate increase in knowledge ($r = -0.33$). All pairwise comparisons regarding knowledge of mustard varieties were statistically significant ($p = 0.000$), and effect sizes increased from B_0 vs. B_1($r = -0.35$) to B_0 vs. B_2 ($r = -0.59$), reflecting a large knowledge gain (68.18% increase from B_0 to B_2 as per median scores). Results of the Mann-Whitney U Test confirm that CFLD training significantly increases knowledge in most PoP, particularly K_2, K_3 and K_7, where large effect sizes were recorded. The non-significant significant difference in K_1 (B_0 vs. B_1), K_6 (B_1 vs. B_2) and K_8 (B_0 vs. B_1) suggest areas where early exposure or prior knowledge may have limited programme effectiveness.

As the three groups have different levels of knowledge, it is important to understand the factors influencing the knowledge level

Table 1. Percentage increase in yield and knowledge of recommended practices over control (B_0)

Yield and Knowledge on Package of Practices		B_0 (%)	B_1 (%)	B_2 (%)	% Increase over B_0
Y	Yield (q ha^{-1})	14.00	15.78	18.61	32.93
K_1	Land preparation	68.33	73.75	79.72	16.67
K_2	Variety	30.45	41.89	56.14	84.33
K_3	Seed rate and treatment	22.92	37.08	48.75	112.73
K_4	Irrigation and sowing	40.58	50.08	57.08	40.66
K_5	Fertilizer application	32.64	45.56	56.25	60.43
K_6	Intercultural practices	31.81	48.11	52.35	34.70
K_7	Plant protection	22.17	29.61	43.39	95.74
K_8	Harvesting and threshing	80.00	86.25	96.25	20.31

Yield of B_0, B_1, and B_2 is in q ha^{-1} and others parameters are in per cent

Table 2. Comparison of knowledge scores among groups using Kruskal-Wallis test

Parameter	B_0 Median (IQR)	B_1 Median (IQR)	B_2 Median (IQR)	χ^2 (df = 2)	p-value	η^2
K_1	66.67(50-83.33)	66.67(50-83.33)	83.33(66.67-100	24.683	0.000*	0.069
K_2	27.27(18.18-45.45)	45.45(36.36-54.55)	63.64(45.45-63.64	105.118	0.000*	0.293
K_3	25.00(0-50)	50.00(25-50)	50.00(25-75)	54.730	0.000*	0.152
K_4	40.00(30-50)	50.00(40-60)	60.00(40-70)	54.814	0.000*	0.153
K_5	33.33(16.67-50)	50.00(16.67-66.67)	50.00(33.33-66.67)	49.406	0.000*	0.138
K_6	36.36(27.27-45.45)	45.45(36.36-54.55)	54.55(45.45-63.64)	50.491	0.000*	0.141
K_7	20.00(6.67-26.67)	33.33(13.33-40)	40.00(33.33-53.33)	75.832	0.000*	0.211
K_8	50.00(50-100)	100.00(50-100)	100.00(100–100)	34.304	0.000*	0.096

Note: *$p < 0.00625$ indicates significance (Bonferroni-adjusted). Medians and IQRs to be inserted after rerunning K Independent Samples with the Quartiles option. $\eta^2 = \chi^2 / (n - 1)$, $n = 360$; interpretation: small ($\eta^2 < 0.06$), medium ($\eta^2 = 0.06$ to < 0.14), large ($\eta^2 \geq 0.14$).

Table 3. Pairwise Comparison of Knowledge Scores Across Groups

Parameter	Comparison	U	Z	p-value	Adjusted p-value	r
K_1	B_0 vs. B_1	6042.00	-2.235	0.025	0.075	-0.14
	B_1 vs. B_2	5889.00	-2.523	0.012	0.036*	-0.16
	B_0 vs. B_2	4566.00	-5.077	0.000	0.000*	-0.33
K_2	B_0 vs. B_1	4344.00	-5.373	0.000	0.000*	-0.35
	B_1 vs. B_2	3445.00	-7.074	0.000	0.000*	-0.46
	B_0 vs. B_2	2350.00	-9.099	0.000	0.000*	-0.59
K_3	B_0 vs. B_1	5035.00	-4.193	0.000	0.000*	-0.27
	B_1 vs. B_2	5445.00	-3.387	0.001	0.003*	-0.22
	B_0 vs. B_2	3407.00	-7.296	0.000	0.000*	-0.47
K_4	B_0 vs. B_1	4816.50	-4.534	0.000	0.000*	-0.29
	B_1 vs. B_2	5453.00	-3.296	0.001	0.003*	-0.21
	B_0 vs. B_2	3415.50	-7.135	0.000	0.000*	-0.46
K_5	B_0 vs. B_1	5186.50	-3.804	0.000	0.000*	-0.25
	B_1 vs. B_2	5483.00	-3.248	0.001	0.003*	-0.21
	B_0 vs. B_2	3487.00	-7.008	0.000	0.000*	-0.45
K_6	B_0 vs. B_1	4629.00	-4.858	0.000	0.000*	-0.31
	B_1 vs. B_2	5847.50	-2.561	0.010	0.030	-0.17
	B_0 vs. B_2	3617.50	-6.754	0.000	0.000*	-0.44
K_7	B_0 vs. B_1	5171.50	-3.796	0.000	0.000*	-0.25
	B_1 vs. B_2	4236.00	-5.548	0.000	0.000*	-0.36
	B_0 vs. B_2	2758.00	-8.297	0.000	0.000*	-0.54
K_8	B_0 vs. B_1	6300.00	-2.043	0.041	0.123	-0.13
	B_1 vs. B_2	5760.00	-4.069	0.000	0.000*	-0.26
	B_0 vs. B_2	4860.00	-5.903	0.000	0.000*	-0.38

Note: *$p < 0.0167$ (Bonferroni-adjusted $\alpha = 0.05 \div 3$) indicates significance. Medians and IQRs are reported in Table 1 (Kruskal-Wallis Test Results). Adjusted p-value = $p \times 3$ (capped at 1.0). Effect size $r = Z / \sqrt{240}$, where $\sqrt{240} \approx 15.49$; interpretation: small (0.1), medium (0.3), large (0.5).

Table 4. Constraints Affecting Knowledge Level of Mustard Growers

S.No.	Constraints Affecting Knowledge Level	B_0 Mean Score	B_1 Mean Score	B_2 Mean Score	Overall Mean
C_1	Lack of awareness about recommended mustard varieties	2.68	2.14	1.72	2.18
C_2	Inadequate knowledge about seed treatment practices	2.74	2.26	1.81	2.27
C_3	Limited exposure to training programmes/demonstrations	2.61	2.03	1.55	2.06
C_4	Lack of timely advisory services from extension personnel	2.52	2.11	1.83	2.15
C_5	Difficulty in understanding plant protection measures	2.41	1.98	1.69	2.03
C_6	Lack of knowledge regarding fertiliser application	2.32	1.92	1.63	1.96
C_7	Limited access to ICT / information sources	2.48	2.05	1.74	2.09
C_8	Insufficient interaction with progressive farmers	2.29	1.84	1.51	1.88

(Mean score based on 3-point constraint scale: 3 = Severe constraint, 2 = Moderate constraint, 1 = Least constraint)

of the three groups. The results indicate (Table 4) that the severity of constraints was highest among non-beneficiaries (B_0), followed by previous beneficiaries (B_1), whereas the lowest was observed among current beneficiaries (B_2). This trend is in line with the earlier findings, where knowledge scores across all eight practices indicate that participation in CFLD programmes helped reduce informational and technical barriers faced by farmers. It improves farmers' exposure to training, demonstrations and extension services. Previous beneficiaries (B_1) showed moderate constraint levels, suggesting that although prior exposure to CFLD improved knowledge, continuous engagement and training are essential to sustain knowledge gains. The findings highlight that extension education interventions such as demonstrations, training programmes and regular advisory services play a critical role in reducing knowledge gaps and of recommended mustard cultivation practices.

DISCUSSION

The yield increased significantly in B_2 respondents as compared to B_0 respondents, while B_1 showed a significant decrease in yield, suggesting that the CFLD programme enhances productivity through training and scientific know-how of the KVK experts, it was also in conformity with the findings of Chahal et al. (2014), Singh et al. (2022), Sarkar et al. (2025), and Jha et al. (2025). Sharma et al. (2022) reported that, upon realising the superior yield potential of the recommended mustard variety Giriraj, all beneficiaries shifted from using hybrid varieties developed by private sector companies and local mustard seed companies to Giriraj, leading to enhanced yields. This growth surpassed the average mustard yield in Uttar Pradesh, which is around 11 Q/ha, according to the Government of India Ministry of Agriculture and Farmers Welfare, which also shows the broader impact of the CFLD programme. Though the yield increases in B_2 (current beneficiaries,

2025), the benefits for previous beneficiaries (B_1) may have been limited due to inadequate follow-up. Mean knowledge scores also follow a consistent upward trend ($B_0 < B_1 < B_2$), highlighting the programme's overall benefits to the farmers (Samajder et al., 2016). Current Beneficiaries (B_2) outperformed in all mustard PoP knowledge, particularly in Variety (K_2) and Seed Rate and Treatment (K_3), likely due to direct and immediate support like recommended seed, knowledge regarding recommended varieties, demonstrations and timely technical guidance. Similar results were observed by Kalita et al. (2019), Jha et al. (2021), and Sangwan et al. (2021). Regardless of the above-mentioned support, knowledge of B_1 (previous beneficiaries 2021-2024) significantly decreases over time, as explained in Ebbinghaus' Forgetting Curve, also explained by Murre and Dros (2015). Practices such as Harvesting and Threshing (K_8) showed high initial knowledge levels, which may be due to traditional familiarity or routine adoption. As well, the lowest scores were seen in Plant Protection (K_7), where scores increased from 22.17 per cent to 43.39 per cent, underlining a critical gap in earlier awareness. This suggests that CFLD efforts should emphasise these technically demanding practices, where farmer knowledge remains limited.

The Mann-Whitney U post-hoc results further validate these findings, that there was a significant difference between non-beneficiaries (B_0) and Current Beneficiaries (B_2) (e.g., K_2, r = -0.59; K_3, r = 0.47), demonstrating CFLD's similar impact. Meanwhile, non-significant differences in K_1 (B_0 vs. B_1) and K_8 (B_0 vs. B_1) indicate practices where initial CFLD exposure made a limited difference, due to baseline knowledge, lower resource dependency, or implementation lag (Kumar & Lahiri, 2023). However, the increase in knowledge between B_1 and B_2 suggests that more intensive or targeted interventions are required for certain practices to increase the yield further. The consistent pattern of knowledge gains, i.e. low in B_0, moderate in B_1 and highest in B_2, confirms that exposure to CFLD interventions contributes to learning progression. However, due to a lack of follow up results in decreased, the knowledge and yield in B_1 decreased. Furthermore, CFLD should focus more intensively on low-scoring practices like Plant Protection, which can also reinforce knowledge retention (Lankinen et al., 2024)

CONCLUSION

The study shows that the CFLD programme significantly improves mustard cultivation knowledge and yield among participating farmers in Uttar Pradesh, with current beneficiaries (B_2) achieving the highest median scores and yield. The consistent increase in medians across practices, particularly in variety and seed rate and seed treatment, underscores the programme's effectiveness in addressing knowledge gaps, and the yield increase highlights the practical impact. The significant Kruskal-Wallis and Mann-Whitney U results, supported by moderate to large effect sizes, validate the hypothesis that CFLD training enhances agricultural outcomes. Reasons for these improvements were targeted training and resource support provided under the CFLD programme, such as seed distribution and technical guidance, which significantly boosted knowledge in practices like K_2 and K_3. Future efforts should focus on low-scoring practices like Plant Protection (K_7) and integrate qualitative insights to refine programme delivery, ensuring sustained yield and knowledge gains across all farmer groups.

DECLARATIONS

Ethical statement: The study was conducted in accordance with ethical research standards. 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.

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Research Article

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (129-134)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Social Media Awareness among Farmers in Haryana: An Age-wise Comparative Analysis

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HIGHLIGHTS

- The majority of respondents exhibited a medium level of social media awareness
- Significant age-wise differences were observed in social media awareness among farmers of different age groups
- The socio-personal and communication variables significantly influenced the awareness level of farmers

ARTICLE INFO

Keywords: Age-wise comparison, Awareness, Determinants, Social media.

https://doi.org/10.48165/IJEE.2026.62221

Citation: Mishra, A., Singh, K., Singh, J., & Malik, J. S. (2026). Social Media Awareness among Farmers in Haryana: An Age-wise Comparative Analysis. *Indian Journal of Extension Education*, *62*(2), 129-134. https://doi.org/10.48165/IJEE.2026.62221

ABSTRACT

The study measured farmers' social media awareness and compared the awareness across different age groups in Haryana. A descriptive and analytical research design was employed, and data were collected from 240 farmers, equally divided into three age groups and selected through multi-stage stratified random sampling from eight villages across two districts. Data were gathered using a structured interview schedule, and analysis was conducted using statistical tools including independent sample t-test, Pearson product-moment correlation and multiple linear regression. The results showed that a majority of respondents possessed a medium level of social media awareness. Further, the young farmers exhibited significantly higher awareness compared to other age groups. Also, it was observed that farmers were largely aware of social media for information sharing, communication, and entertainment, but awareness regarding marketing applications remained low. Socio-economic variables such as age, education, extension participation and contact and scientific orientation emerged as the strongest predictors of social media awareness. The study proposes targeted training programmes on digital literacy and institutional linkage to enhance farmers' awareness and professional use of social media platforms.

INTRODUCTION

Social media is an e-communication technology that allows users to exchange knowledge, concepts, private messages, and other types of content by forming an interconnected social relationship called online communities (Merriam-Webster, 2015). These computer-mediated tools are interactive in nature, which makes it easier to create or share content through online communities and networks. They also help people express themselves in various ways. By building online communities, social media enables users to share stuff such as knowledge, concepts, thoughts, and private messages. Additionally, it aids in developing viewpoints, stimulating conversation, and forging connections (Saravanan & Bhattacharjee, 2014). According to Digital 2025, there were 5.66 billion social media users across the world, and an average user spent 2.6 hours each day on various social media platforms. India, home to more than 1.4 billion people, had approximately 950 million internet users, of which about 548 million were in rural areas by the end of 2025. The rapid growth of internet infrastructure, along with the rise of 5G internet connectivity, has expanded the reach of social media

Received 10-03-2026; Accepted 20-03-2026

even in the rural parts of India. As of October 2025, there are over 500 million active users of social media in India, with WhatsApp having the highest number of active users followed by YouTube (500 Million users), Instagram (481 million users), Facebook (403 million users), Snapchat (213 million users), LinkedIn (170 million users), Reddit (30.8 million users) and X (formerly Twitter) with 22.2 million active users (Digital, 2026).

The dissemination of agricultural knowledge and the transfer of technologies both benefit greatly from social media. Farmers can now use social media to enhance their operations and marketing strategies. It gives farmers the chance to collaborate on content creation and encourages farmer-to-farmer learning through creation of groups on Facebook and WhatsApp where they can connect with multiple people simultaneously and share ideas in real time (Singh et al., 2021). Additionally, social media can assist extension specialists in offering expert advice, guidance, and facilitating interactions with progressive farmers and peers. It is a cheap and readily available tool which used to create awareness, mobilise communities, disseminate information, alter farmers' behaviour, obtain feedback, and measure the results of the extension activities (Gharis et al., 2014; Doyle & Briggeman, 2014). By fostering connections between extension experts and the customers who read that material, social media facilitates the delivery of useful, timely, and scientific information to the clients (Jones et al., 2011). Social media platforms offer farmers a comprehensive understanding of local development, going beyond the simple transmission and sharing of agricultural information to become socially, economically, politically, and culturally aware. This improves their decision-making ability and reduces the information gap, leading to their empowerment (Geethalakshmi et al., 2024). Social media can also be used for marketing of agricultural commodities, directly to consumers or grocery stores in cities (Nain et al., 2019; Mishra et al., 2022).

However, despite the increasing penetration of smartphones in rural India, empirical evidence on farmers' awareness regarding the diversified uses of social media, particularly the age-wise differences, remains limited. So keeping these points in view, the research was undertaken to assess the awareness of farmers to different uses of social media, compare social media awareness among farmers of different age groups, and to identify the key determinants of the social media awareness among the farmers.

METHODOLOGY

The study adopted a descriptive and analytical research design to assess the level of social media awareness among farmers and to examine differences in social media awareness across different age groups, in Haryana state. The study chose multistage stratified random sampling technique for selection of the respondents. Two districts i.e., Hisar and Sonipat were randomly selected from the western and eastern zone of Haryana, respectively. From Hisar, Hansi-1 and Hisar-2 blocks, and from Sonipat, Rai and Kharkhoda blocks were selected, randomly. Additionally, two villages were chosen randomly from each of the four blocks. Balsamand and Arya Nagar were chosen from Hisar- 2 block, whereas Umra and Garhi were chosen from Hansi-1 block, respectively. Similarly, Kanwali and Rohat were chosen from the Kharkhoda block, while Manouli and Halalpur were chosen from the Rai block, respectively. After selecting the districts, blocks and villages through random sampling, farmers within each village were stratified into three age categories (young, middle and old). From each age category, ten farmers were selected randomly, resulting in thirty respondents per village and a total sample size of 240 farmers. Equal allocation across strata was adopted to ensure balanced representation and reliable comparison among age groups. A well-structured interview schedule created in consultation with the experts and validated by a panel of discipline specialists, was used to gather the data through the personal interview approach, and MS Excel and IBM-SPSS were used for analysis. Social media awareness was operationalized across five functional domains: general information, agricultural advisory, social networking, marketing and recreational purposes. These domains were derived from Uses and Gratifications framework (Katz et al., 1974) and subsequent ICT and agricultural extension studies, which classify media use according to informational, social, instrumental (economic) and entertainment motivations. Considering the agricultural context of the study, informational use was further differentiated into general information and agricultural advisory functions to capture farm-specific knowledge needs of farmers. Also, a total of five social media platforms i.e. Facebook (profile based), WhatsApp (instant chat), YouTube (video streaming), Instagram (media sharing) and X (micro blogging) were selected for the study as each of them belonged to a different category (type) of social media and were most popular in rural India as per the report of Digital 2026. The awareness was measured using items arranged on a three-point continuum (fully aware, partially aware and not aware). Descriptive statistics such as frequency, percentage, mean and standard deviation were used to describe the awareness levels. The farmers were categorized into three categories i.e., low, medium and high based on their social media awareness using mean and standard deviation. Also, for direct comparison between two independent age-groups at a time and to obtain clearer interpretation of inter-group differences, an independent sample t-test was used. Additionally, Pearson product moment correlation and multiple linear regression was conducted to identify the important socio-economic variables that affect the farmers' social media awareness.

RESULTS

Social media awareness

Respondents were grouped into three categories i.e., high, medium and low based on their degree of awareness to social media. A majority (52.50%) of respondents exhibited a medium level of social media awareness which indicates a moderate familiarity with social media platforms among farmers in Haryana (Figure 1).

Awareness to different uses of Social media

It could be inferred from the findings (Table 1) that farmers were most aware of Facebook's informational use of getting general information and news followed by its social use (networking and interaction with peers and professionals), and recreational use, respectively. In terms of awareness regarding WhatsApp, most farmers were aware of WhatsApp's social use as a medium for networking and recreation, followed by its agricultural use which

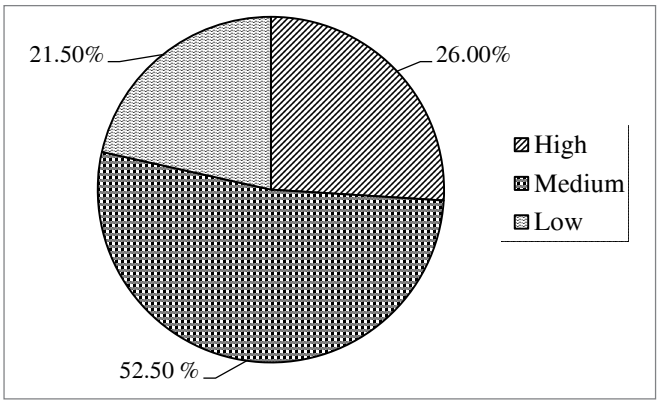

Figure 1. Categorization of farmers on the basis of their social media awareness

includes getting agricultural advisory services. For YouTube, most of the farmers were aware of its recreational use followed by the informational use. Also, for X (Twitter), the awareness was highest for its informational use whereas for Instagram, the awareness was highest for the recreational use. However, in general majority of farmers were unaware of the informational, agricultural, social, economic and recreational use of X and Instagram.

Across the five social media platforms, awareness was highest for recreational and networking functions, whereas it was lowest for economic functions related to marketing and market linkage. This clearly suggests that farmers mainly associate social media with communication and entertainment rather than economic functions. Also, the results (Table 1) indicate that there was a platform specific functional specialization of different social media as recognized by the farmers. YouTube has emerged as a medium for recreation (entertainment) whereas Facebook was recognized as an informational platform. Moreover, WhatsApp emerged as a networking application mainly used for interaction with peers and professionals, whereas the familiarity with X remains low as proved by its lack of awareness among the majority of the farmers. Instagram was also recognized as a recreational medium but its awareness remains mostly restricted to the young farmers.

Comparison of social media awareness across different age groups

The study used independent sample t-test to examine specific pairwise differences in the awareness of different social media between predetermined age categories (young-old, young-middle, and middle-old) of farmers. Since the age groups were conceptually

Table 1. Farmers' awareness regarding functional uses of different social media platforms (n=240)

Functional Domain	Specific Use	Fully Aware	Partially Aware	Not Aware	TWS	WMS	Rank Order
Facebook							
Informational	General Information & News	169(70.41)	58(24.17)	13(05.42)	636	2.65	1
Agricultural	Agricultural Advisory	131(54.58)	87(36.25)	22(09.17)	589	2.45	4
Social	Networking and Interaction	155(64.58)	66(27.50)	19(07.92)	616	2.57	2
Economic	Marketing & Market linkage	65(26.08)	82(34.17)	93(38.75)	452	1.88	5
Recreational	Entertainment	151(62.92)	60(25.00)	29(12.08)	602	2.51	3
WhatsApp							
Informational	General Information & News	104(43.34)	65(27.08)	71(29.58)	513	2.13	3
Agricultural	Agricultural Advisory	124(51.67)	62(25.83)	54(22.50)	550	2.29	2
Social	Networking and Interaction	223(92.91)	11(04.59)	06(02.50)	697	2.90	1
Economic	Marketing & Market linkage	27(11.25)	58(24.17)	155(64.58)	352	1.47	5
Recreational	Entertainment	37(15.42)	84(35.00)	119(49.58)	398	1.66	4
YouTube							
Informational	General Information & News	156(65.00)	73(30.42)	11(04.58)	625	2.60	2
Agricultural	Agricultural Advisory	117(48.75)	89(37.08)	34(14.17)	563	2.34	3
Social	Networking and Interaction	52(21.67)	82(34.16)	106(44.17)	426	1.77	4
Economic	Marketing & Market linkage	46(19.17)	57(23.75)	137(57.08)	389	1.62	5
Recreational	Entertainment	222(92.50)	15(06.25)	03(01.25)	699	2.91	1
X (Twitter)							
Informational	General Information & News	19(07.92)	37(15.42)	184(76.66)	315	1.31	1
Agricultural	Agricultural Advisory	11(04.58)	31(12.92)	198(82.50)	293	1.22	3
Social	Networking and Interaction	14(05.83)	29(12.09)	197(82.08)	297	1.24	2
Economic	Marketing & Market linkage	02(00.83)	07(2.92)	231(96.25)	251	1.04	5
Recreational	Entertainment	06(02.50)	16(06.67)	218(90.83)	268	1.12	4
Instagram							
Informational	General Information & News	63(26.25)	59(24.58)	118(49.17)	425	1.77	2
Agricultural	Agricultural Advisory	29(12.08)	54(22.50)	157(65.42)	352	1.46	4
Social	Networking and Interaction	54(22.50)	53(22.08)	133(55.42)	401	1.67	3
Economic	Marketing & Market linkage	21(08.75)	38(15.83)	181(75.42)	280	1.17	5
Recreational	Entertainment	79(32.92)	53(22.08)	108(45.00)	451	1.88	1

Note: Values in parenthesis denote percentage, TWS= Total Weighted Score, WMS= Weighted Mean Score

distinct categories rather than ordered treatment levels, pairwise comparisons using the independent t-test were considered appropriate for targeted hypothesis testing. Further, five social media, i.e., Facebook, WhatsApp, YouTube, Instagram and X, were used to compare means among the three-age group of farmers.

The findings (Table 2) showed a significant mean difference in the social media awareness between young and old farmers with respect to Facebook, YouTube, Instagram and X (Twitter) with t-values of 3.423, 3.139, 14.702 and 7.425 (significant at 1 per cent probability level, $p<0.01$), respectively. Similarly, the findings revealed a significant difference in the social media awareness among young and middle-aged farmers with respect to YouTube, Instagram and X with t-values of 2.649, 10.257 and 3.697 (significant at 1 per cent probability level, $p<0.01$), respectively. Also, a significant difference in social media awareness was observed for old and middle-aged farmers, with respect to Facebook, Instagram and X with t-values of 2.972, 5.850, and 5.003 (significant at 1% level of significance, $p<0.01$), respectively. There was no significant difference in awareness of WhatsApp and YouTube among the old and middle-aged farmers.

These findings reveal a considerable difference in the awareness level of farmers across the different age groups and social media. The difference was widest for Instagram and X (Twitter), that clearly reflect that familiarity was much higher in young farmers compared to the old farmers. Also, unlike other social media platforms, the awareness regarding WhatsApp did not significantly differ across the young, middle and old age farmers which indicates the universal penetration of WhatsApp as a networking (social) application. Also, old farmers exhibited a comparable awareness level for WhatsApp and YouTube which suggests a high familiarity with these platforms compared to the other social media platforms. Moreover, the awareness of Facebook was comparable among young and middle-aged farmers, suggesting its recognition as an informational and social tool.

Determinants of social media awareness among farmers

The findings in Table 3 inferred that, socio-economic variables such as education, annual income, media exposure, social participation, extension contact and participation, scientific orientation and economic motivation had significant and positive correlation (at 1% probability level) with awareness level, while age showed a negative correlation with awareness.

The multiple linear regression analysis gave R^2 as 0.546 which means, 54.60 per cent variation in farmers' social media awareness can be explained by the selected socio-economic variables. Education, extension contact, extension participation and economic motivation emerged as the strongest predictor of social media awareness, suggesting the importance of social and institutional linkage in promoting digital literacy among the farmers. The relatively high value of coefficient of determination (R^2) suggests that social media awareness among farmers is structurally influenced by educational status, communication and institutional exposures and motivational factors. Also, the diagnosis of multicollinearity (using Variance Inflation Factor and tolerance values) revealed that all predictor variables had VIF values less than 5.00 and tolerance values greater than 0.10, which confirmed the relative stability of the regression estimates.

DISCUSSION

The results on the overall social media awareness of farmers are backed by Mishra et al. (2022) who concluded that most of the farmers fall in the medium category in terms of the overall use of social media. Singh et al. (2020) also observed that in terms of ICT usage most of the respondents were in medium category. Also, it is evident from the results that, while the farmers were aware of the informational, social and recreational functions of the Facebook, WhatsApp and YouTube, their awareness towards agricultural and economic use of social media remains low. The low awareness

Table 2. Age-wise Comparison of social media awareness

Social media platform	Mean (Y)	Mean (O)	Mean difference	t-value	p value
Young (Y) vs Old (O)					
Facebook	2.789	1.998	0.791	4.023**	0.002
WhatsApp	2.799	2.466	0.334	1.553	0.061
YouTube	2.975	2.309	0.666	3.139**	0.005
Instagram	2.159	0.154	2.005	14.702**	0.001
X (Twitter)	1.157	0.119	1.038	7.425**	0.001
Social media platform	Mean (Y)	Mean (M)	Mean difference	t-value	p value
Young (Y) vs Middle (M)					
Facebook	2.789	2.672	0.117	0.596	0.127
WhatsApp	2.779	2.572	0.207	1.107	0.079
YouTube	2.975	2.591	0.384	2.649**	0.006
Instagram	2.159	0.733	1.426	10.257**	0.001
X (Twitter)	1.157	0.633	0.524	3.697**	0.001
Social media platform	Mean (M)	Mean (O)	Mean difference	t-value	p value
Middle (M) vs Old (O)					
Facebook	2.676	1.998	0.678	3.172**	0.003
WhatsApp	2.572	2.466	0.106	0.529	0.134
YouTube	2.591	2.309	0.282	1.572	0.059
Instagram	0.733	0.154	0.579	5.850**	0.001
X (Twitter)	0.633	0.119	0.514	5.003**	0.001

** Significant at 1 per cent level of probability

Table 3. Relationship between socio-economic profile of respondents with their social media awareness

S. No.	Socio-personal variables	Pearson's product moment coefficient ('r' value)	Regression coefficient (B value)
1	Age	-0.317**	-3.927**
2	Education	0.465**	2.342*
3	Annual family income	0.422**	0.783
4	Land Holding	0.171	0.152
5	Cosmopoliteness-Localiteness		
A	Personal Localite	0.367**	0.423
B	Personal Cosmopolite	0.469**	0.347
6	Mass Media Exposure	0.322**	0.569
7	Social Participation	0.412**	1.214*
8	Extension Contact	0.532**	2.791*
9	Extension Participation	0.353**	1.376*
10	Economic Motivation	0.427**	1.967**
11	Scientific Orientation	0.489**	1.568**
	R^2 = 0.546		
	Constant=17.872		

** Significant at 1 per cent level of probability, *Significant at 5 per cent level of probability

towards the economic function of social media (i.e. marketing and market linkages) proves that social media applications are still perceived as tools for accessing information, communication and recreation rather than marketing and transaction by the farmers. This could be credited to the lack of digital marketing skills, low awareness of digital marketing opportunities and lack of exposure to the cases of successful social media marketing. The domination of informational and recreational awareness is also backed by the Gratification theory, which suggests that users of mass media primarily seek recreation and information. Joshi and Dhaliwal (2019), too observed that most farmers consider social media as a source of news, recreation and social interactions and lacks the ability to use it for economic purposes. Additionally, they revealed that while most farmers were aware of different functions of Facebook, WhatsApp and YouTube, their awareness towards X (Twitter) and Instagram were quite low. The results are also supported by Khou and Suresh (2018), who observed that the use of WhatsApp, Facebook and YouTube are the most prevalent amongst the farmers.

The findings on age wise comparison of social media awareness revealed major differences between the farmers of different age groups. The results can also be understood through the lens of digital divide, that refers to the wide disparity in access and familiarity with digital tools including social media between younger and older individuals. Younger farmers are more exposed to smartphones, internet and social media, which increases their awareness of different functions of social media whereas the awareness among older farmers remains low due their limited digital literacy and exposure to social media platforms. The results were supported by Balkrishna and Deshmukh (2017) and Panda et al. (2019), who observed that younger farmers were making greater and more diversified use of social media with respect to older farmers. Jha (2017) also reported that the younger generation in India spends many hours a day browsing YouTube and Facebook. Additionally, the findings revealed that young farmers were much more aware of Instagram and X compared to farmers from middle and older age groups. This pattern again strengthens the argument of digital divide, where old farmers show preference to simpler and easy to use platforms like YouTube and WhatsApp, that satisfy their information and recreational needs whereas younger farmers with higher digital literacy and exposure to new tools tend to experiment with wider range of social media applications like microblogs (X), that requires familiarity with real-time information and digital discourse and short-form media sharing (Instagram), that appeals to younger generation, who prefers image and visual based communication, beyond the more conventional platforms like WhatsApp, YouTube and Facebook.

The results on Pearson product moment correlation revealed that variables such as income, education, mass media exposure, extension contact and participation, social participation, scientific orientation and economic motivation were significantly and positively correlated with social media awareness of farmers, which indicate that the awareness level of farmers towards different functions of social media are affected by socio-personal variables like education, income, communication and social exposure along with their motivations. The findings were backed by Raghuprasad et al. (2012), Kaur (2014) and Mishra et al. (2022) who reported that social media use varied between different income, exposure and motivation levels of farmers. Further, they revealed that farmers from younger and high-income group spend more time on social media with respect to farmers who were older and fall in the low-income group. Also, as social contacts and exposure with different localite and cosmopolite sources, including extension workers, increase, the awareness towards social media and its different functions also increases, as individuals learn and use these emerging tools for building relationships, gain access to information and interaction with colleagues. The negative but significant relationship between age and social media awareness was supported by Joshi and Dhaliwal (2019), who observed that age showed an inverse relationship with social media use. The multiple linear regression analysis also indicates a strong explanatory power of the model where the selected independent variables explain 54.60 per cent variation in the awareness level of farmers. Variables such as education, extension contact and participation, economic motivation and scientific orientation emerged as the most important predictors of social media awareness. This was backed by Satapathy et al. (2024) who observed that educational qualification, social participation and extension exposure are the strongest predictors of ICT use by the farmers. These results highlight the role of strengthening social and institutional (extension) linkages and improving digital literacy of farmers for enhancing their digital awareness and effective use of social media applications. The trainings may be instrumental as the number of training programmes attended, learning motivation, innovativeness, motivation to transfer learning, self-efficacy and achievement motivation significantly affect the training effectiveness (Arunkumar et al., 2021). This will ensure integration of social media into the agro-advisory services, thereby modernizing the conventional extension system and supporting the shift towards the digital agriculture.

CONCLUSION

Farmers were relatively more aware of informational, social and recreational functions of social media that included getting general information and news, connecting with peers and professionals and entertainment; however, awareness of agricultural and economic uses of social media remained low. Among the five platforms selected for the study, Facebook, WhatsApp and YouTube had higher awareness among farmers than Instagram and X. Age-wise comparison of social media awareness revealed that young farmers possessed higher awareness of social media platforms compared to middle-aged and old farmers. Socio-economic variables such as age, education, extension contact and participation, economic motivation and scientific orientation emerged as the strongest predictors of social media awareness among the farmers. The study suggests strengthening digital literacy along with institutional linkages through targeted training programmes to enhance farmers' awareness of different social media functions, particularly the economic and agricultural uses.

DECLARATIONS

Ethical statement: The study was conducted in accordance with ethical research standards. 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 and the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The author declares that they have 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 Tool

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (135-140)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Construction of an Index to Assess the Awareness of Horticultural Farmers towards e-Extension Services

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HIGHLIGHTS

- A scientifically validated, index was developed to assess horticultural farmers' awareness among e-extension services.
- The index captures three core domains: general awareness about e-extension, awareness of public e-extension services, and awareness of private e-extension services.
- A rigorous item development process, expert validation (n = 70), and statistical screening (RW ≥ 0.80; MRS ≥ OMRS) resulted in 48 high-quality statements.
- The index demonstrates excellent reliability (Cronbach's alpha = 0.951), confirming its suitability for large-scale field assessment.
- The tool provides a robust framework for examine the awareness level, and evaluation in horticultural systems.

ARTICLE INFO

Keywords: e-Extension services, Information and Communication Technologies (ICTs), Horticultural farmers, Awareness index and Digital advisory systems.

https://doi.org/10.48165/IJEE.2026.622RT01

Citation: Sahu, V., Singh, V. K., Maji, S., Lakshmi, R., Kumar, M., & Singh, M. (2026). Construction of an Index to Assess the Awareness of Horticultural Farmers towards e-Extension Services. *Indian Journal of Extension Education*, *62*(2), 135-140. https://doi.org/10.48165/IJEE.2026.622RT01

ABSTRACT

The rapid expansion of Information and Communication Technologies (ICTs) has reshaped agricultural extension, offering scalable pathways for disseminating timely, location-specific information to farmers. Horticulture crops are highly perishable in nature and decision-making time-sensitive; the effectiveness of e-extension systems depends strongly on farmers' awareness and understanding of digital advisories. This present study, conducted during 2025, aimed to construct a scientifically valid and reliable index to measure the awareness of horticultural farmers towards e-extension services. Based on an extensive literature review, expert consultations and field insights, 112 statements were initially generated across three conceptual domains: general awareness about e-extension, awareness of public e-extension services, and awareness of private e-extension services. Following rigorous screening using Edward's criteria and relevancy testing by 70 experts, 48 statements met the established criteria of Relevancy Weightage (≥0.80) and Mean Relevancy Score (≥ OMRS = 2.44). The index was validated through field administration among 60 horticultural farmers in non-sampled areas. Reliability analysis indicated excellent internal consistency (Cronbach's alpha = 0.951) and strong split-half reliability (Spearman-Brown coefficient = 0.936). The validated index provides a robust measurement framework to assess awareness gaps and strengthen ICT-enabled advisory systems, thereby enhancing the accessibility, effectiveness, and impact of e-extension services in the horticultural sector.

INTRODUCTION

Over recent decades, the expansion of Information and Communication Technologies (ICTs) has transformed agricultural extension, creating new pathways for farmers to access expert knowledge and digital resources that enhance farm management, reduce production costs, and improve productivity (Paliwal et al.,

Received 14-01-2026; Accepted 18-02-2026

2025; Singh et al., 2025). e-Extension services, enabled through diverse ICT tools, provide timely and location-specific information on soil health, pest and disease management, climate risks, and input use (Shukla et al., 2022; Singh et al., 2023; Singh et al., 2024; Shukla et al., 2024). This transformation is particularly critical in horticulture, where highly perishable crops demand immediate and precise decision-making to minimise post-harvest losses. In India, the substantial horticultural farming population and the limited availability of extension personnel render traditional face-to-face advisory services insufficient. Consequently, e-extension has emerged as a scalable alternative to bridge information gaps and improve farmers' access to expert advisories (Shukla et al., 2024). International evidence reinforces these benefits. Quaye et al. (2019) demonstrated that e-extension significantly enhanced yields and reduced production costs in Ghana, while Baig et al. (2022) reported improved knowledge and adoption of climate-smart practices among Pakistani farmers. Within India, Abdullahi et al. (2021) highlighted ICT infrastructure as a key determinant of farmers' engagement with digital advisories.

Despite these advantages, many rural farmers still face barriers such as low digital literacy, socio-economic constraints, and limited trust in ICT-based information (Singh et al., 2024; Paliwal et al., 2025). Horticulture remains a vital component of India's agricultural economy, contributing substantially to income and employment. The country's diverse agro-climatic conditions support extensive cultivation of fruits, vegetables, tubers, and medicinal plants, which increasingly serve as profitable alternatives to staple crops. Uttar Pradesh, in particular, provides favourable conditions for horticultural production and is home to a large number of small and marginal farmers who are highly dependent on this sector (Kumar et al., 2019).

However, the labour-intensive nature and perishability of horticultural crops necessitate timely and accurate information on climate, irrigation, soil, and input management, reinforcing the need for robust e-extension systems. The proliferation of ICT-based agro-advisory tools including SMS alerts, mobile applications, and digital platforms has reshaped knowledge dissemination and facilitated more responsive decision-making (Paliwal & Kumari, 2023). Nonetheless, the effectiveness of these advisories largely depends on farmers' awareness, perceptions of usefulness, ease of use, and trust in digital information. To address these gaps, the present study focuses on constructing a scientifically validated index to assess the awareness of horticultural farmers towards e-extension services. The index will strengthen the methodological base for evaluating ICT-enabled advisory systems and contribute to improving their design, targeting, and effectiveness for advancing smallholder horticulture in India (Abate et al., 2023).

METHODLOGY

The present study, conducted in 2025, aimed to develop an index for measuring the awareness level of horticultural farmers towards e-extension services. A comprehensive review of literature, including research papers, journals, magazines, thesis, books, and expert inputs, was carried out to identify suitable dimensions for index development. Accordingly, three major dimensions of awareness were conceptualised: "general awareness about e-extension", "awareness of public e-extension services", and "awareness of private e-extension services". Statements for each dimension were collected from diverse sources such as discussions with scientists, service providers, extension personnel, agricultural officers, KVK experts, and horticultural farmers. Initially, 112 statements were framed under the three dimensions and screened using Edward's 14-point criteria propounded by Edward (1957). After scrutiny, 83 statements were retained, comprising 21 under general awareness about e-extension, 37 under awareness of public e-extension services, and 25 under awareness of private e-extension services. To assess relevancy, both Google Forms and printed schedules were sent to 150 judges. Each statement was evaluated on a three-point continuum: Most Relevant (3), Relevant (2), and Least Relevant (1). Relevancy Weightage (RW), Mean Relevancy Score (MRS), and Overall Mean Relevancy Score (OMRS) were calculated to determine statement appropriateness. Following criteria similar to Prasad et al. (2016) and Roy et al. (2022), statements with RW $\geq$0.80 and MRS greater than OMRS (2.44) were retained. The formulas used for these calculations are as follows:

$$RW = \frac{MRR \times 3 + RR \times 2 + LRR \times 1}{MPS}$$

MPS (Maximum Possible Score) = No. of Judges × 3 = 70 × 3 = 210

$$MRS = \frac{MRR \times 3 + RR \times 2 + LRR \times 1}{\text{Number of Judges}}$$

$$OMRS = \frac{\text{Sum of obtained Relevancy Score}}{\text{No. of Judges} \times \text{No. of Statements}}$$

RW – Relevancy Weightage, MRR – Most Relevant Response, RR – Relevant Response, LRR – Least Relevant Response, MRS – Mean Relevancy Score, OMRS – Overall Mean Relevancy Score.

Based on this analysis, 48 statements were finalized, while 35 were rejected for not meeting the selection criteria. An interview schedule containing the selected statements was developed for field administration in a non-sampled area. Responses were recorded on a two-point continuum ("Yes" = 1 and "No" = 0). Finally, data were collected from 60 randomly selected horticultural farmers to assess the reliability and validity of the developed index. This systematic procedure ensured the development of a scientifically valid and reliable instrument for measuring the awareness level of horticultural farmers toward e-extension services.

RESULTS

Domain selection and its operationalisation

The construction of an awareness index to measure "Awareness of Horticultural Farmers towards e-Extension Services" began with the identification of key dimensions, including general awareness about e-extension, awareness of public e-extension services, and awareness of private e-extension services. General awareness about e-extension refers to the extent to which

horticultural farmers possess basic knowledge, recognition, and understanding of the existence, purpose, and usefulness of Information and Communication Technology–based agricultural advisory services. This includes awareness of various digital platforms, web portals, mobile applications, social media channels, and online information systems that deliver agricultural information, training, and problem-solving support. Public e-extension services related to the ICT-based agricultural information and advisory services provided, managed, or supported by government departments, public institutions, universities, and state/national agricultural organisations. These services are delivered through official digital platforms such as government web portals, mobile applications, SMS services, call centres, and social media channels operated by public agencies, with the objective of disseminating scientific information, schemes, and support to farmers. Private e-extension services include the ICT-enabled agricultural information, advisory, input support, and knowledge dissemination services provided by private companies like agri-tech firms, NGOs, producer organizations, and commercial platforms. These services are delivered through privately managed digital platforms such as mobile applications, web portals, subscription-based advisory systems, corporate call centres, SMS alerts, and social media channels, primarily aimed at supporting farmers with timely advisories, product information services, and decision-making support, often with a commercial component. Each of these dimensions consisted of a substantial number of statements to ensure that the index value could be standardized across varying domains.

Item selection process

The results presented in Table 1 demonstrate the assessment conducted by 70 judges who evaluated the relevance of the set of items. Out of the initial pool, 48 items were identified as relevant and subsequently used to collect responses from 60 farmers located in non-sampling areas. The expert feedback was gathered and analysed to calculate three key parameters: Relevancy Weightage (RW), Mean Relevancy Score (MRS), and Overall Mean Relevancy Score (OMRS). To ensure the selection of only the most relevant items, criteria were established: the Relevancy Weightage (RW) must be greater than 0.80, and the Mean Relevancy Score (MRS) must exceed the Overall Mean Relevancy Score (OMRS), which was set at 2.44. Using this process, 48 items were deemed suitable in the first stage, with these items being revised based on expert suggestions.

Relevance analysis of items

An initial pool of 112 items was identified to measure the awareness of horticultural farmers towards e-extension services. These items were subjected to a screening process using the fourteen informal criteria proposed by Edwards (1957), commonly applied in index development to ensure clarity, relevance, and the non-redundancy of items. Following this screening, 83 items were retained for further evaluation and were proposed for relevancy testing by a panel of experts. A total of 150 experts from various relevant professional backgrounds, including academicians, extension professionals, researchers, and government officials, were approached. Out of the 150 experts contacted, 70 judges, possessing the requisite subject knowledge and professional experience, responded within the stipulated timeframe of one month. The responses of these judges were systematically compiled and each statement was analysed using Microsoft Excel to determine its Relevancy Weightage (RW), Mean Relevancy Score (MRS), and Overall Mean Relevancy Score (OMRS). This rigorous analysis ensured that only items meeting both statistical and conceptual criteria were selected. Specifically, statements with a Relevancy Weightage greater than or equal to 0.80, and a Mean Relevancy Score greater than or equal to the Overall Mean Relevancy Score (OMRS), were considered suitable for inclusion (Shitu et al., 2018; Panigrahi et al., 2024; Vavilala et al., 2024; Singh et al., 2025; Shukla et al., 2026). As a result of this robust analysis, 48 statements were finalised for inclusion in the index, and their distribution across three broad categories was as follows: 14 statements under general awareness, 24 under public e-extension services, and 10 under private e-extension services.

Validity of the index

The validity of the index was established through content validity testing. Content validity was ensured by verifying that the content of individual items, as well as the full set of items, accurately represented the construct they were intended to measure. The content of the index was thoroughly reviewed through extensive literature and expert opinions related to the awareness level of horticultural farmers towards e-extension services. Given the alignment with these sources, it was assumed that the awareness index meets the criteria for content validity, confirming that it measures what it is intended to measure.

Reliability of the index

Reliability refers to the consistency of the measurement when repeated assessments are conducted. In this study, data for reliability analysis were collected through personal interviews with 60 farmers from a non-sampling area. The internal consistency of the index was assessed using the Cronbach's alpha coefficient, a widely accepted measure for reliability (Singh et al., 2025; Jagriti et al., 2026; Singh et al., 2026; Shukla et al., 2026). As shown in Table 2, the Cronbach's alpha coefficient for the overall index was found to be 0.951, indicating an excellent level of reliability for the scale. To further confirm the reliability, the split-half method was employed, with the Spearman-Brown coefficient calculated to be 0.936, which corroborates the strong consistency of the index.

The strong reliability values across both the Cronbach's alpha and the split-half methods provide confidence in the consistency and stability of the awareness index, ensuring that it can be reliably used for future assessments of horticultural farmers' awareness of e-extension services.

DISCUSIONS

The present study sought to construct a scientifically validated and reliable index to assess the awareness of horticultural farmers towards e-extension services. The findings reveal a strong methodological foundation for the instrument, supported by systematic item generation, expert validation and rigorous reliability

Table 1. The Relevancy Weightage (RW), Mean Relevancy Score (MRS), Overall Mean Relevancy Score (OMRS)

S.No.	Statement	RW	MRS
	General Awareness about e-extension		
1	I am aware about e-Extension	0.86	2.57
2	I know about e-Extension is useful for me	0.87	2.60
3	I know about the ICT tools and techniques	0.88	2.63
4	I am aware about internet based mobile phone applications	0.87	2.61
5	I am aware of some websites for farmers	0.82	2.46
6	I am aware of the some web-portal for farmers	0.81	2.44
7	I am aware of other digital platforms like- social media	0.84	2.51
8	I know about the digital platform for agriculture farmers	0.82	2.46
9	I am aware about Google assistance	0.83	2.50
10	I am aware about Google Lens	0.83	2.49
11	I am aware about OTP	0.83	2.50
12	I know about OTP do not share anyone	0.85	2.56
13	I am aware about YouTube	0.91	2.74
14	I am aware about Play Store, used for downloading mobile app	0.92	2.77
	Awareness of public e-extension services		
15	I know that public e-extension services may supplement/complement traditional extension agent/services	0.93	2.79
16	I know about the Krishi Vigyan Kendra located in our district	0.90	2.71
17	I am aware about KVK web portal	0.87	2.61
18	I heard about Kisan Call Centre	0.80	2.40
19	I know Kisan Call Centre can be contacted by dialling a toll-free number-(1800 180 1551)	0.90	2.69
20	I know Kisan Call Centre is available from 6:00 am to 10:00 pm on all seven days of the week	0.85	2.56
21	I know about online training programme	0.80	2.41
22	I am aware about online training programme for cutting, budding and grafting for horticulture crop	0.95	2.86
23	I am aware about DD Kisan channel	0.96	2.89
24	I know DD Kisan channel gives free of cost agriculture related information on my television	0.93	2.80
25	I know DD Kisan channel share seasonal crop basis information	0.91	2.73
26	I know DD Kisan channel provides information related to scientific orientation farming	0.87	2.60
27	I am aware about e-Newspaper	0.82	2.46
28	I am aware about e-NAM (e-National Agriculture Market)	0.89	2.66
29	I know under e-NAM farmers sell our products	0.87	2.61
30	I know about how can get recent market price through e-NAM	0.87	2.61
31	I receive agricultural information in WhatsApp Group	0.87	2.60
32	I know about the scheme and services provided online by the Department of Horticulture and Food Processing (like- MIDH, SCSP, RKVY, etc.)	0.85	2.54
33	I have the Damini App on my phone	0.83	2.50
34	I have the Meghdoot App on my phone	0.91	2.73
35	I am aware about District Agro-Met Unit (DAMU)	0.87	2.60
36	I am aware about Kisan Sarathi Portal	0.87	2.60
37	I am aware about Pradhan Mantri Fasal Bima Yojana	0.81	2.44
38	I am aware about PM Kisan Samman Nidhi	0.80	2.41
	Awareness of private e-extension services		
39	I am aware about amazon app	0.82	2.46
40	I know amazon app to purchase seeds, insecticides, pesticides etc.	0.80	2.41
41	I know Flipkart Online Shopping App sales of different agricultural inputs	0.85	2.56
42	I know YouTube channel has different video content (like- success story, new technology, and new varieties) for farmers	0.81	2.44
43	I am aware about Plantix App	0.85	2.54
44	I know Plantix App, it is identification of plant disease and gives plant cure guidance	0.80	2.40
45	I am aware about DeHaat App	0.89	2.67
46	I am aware about BigHaat App	0.88	2.64
47	I am aware about AgroStar App	0.82	2.46
48	I am aware about weed manager app	0.81	2.43

*Criteria for statement selection= RW>0.80, MRS>OMRS, *OMRS = 2.44

Table 2. Reliability Statistics of Index

Cronbach's Alpha	Part 1	Value	.902
		N of Items	24[a]
	Part 2	Value	.914
		N of Items	24[b]
	Total N of Items		48
	For whole index		.951
Correlation Between Forms			.881
Spearman-Brown Coefficient	Equal Length		.936
	Unequal Length		.936
Guttman Split-Half Coefficient			.936

a. The items are: S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24.
b. The items are: S25, S26, S27, S28, S29, S30, S31, S32, S33, S34, S35, S36, S37, S38, S39, S40, S41, S42, S43, S44, S45, S46, S47, S48.

testing. The results underscore both the robustness of the index and the increasing relevance of ICT-enabled agricultural advisory systems in the horticultural sector.

The multidimensional structure of the index, comprising general awareness, public e-extension services and private e-extension services, aligns with the evolving landscape of digital agricultural extension. The identification and operationalisation of these three domains reflect the growing diversity of information sources available to farmers, ranging from government-led portals to commercial agri-tech applications. This classification is consistent with earlier studies emphasising the need for domain-specific assessment tools to capture the heterogeneity of digital platforms in agriculture (Panigrahi et al., 2024; Vavilala et al., 2024).

The item selection process demonstrated a high degree of expert consensus. Of the initial 112 statements developed from literature reviews and field consultations, 83 items progressed through preliminary screening based on Edward's criteria (Edwards, 1957), ensuring conceptual clarity and non-redundancy. Subsequent relevancy testing by 70 judges resulted in the selection of 48 items that met the dual criteria of RW $\geq$ 0.80 and MRS $\geq$ OMRS (2.44). The strong relevancy scores observed across statements particularly those related to digital literacy (e.g., mobile applications, web portals, social media), public advisory channels (e.g., KVK portals, DD Kisan, Kisan Call Centre) and private applications (e.g., DeHaat, Plantix, BigHaat) indicate a high degree of perceived importance attached to these tools by experts.

These findings reflect broader trends in the agricultural sector, where farmers increasingly rely on ICTs for timely, location-specific information (Paliwal & Kumari, 2023; Singh et al., 2024b). The high relevance of statements related to agro-meteorological services (e.g., Meghdoot, Damini, DAMU) further highlights the growing significance of climate-related advisories, especially for horticultural crops that are highly sensitive to weather variability.

The reliability analysis provides additional support for the stability of the index. The Cronbach's alpha value of 0.951 indicates excellent internal consistency, surpassing the threshold commonly accepted in psychometric research. Furthermore, the Spearman-Brown coefficient of 0.936 reinforces the reliability of the split-half structure. These values are comparable to or exceed those reported in similar studies developing indices for behavioural or attitudinal assessment in agriculture (Kumar et al., 2015; Singh et al., 2025; Kumari, et al., 2026; Shukla et al., 2026; Singh, et al., 2026). The high reliability suggests that the instrument is robust enough for repeated administration and suitable for large-scale field application.

Overall, the findings reveal that the developed index successfully captures the multidimensional construct of awareness towards e-extension services. The inclusion of both public and private service-related items provides a holistic measurement framework, reflective of the increasingly pluralistic extension ecosystem in India. The high reliability and strong expert validation demonstrate that the index can be effectively employed by researchers, policymakers, and extension organisations to identify awareness gaps, design targeted capacity-building interventions and assess the responsiveness of farmers to digital advisory systems. Given the rising importance of ICTs in horticultural farming driven by perishability, climate sensitivity, and market volatility the availability of a validated awareness-measurement tool represents a significant contribution. By providing a standardised mechanism to quantify awareness, this index can support the optimisation of e-extension strategies, enable evidence-based policy formulation and enhance the reach and relevance of both public and private digital services.

CONCLUSION

The study successfully developed a reliable and scientifically validated index for assessing the awareness of horticultural farmers towards e-extension services. By integrating three complementary domains general awareness, public e-extension services, and private e-extension services the index offers a comprehensive and structured mechanism for evaluating farmers' engagement with digital advisory platforms. The rigorous item selection process and strong reliability coefficients confirm the robustness and applicability of the tool for large-scale research and field assessments. This index fills a critical methodological gap in ICT-based extension research and provides policymakers, researchers, and extension agencies with an evidence-based instrument to diagnose awareness levels, design targeted interventions and strengthen digital extension ecosystems. Its adoption can significantly enhance the responsiveness, inclusiveness and effectiveness of e-extension services, ultimately contributing to improved decision-making and resilience among horticultural farmers.

DECLARATION

Ethical approval and consent to participate: The informed consent was sought from the respondents.

Availability of supporting data: Supporting data are available upon request.

Competing interests: No competing interests were declared.

Conflict of interest: No conflicts of interest among the authors.

The authors declare that during the preparation of this work, 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 Tool

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (141-148)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Assessing 21st Century Skills: Development and Validation of a Multidimensional Tool for College Students

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HIGHLIGHTS

- A standardized assessment tool for college students in the 21st century was finalised, consisting of 54 items.
- Confirmatory factor analysis indicated a seven-factor structure to assess 21st century skills.
- The tool was aimed to assess 21st century skills in college students precisely.

ARTICLE INFO

Keywords: Transversal skills, Factor analysis, Holistic development, Item analysis, Skill assessment.

https://doi.org/10.48165/IJEE.2026.622RT02

Citation: Yadav, N., & Vatta, L. (2026). Assessing 21st Century Skills: Development and Validation of a Multidimensional Tool for College Students. *Indian Journal of Extension Education*, *62*(2), 141-148. https://doi.org/10.48165/IJEE.2026.622RT02

ABSTRACT

This study endeavours to develop and validate a multidimensional tool for the assessment of 21st century skills among college-going students during 2024-25 at Banaras Hindu University (BHU), Varanasi. Initially, 120 items were identified through a comprehensive literature review. Experts from the teaching and research domains reviewed these items, and their feedback was incorporated to refine the tool, resulting in 56 items. The refined tool was administered to 350 respondents. The construct validity was established through exploratory factor analysis (EFA) and subsequently confirmed through confirmatory factor analysis (CFA) to ascertain the adequacy of the model fit. EFA revealed that the seven-factor structure accounted for a substantial proportion of the total variance. The CFA of the 54-item 21st-century skills assessment tool identified seven factors with good internal consistency. CFA indicated that items were loaded on the relevant factors and evidenced satisfactory model fit indices. The reliability of the tool was established by the Cronbach's alpha coefficient, which yielded a value of 0.81. Thus, the tool was indicated to be relevant for college students and served as a valuable metric to assess college students' 21st century skills.

INTRODUCTION

The 21st century has such dynamic demands that require a sound combination of skills to enable students excel in their academic, career and personal life. The importance of leadership skills, communicative skills, decision-making, and the role of financial literacy cannot be underestimated because they make it possible to cope with the complexities. With the ethos of the 21st century education, students need the four key competencies of critical thinking, creativity, communication, and collaboration (Erdogan, 2019), and they are essential to success. These skills include other advanced skills and learning methods vital in surviving in the information age (Karadas et al., 2021). Graduates should have skills of the 21st century to handle complex information and keep up with the changing professional requirements (van Laar et al., 2017, Tight, 2022; Kaya et al., 2023). Based on this, educators should integrate such skills in their instruction methods. It is worth noting that critical thinking is existentially required in order to promote high-order intellectual pursuits, enhance cognition, and enable students to audit their own position and solve problems in a competent manner (Tuzlukova et al., 2018). A standardised tool should be created to measure the acquisition of these foundational skills by students in order to execute this. The measurement of

Received 23-01-2026; Accepted 24-02-2026

21st century competencies can provide insight into the development of the skills in students and, hence, inform the course design as well as the ability to incorporate these skills in the curriculum (Koretz, 2017). However, these competencies are difficult to measure, especially in the case of monitoring the student progress throughout the duration (Holec & Marynowski, 2020). The need to have accurate and reliable assessment tools has been generated owing to the insistence on inculcating skills in the curricula. In order to translate abstract ideas into measurable skills, creativity, critical thinking, and cooperation need to be assessed in reference to certain conceptual frameworks. Factor analysis has become one of the common tools used in educational research to ensure validity and reliability (Kumar et al., 2015; Kline, 2023). To measure the 21st century skills, recent studies have proposed a diverse array of instruments indicating that the different scales might be needed in different disciplines and cohorts of students (Cevik, 2019; Huang, 2023). Even despite the spread of theoretical frameworks that claim to describe these competencies, it has proven difficult to agree on the specific list of skills that they entail (van Laar et al., 2017; Tight, 2021; Saleem et al., 2024). Partnership for 21st century skills provides an extensive framework in which the essential skills are listed that cannot be ignored in order to be successful in the modern age. The competencies in this framework will be divided into three main areas, namely; learning and innovation skills, information, media, and technology skills, and life and career skills (Kennedy & Sundberg, 2020). The research study aimed at developing and validating a tool to assess 21st century skills for college students, relying on the Partnership for 21st century skills framework.

METHODOLOGY

The development of the standardized tool in this study adhered to the widely accepted Likert summated rating scale methodology. The tool was constructed meticulously and stepwise, as recommended in the procedures by Likert (1932). A set of 120 statements was initially collected and narrowed down using the 14-point criteria described by Edward (1959). Experts were consulted to assess the relevance of every item that was retained (Junger et al., 2017; Shitu et al., 2018; Gupta et al., 2022; Kademani et al., 2025). The relevance assessment was conducted by 35 experts in the fields of education, psychology, and extension education. The suitability of each item was measured with the help of two indicators, Mean Relevance Score (MRS) and Relevancy Percentage (RP). The selection followed the criteria that an item has a mean relevancy score higher than the overall mean score (≥ 2.00) and a relevancy percentage greater than 80%.

$$\text{Mean Relevancy Score (MRS)} = \frac{(\text{MRR } 3) + (\text{RR } 2) + (\text{LRR} \times 1)}{\text{Number of judges}}$$

(MRR= most relevant response, RR= relevant response, LRR= least relevant response)

$$\text{Relevancy Percentage (RP)} = \frac{\text{FS}}{\text{Number of respondents}} \times 100$$

(FSS= frequency of MRR and RR score)

The Exploratory Factor Analysis (EFA) was used to determine construct validity of the instrument (Watkins, 2018). The analyses were conducted on responses from 350 undergraduate students across multiple academic streams at Banaras Hindu University, selected through purposive sampling. The degree of sampling adequacy was measured using the Kaiser-Meyer-Olkin (KMO) measure and the test of sphericity of Bartlett. The EFA was used to explain the underlying factor construct of the tool (Winters, 2016). Items with weak loadings or cross-loadings were eliminated. The criteria required primary loadings of 0.40 and below, cross-loadings of 0.30 (Howard, 2016). Confirmatory Factor Analysis (CFA) was conducted to validate the factor structure using R (version 4.5.0). Model fit was assessed using multiple indices, Comparative Fit Index (CFI) and Tucker–Lewis Index (TLI) with thresholds ≥0.90, Root Mean Square Error of Approximation (RMSEA) with 90% confidence interval, and Standardised Root Mean Square Residual (SRMR≤0.08). Convergent validity was examined using Average Variance Extracted and composite reliability (CR ≥0.70). Discriminant validity was evaluated via the Fornell-Larcker criterion, comparing the square root of each construct's AVE with inter-construct correlations. Cronbach's alpha was computed for each dimension. An internal consistency value exceeding 0.8 was deemed satisfactory.

RESULTS

Established approaches, such as relevancy testing, item analysis, reliability assessment, and validity checking, were followed in the development of 21st century skills assessment tool intended for assessing college students' 21st century skills.

Relevancy and item analysis

The mean relevancy score and relevancy percentage were calculated by analyzing the responses from 35 subject experts as presented in Table 1. As part of the item analysis, final statements (comprising 40 positive and 14 negative statements) that confirmed the predefined criteria, mean relevancy scores exceeding 2.0, and a relevancy percentage greater than 80% were retained. Additionally, to enhance the precision and coherence of the tool, redundant and duplicate statements were systematically reviewed and refined based on expert recommendations.

Exploratory factor analysis

EFA was conducted on data from 350 respondents using the full item pool of 56 items. The initial step involved assessing data suitability with the Kaiser-Meyer-Olkin (KMO) (Ledesma et al., 2021). The KMO test evaluates sampling adequacy for each variable, where a higher KMO value (>0.6) indicates greater variance among variables, confirming data appropriateness for factor analysis. The Bartlett's test of sphericity was significant (χ^2= 4958.56, df = 1953, p .000), implying that the intercorrelation matrix contained adequate common variance. The correlation matrix, anti-image correlation matrix and measures of sampling adequacy were analysed to ensure that the application of the factor analysis to the data set was appropriate. A total number of two items indicated a consistently low correlation and were excluded from

Table 1. Mean relevancy score and relevancy percentage of selected items

S.No.	Items	MRS	RP
	Communication		
1.	I always pronounce words confidently.	2.37	85.71
2.	I find it challenging to easily connect with others.	2.43	88.57
3.	I can use nonverbal gestures to convey my messages effectively.	2.43	94.29
4.	I am hesitant to express my opinions in a group.	2.49	88.57
5.	I am able to observe people's body language.	2.17	77.14
6.	I am able to understand other viewpoints.	2.29	91.43
7.	I usually pay attention when others are speaking.	2.11	82.86
8.	My words are often misunderstood by people.	2.20	88.57
9.	I regularly share and receive constructive feedback.	2.46	97.14
10.	I often hesitate to ask for clarification when I don't understand something in conversation.	2.31	94.29
	Creative Thinking		
11.	I prioritise continuously learning and expanding my knowledge and skills.	2.46	97.14
12.	I try new things and step out of my comfort zone to learn and grow.	2.31	94.29
13.	I find it hard to challenge my existing beliefs and assumptions	2.63	98.15
14.	I seek opportunities to unlearn outdated assumptions and relearn new knowledge to stay relevant and up to date.	2.31	85.71
15.	I am able to seek out different perspectives and consider alternative viewpoints.	2.54	97.00
16.	I am able to explore creative solutions and think outside the box.	2.31	88.57
17.	I can identify multiple ways to solve a problem.	2.40	91.43
18.	I find it hard to think of creative and useful solutions for problems.	2.46	91.43
	Critical thinking		
19.	I can accept criticism gracefully and use it to improve my skills and knowledge.	2.34	94.29
20.	I find it difficult to generate innovative ideas and approaches to challenges.	2.54	94.29
21.	I have the ability to identify and avoid logical fallacies in arguments or discussions.	2.17	90.91
22.	I enjoy solving difficult problems and finding solutions.	2.40	97.14
23.	When I encounter a problem, I am unable to think about anything else.	2.31	88.57
24.	I visit websites with a clear purpose and within preset time limits	2.23	91.43
25.	I reflect on situations and learn from them.	2.66	97.14
	Digital Literacy		
26.	I am confident in using various digital devices, such as computers, smartphones, and tablets.	2.63	98.01
27.	I can manage and organize digital files and documents in a systematic manner.	2.31	85.71
28.	I generally solve common digital issues.	2.34	94.29
29.	I create and share content online using digital tools, including editing images, recording sounds, and producing videos.	2.54	94.29
30.	I often make use of software like Photoshop, SPSS, or Microsoft Word.	2.17	90.91
31.	I am familiar with controlling apps' access to my personal information.	2.09	85.71
	Financial Literacy		
32.	I can manage my personal finances effectively.	2.31	88.57
33.	I am capable of making decisions about borrowing money and managing debt.	2.31	88.57
34.	I can interpret financial statements, such as income statements and balance sheets.	2.40	91.43
35.	I regularly check my bank statements and transactions.	2.46	91.43
36.	I find it hard to create and follow a realistic and effective budget.	2.23	91.43
37.	I am unable to distinguish between needs and wants in financial decision-making.	2.11	82.86
38.	I always look for financial education and resources to improve my financial literacy.	2.20	88.57
	Information & Media Literacy		
39.	I use social media platforms responsibly and ethically.	2.57	97.14
40.	I am able to quickly get rid of outdated or incorrect information and adopt new and accurate knowledge.	2.57	97.14
41.	I find it difficult to determine how useful the information is for my purpose.	2.31	88.57
42.	I often search for information online using search engines and databases.	2.40	91.43
43.	I prioritize gathering information to make better decisions.	2.46	91.43
44.	I am able to identify and discard irrelevant or outdated information.	2.23	91.43
	Leadership		
45.	I can positively influence a group of individuals.	2.43	88.57
46.	I do consider the individual opinions of group members.	2.37	88.57
47.	I generally express appreciation for the achievements of others.	2.54	94.29
48.	In my studies, I enjoy helping others with their questions and concerns.	2.46	94.29
49.	I can manage conflicts and disagreements within the team fairly and constructively.	2.43	94.29
50.	I find it hard to build relationships with others to reach a mutual goal.	2.49	94.29
51.	I can reflect on situations and learn from them.	2.66	97.14
52.	I am not able to make decisions quickly under pressure.	2.31	80.00
53.	I cannot convince others of my opinions.	2.23	88.57
54.	I can collaborate with others to share and manage information collectively.	2.54	97.00

Table 2. Factor loadings for the EFA with varimax pattern matrix

S.No.	Matrix	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Communality
	Communication								
1.	COMM 1		.815						.669
2.	COMM 2		.795						.662
3.	COMM 3		.857						.691
4.	COMM 4		.828						.657
5.	COMM 5		.833						.661
6.	COMM 6		.811						.694
7.	COMM 7		.809						.703
8.	COMM 8		.798						.659
9.	COMM 9		.847						.646
10.	COMM 10		.779						.675
	Creativity								
11.	CreatT 1			.811					.672
12.	CreatT 2			.814					.677
13.	CreatT 3			.825					.680
14.	CreatT 4			.841					.721
15.	CreatT 5			.833					.695
16.	CreatT 6			.806					.669
17.	CreatT 7			.805					.667
18.	CreatT 8			.814					.653
	Critical Thinking								
19.	CritT 1					.833			.698
20.	CritT 2					.810			.675
21.	CritT 3					.830			.685
22.	CritT 4					.842			.711
23.	CritT 5					.833			.690
24.	CritT 6					.834			.682
25.	CritT 7					.779			.222
	Digital Literacy								
26.	DL 1							.797	.631
27.	DL 2							.812	.635
28.	DL 3							.817	.654
29.	DL 4							.834	.665
30.	DL 5							.830	.667
31.	DL 6							**.77**4	.692
	Financial Literacy								
32.	FL 1				.811				.665
33.	FL 2				.808				.657
34.	FL 3				.841				.702
35.	FL 4				.829				.703
36.	FL 5				.849				.713
37.	FL 6				.822				.670
38.	FL 7				.803				.642
	Information and Media Literacy								
39.	IML 1						.817		.655
40.	IML 2						.814		.673
41.	IML 3						.825		.679
42.	IML 4						.808		.637
43.	IML 5						.809		.655
44.	IML 6						.815		.647
	Leadership								
45.	LEAD 1	.815							.695
46.	LEAD 2	.795							.670
47.	LEAD 3	.857							.752
48.	LEAD 4	.828							.704
49.	LEAD 5	.833							.702
50.	LEAD 6	.811							.683
51.	LEAD 7	.809							.660
52.	LEAD 8	.798							.663
53.	LEAD 9	.847							.738
54.	LEAD 10	.779							.672

further analysis. Factors were extracted with Principal Component Analysis (PCA) and 54 items converged into seven factors with >65% of total variance. Parallel analysis was used to determine number of factors to retain compared to use of eigenvalues and scree plots. Table 2 outlines the findings, indicating a seven-factor structural solution consisting of 54 items as follows: communication (10 items, loadings 0.63-0.8); creativity (7 items, loadings 0.63-0.8); critical thinking; (6 items, loadings 0.63-0.8); digital literacy (6 items, loadings 0.63-0.8); financial literacy; (7 items, loadings 0.63-0.8); information and media literacy (6 items, loadings 0.63-0.8); leadership (10 items, loadings 0.63-0.8).

Confirmatory factor analysis

CFA confirmed the factor structure using a dataset of 350 respondents. 21st century skills assessment questionnaire demonstrated a good overall fit. The results demonstrated that the hypothesized model provided a satisfactory representation of the data as illustrated in Figure 1. The chi-square statistic was statistically significant (χ^2 = 1507.37, p = .002). The Comparative Fit Index (CFI) and Tucker–Lewis Index (TLI) were well above the recommended threshold of .95, indicating satisfactory model fit. Similarly, the Root Mean Square Error of Approximation

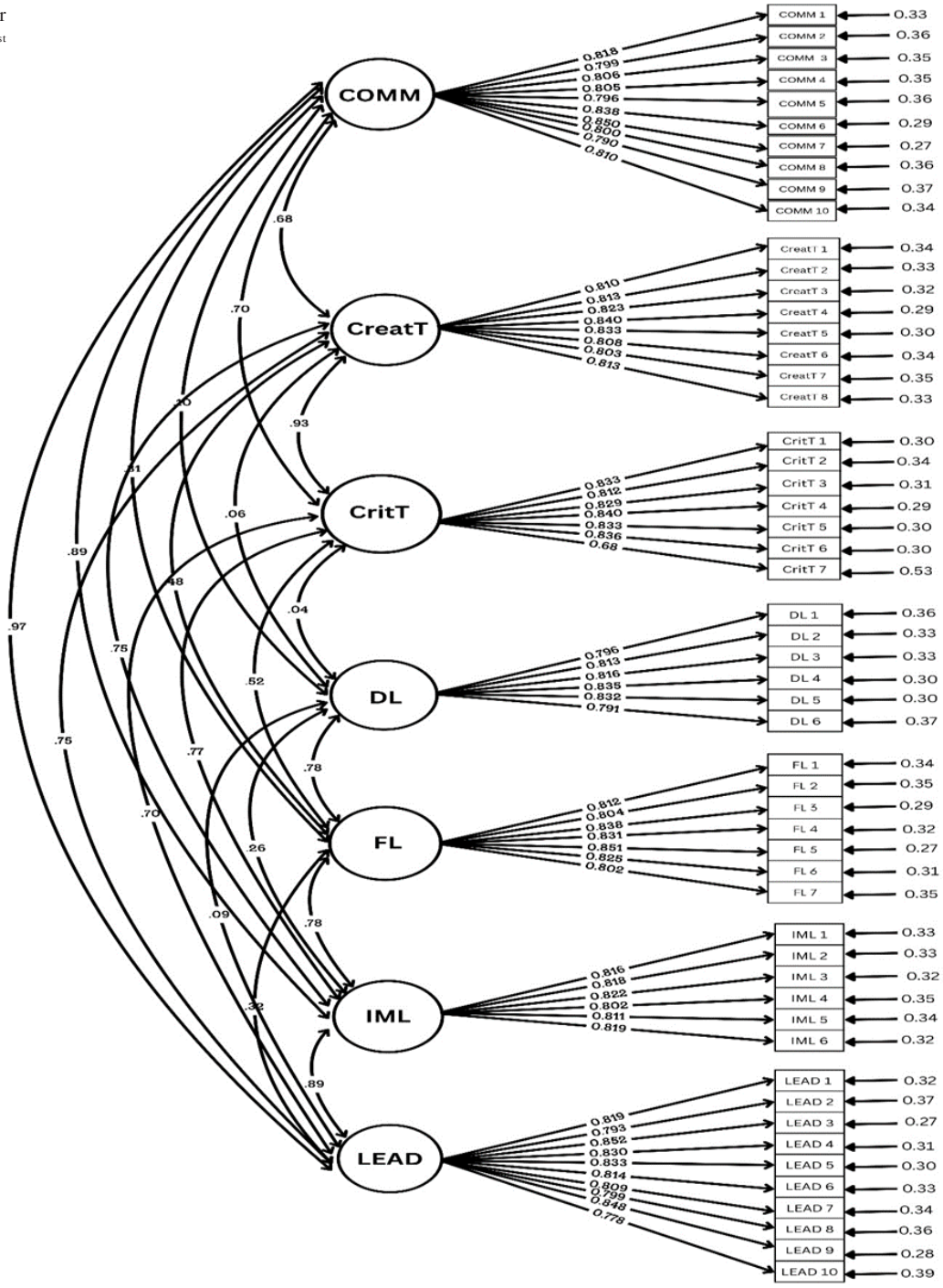

Figure 1. Confirmatory factor analysis path diagram for 21st century skills assessment tool

(RMSEA = .017; 90% CI (.011, .022) was within the range indicative of close fit (< .05), and the Standardized Root Mean Square Residual (SRMR = .036) was below the cut-off value of .08, confirming the adequacy of the model. These indices surpass conventional benchmarks (CFI/TLI≥0.90; RMSEA≤0.08; SRMR≤0.08), indicating that the proposed seven-factor structure closely reproduces the observed covariance matrix and is suitable to retain for subsequent reliability and validity analyses.

Realiability analysis

The internal consistency of the instrument was evaluated using Cronbach's Alpha. As Cronbach's alpha serves as a measure of reliability, reflecting how well the particulars inclusively assess the same underpinning dimension (Revelle & Condon, 2019). The reliability analysis was conducted for both the entire tool and its 7 dimensions separately. The Cronbach's Alpha values for each dimension ranged from 0.80 to 0.82, indicating acceptable to good internal consistency. The overall reliability for the complete scale was 0.81, confirming the robustness of the instrument for assessing the targeted constructs.

DISCUSSION

In the modern context, cognitive and emotional abilities to a great extent are associated with the ability to make evidence-based decisions and adequately adjust to the complex and dynamic environment (Adeoye et al., 2024). These seven factors, communication, critical thinking, creativity, digital literacy, financial literacy, information and media literacy and leadership, all act as a tool of assessment that gives a chance to understand how well learners can adapt, think creatively and make a difference in a variety of environments. Communication is the core of the knowledge sharing, relationship building, and effective collaboration. It includes the ability to deliver clear ideas, to be an active listener, and to tune the messages to a variety of people (Pepe et al., 2025). As a student, communication allows to collaborate, engage in academic dialogues, and argue over relevant causes and critical thinking refers to the capacity to use logic, evidence and reasoning to make decisions and resolve issues. It is an art of questioning assumptions, taking into account several positions, and making sensible conclusions (Yagci, 2019). Critical thinking equips students with clear mindedness in order to deal with work-related issues professionally. Creativity is the ability to be innovative, and find new solutions to problems. Development and implementation of novel approaches indicate an overlap of the creativity and critical thinking (Korkmaz et al., 2017). Digital literacy is defined as the competent and responsible utilization of digital tools, devices and technology. It is about the technical expertise to include ethical internet use and data safety (Falloon, 2020). The digital literacy of navigation, evaluation, and utilization of digital resources is essential becoming not only to educational success but also to lifelong learning (Saxena, et al., 2018; Chandra, et al., 2024). With potent digital skills, young people are better able to maintain balanced screen use and navigate digital spaces responsibly (Gupta & Vatta, 2025). Financial literacy is the ability of people to obtain, analyze, and interpret financial data and make wise economic choices as well as manage resources effectively (Goyal & Kumar, 2021). Information and media literacy have changed their definitions with the changing media technologies. Media literacy, in its simplest sense, relates to media message access, analysis, critique, and production (Yamaguchi et al., 2023). This opinion is supported by the conceptual model developed by Potter (2022), which pays attention to the interconnection with information literacy and emphasizes the manner in which people process and create information in the digital and media space. Its dimensions are information seeking, source evaluation, and ethical media use. This ability is crucial to the academic education of students, their digital citizenship, and decision-making. Media literacy protects against misinformation and makes people responsible citizens in a world full of information (Jones-Jang et al., 2021; Chen et al., 2025). The process of leadership can be characterized as the capacity to see the path ahead, make rational choices, and leveraging interpersonal power to influence and motivate other people to achieve common goals (Northouse, 2021). Its dimension includes mindfulness, strategic vision, and resilience (Durnali, 2022). Within the student milieu, leadership provides an opportunity to do business together, motivate others, and attain group outcomes (Stewart, 2017; Smith et al., 2022).

CONCLUSION

In the contemporary, rapidly evolving educational and professional environment, the acquisition of potent 21st century competencies needs to be an essential element. Furthermore, learners' attitudes and desire to participate in pertinent educational initiatives are increasingly essential for producing significant outcomes. The assessment tool may result in very specific foundational assessments that serve as the basis for data-driven decisions pertaining to skills enhancement programs and policy formulation. The tool offers explicit insights into strengths and areas for enhancement, thereby enhancing the evidential basis for decision-making and establishing a strategic framework for the curriculum and regulations that can facilitate students' continued success and intellectual growth.

DECLARATION

Ethical approval and consent to participate: Informed consent was sought from the respondents.

Availability of supporting data: Supporting data are available upon request.

Competing interests: No competing interests were declared.

Conflict of interest: No conflicts of interest among the authors.

The authors declare that during the preparation of this work, 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 Tool

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (149-155)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Development and Standardization of a Scale to Measure Farmers' Risk Perception towards Climate Change

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HIGHLIGHTS

- Developed a 22-item scale to measure farmers' climate change risk perception.
- Achieved high internal consistency (Cronbach's $\alpha > 0.70$), confirming scale reliability.

ARTICLE INFO

Keywords: Climate change, Risk perception, Content validity, Scale, Extension intervention.

https://doi.org/10.48165/IJEE.2026.622RT03

Citation: Pathak, D. K., Gupta, B. K., Mishra, G., Suryavanshi, A., Mishra, B. P., & Singh, L. (2026). Development and Standardization of a Scale to Measure Farmers' Risk Perception towards Climate Change. *Indian Journal of Extension Education*, *62*(2), 149-155. https://doi.org/10.48165/IJEE.2026.622RT03

ABSTRACT

Farmers' perceptions of risks related to climate change significantly influence their adaptation behaviour and their responses to climatic stressors. The present study sought to develop and standardize a valid and reliable scale to quantify farmers' risk perception of climate change. Using the Likert summated rating technique, an initial pool of 70 statements was generated based on a review of the literature and consultation with experts. After systematic editing and relevancy testing through expert judgment, 45 statements were screened, and 28 statements were subjected to item analysis using responses from 40 farmers in a non-sampled area. Based on discriminating power ('t' value ≥ 1.75) and reliability criteria, 22 statements were finally selected for inclusion in the scale. The reliability of the scale was established using Cronbach's alpha, which exceeded the acceptable threshold of 0.70, representing high internal consistency. Content validity was ensured through comprehensive coverage of climate-related risks affecting crop, livestock and livelihood systems. The final scale enables categorization of farmers into low, medium and high levels of climate change risk perception. The developed scale is a useful tool for researchers, extension professionals and policymakers to assess farmers' risk perception and to design location-specific, evidence-based climate change adaptation and extension interventions.

INTRODUCTION

Changes in the global climate have attracted widespread attention from experts across disciplines due to their potential to cause far-reaching consequences for human civilization (Singh, 2020). Although the impacts of climate change vary across regions worldwide, particularly in developing countries such as India (Singh et al., 2019). Variations in rainfall and temperature associated with climate change have emerged as major concerns for planners, environmentalists, economists and communities whose livelihoods depend directly on natural resources (Kundu & Mondal, 2022).

Agriculture, which forms the backbone of the Indian economy, is highly sensitive to weather and climatic conditions, with nearly 80 per cent of variations in agricultural output attributed to fluctuations in local weather and climate (Nageswara Rao et al., 2018). The region is already witnessing significant climate-related impacts, including altered rainfall patterns, increasing temperatures and declining river water conditions (IPCC, 2021). As climate change represents a long-

Received 11-02-2026; Accepted 06-03-2026

term shift in global or regional climatic patterns, farmers today face complex and multifaceted challenges. From an agricultural perspective, they are required to ensure food and nutritional security while simultaneously protecting environmental quality and promoting sustainable farming practices (Asrat & Simane, 2017).

Poor households in developing countries like India are particularly vulnerable to climate change because of their limited adaptive capacity and restricted access to alternative livelihood opportunities (Alam et al., 2017). Moreover, extreme weather events are projected to become more frequent and intense in the future, posing serious threats to the livelihoods of farmers across developing nations, including India (Dastagir, 2015). Climate-related hazards such as droughts, floods and heatwaves have already led to substantial reductions in crop yields and disrupted the livelihoods of millions of households. In response to these risks, farmers adopt various adaptation strategies, although the nature and extent of these measures vary across different livelihood groups.

In the present study conducted in 2024, climate change is understood as the observed or perceived changes in local weather patterns over the past three decades, particularly with respect to the increasing frequency of extreme events such as droughts, floods, dry spells and extreme temperatures. Recent research indicates that monsoon rainfall has become increasingly erratic, while extreme events such as floods, droughts and cyclones are occurring more frequently and with greater intensity (Kumar & Saxena, 2021; Kumar & Saxena, 2024). Within this broader global and national framework, the present study, conducted in the year 2024, focuses on how farmers in the Jalaun and Datia districts of the Bundelkhand Region perceive climate change and the strategies they adopt in response. Bundelkhand is highly susceptible to climatic stress due to irregular rainfall, rising temperatures and chronic water scarcity. Given its heavy dependence on rain-fed agriculture and frequent exposure to drought conditions, the region offers a critical context for examining how smallholder farmers, policymakers and other stakeholders perceive, interpret and respond to climate change in their everyday lives.

METHODOLOGY

Climate change risk assessment is the recognition of the probability of hazards or adverse outcomes associated with climate change. Therefore, it is essential to assess farmers' knowledge and understanding of changing climatic conditions, as well as the extent to which they perceive the consequences and associated risks of climate change. In the present study, the Likert summated rating scale method (Likert, 1932) was adopted to develop a scale for measuring the varying degrees of farmers' risk perception towards climate change. A summated rating scale comprises a series of statements that are regarded as having approximately equal importance. Respondents indicate their level of agreement or disagreement with each statement, and each response is assigned a specific score. This method was adopted in the study to avoid assessing a concept through a single statement. Instead, several statements covering different dimensions of the concept were included to enable a more comprehensive and balanced assessment.

To assess the relevance of each statement, several statistical tools were applied, namely Relevancy Weightage (RW), Relevancy Percentage (RP), Mean Relevancy Weightage (MRW) and Scale Value (S). Responses obtained from 90 experts were utilized for the final analysis. Statements were selected for inclusion in the scale, whereas statements exhibiting lower relevance or higher variability were excluded. Through this screening process, a total of 22 statements were finalised. To ensure content validity, all statements were derived from an extensive review of relevant literature and further refined based on expert feedback. The reliability of the scale was evaluated using Cronbach's alpha coefficient with the aid of SPSS software version 26. A Cronbach's alpha value greater than 0.70 was considered indicative of acceptable reliability (Cronbach, 1951). According to this criterion, the statements were evaluated for relevance. The final selection of statements was based on statements with a relevancy percentage over 70%, a mean relevancy weightage over 0.70, a mean relevancy score over 2 and a Cronbach's alpha coefficient greater than 0.70.

The scale was developed through following the standard steps. Statements related to various risks associated with climate change were compiled from relevant literature, including books, journals, magazines and online sources. In addition, consultations were held with experts, researchers, scientists and farmers, resulting in the preparation of an initial pool of 70 statements. The statements were carefully edited according to the fourteen criteria given by Likert (1932), Bird (1940) and Edwards and Kilpatrick (1957). Out of 70 statements, 45 statements were selected as they were found to be non-factual and non-ambiguous. The relevance test acknowledged that not all collected statements might be equally appropriate for measuring farmers' risk perception towards climate change. Therefore, the statements were critically reviewed by an expert panel to assess their relevance and screen them for final inclusion in the scale. The panel comprised scientists and researchers from the discipline of extension education representing various state agricultural universities, state departments and extension institutes. A total of 45 statements were circulated to 220 judges with clear instructions to evaluate the relevance of each item. The judges were requested to rate each statement on a three-point scale, namely most relevant, relevant and least relevant. Within a period of two months, responses were received from 90 judges. The scores awarded by these judges were aggregated, and the total score for each of the 45 statements was computed.

RESULTS

Based on these scores, Relevancy Percentage (RP), Mean Relevancy Weightage (MRW) and Mean Relevancy Scores (MRS) were calculated individually for all statements using the prescribed formulae:

Relevancy Percentage (RP)

It is the number of respondents who scored the given items as "most relevant" and "relevant", which was converted into a percentage.

$$RP = \frac{FS}{\text{Number of Respondents}} \times 100$$

Where FS = Frequency score of the most relevant and relevant

Table 1. Selection of statements based on the judges rating: RP, MRW and MRS"

S.No.	Statement	Mean Relevancy Weightage (MRW)	Mean Relevancy Score (MRS)	Relevancy Percentage (RP)
1.*	I perceived that the heavy floods and flash floods in the rainy season are increasing year by year.	0.81	2.45	91.11
2.*	I think that crop losses increased due to an increase in temperature.	0.73	2.22	75.55
3.	Land use patterns of farmers are not affected by climate change.	0.60	1.82	55.55
4.*	I do not think that adjusting the sowing date and time is an effective strategy for adapting to climate change.	0.90	2.71	95.55
5.*	I think the frequency of droughts, floods, and dry spells increased due to climate change.	0.95	2.86	100
6.	Climate change is not a real phenomenon.	0.60	1.81	51.11
7.*	I think that flowering and fruiting times of various crops and fruit trees will change due to climate changes.	0.87	2.61	95.55
8.*	I perceive that although climate change is occurring in other regions, it is not happening in my own region.	0.72	2.17	75.55
9.*	Climate change increases the risk of human life, risk of infectious disease epidemics, and many other risks.	0.90	2.72	95.55
10.	Agriculture is not adversely affected by climate change.	0.62	1.86	53.30
11.	There is no crop loss due to climate change.	0.60	1.80	47.77
12.*	Livestock rearing has become more vulnerable because of climate change.	0.92	2.77	98.88
13.	I think that the transportation of agricultural produce has not been affected by climate change.	0.60	1.82	55.55
14.	The productive capacity of livestock was not adversely affected by extreme climatic conditions.	0.65	1.97	61.11
15.	I feel that the decrease in the quality of water due to climate change.	0.63	1.90	61.11
16.*	I think that there is a change in the feeding behavior of dairy animals due to climate change.	0.81	2.43	91.11
17.*	I believe that extreme weather events will happen more frequently in the future.	0.80	2.40	92.22
18.*	I perceive that the climate is changing year by year.	0.80	2.42	93.33
19.	I think climate variability is nearly a hoax.	0.67	2.03	68.88
20.*	I do not believe that food security decreasing due to climate change.	0.87	2.63	94.44
21.*	I feel difficulty in adopting climate-smart agriculture practices.	0.79	2.37	87.77
22.	Climate change is a global issue that needs not worry.	0.62	1.87	51.11
23.*	I feel that the reduction in certain plant, animal, and bird species is due to climate change.	0.89	2.68	98.88
24.*	I think that there is a fall in the groundwater level due to climate change.	0.88	2.65	96.66
25.	I feel that there is no effect of climate variability on crop-livestock farming.	0.59	1.77	46.66
26.	I think that climate variability will increase agricultural production.	0.61	1.85	52.22
27.	I feel that my standard of living will improve due to climate variability.	0.56	1.70	47.77
28.*	I think that there is a change in current farm management practices due to climate change.	0.86	2.60	92.22
29.*	I think people will not migrate from more vulnerable areas to less vulnerable areas.	0.87	2.61	95.55
30.	I believe that climate variability is not a problem in the future.	0.55	1.67	38.88
31.*	I perceive late rainfall records or delays in the onset of rainfall due to climate change.	0.86	2.58	93.33
32.*	I believe that the changes in weather patterns are hurting my farm operations.	0.88	2.65	96.66
33.*	I don't think that industrialization is responsible for climate change.	0.86	2.58	91.11
34.	I believe that climate change is not caused by human interventions.	0.58	1.75	45.55
35.*	I feel that the increase in the cost of cultivation is due to climate change.	0.78	2.35	81.11
36.*	I think that due to climate variability seriously affects the ability to invest in business.	0.79	2.37	87.77
37.*	I think climate change is beneficial for farming and will improve our agricultural prospects.	0.88	2.64	95.55
38.*	I think that decrease in natural rangeland/grassland due to climate change.	0.83	2.50	86.61
39.	I think that climate variability has not been scientifically proven.	0.60	1.80	47.77
40.*	I feel that the frequency and extent of heat waves have become a major concern as they affect agricultural production.	0.89	2.68	95.55
41.*	I believe that the production and productivity of major crops decline under changing climatic situations.	0.90	2.71	95.55
42.*	I believe that the extreme cold weather, heavy fog, etc. due to climate change would affect the livelihood.	0.91	2.74	95.55
43.*	I believe that the increase in the temperature of the earth due to climate change is very dangerous for our next generation.	0.91	2.75	97.77
44.*	I believe that climate change-related disasters have increased people's belief in God.	0.90	2.70	93.33
45.	I feel that climate variability is more beneficial than harmful.	0.59	1.78	46.661

*Denotes statements/ items selected for further analysis

Mean relevancy weightage (MRW)

It is the ratio of the actual score obtained to the maximum possible scores (MPS) obtainable for each statement. It was calculated using the following formula:

$$MRW = \frac{MRR \times 3 + RR \times 2 + LRR \times 1}{MPS}$$

Where, MRR= Most Relevant Response, RR= Relevant Response, LRR= Least Relevant Response

MPS = Maximum Possible Scores [No. of judges responded * 3(45 * 3=135)]

Mean relevancy score (MRS)

It is the ratio of the actual score obtained by each respondent to the number of judges who respondent to the variable.

$$MRS = \frac{MRR \times 3 + RR \times 2 + LRR \times 1}{\text{Number of Judges}}$$

Where, MRR= Most Relevant Response, RR= Relevant Response, LRR= Least Relevant Response. Following this procedure, a total of 28 statements were finally chosen and subsequently revised/ rephrased based on the feedback provided by the experts.

Item analysis

Item analysis is an important step in the Likert technique for developing a valid and reliable scale. It was necessary to identify items based on their ability to discriminate between respondents with a high level of risk perception and those with a low level of perception regarding climate change. Accordingly, an item was conducted on the 28 statements shortlisted during the first stage. A schedule containing these 28 statements was prepared and administered through personal interviews with a sample of 40 farmers selected from a non-sampled area. Responses to each statement were recorded on a five-point continuum, namely Strongly Agree, Agree, Undecided, Disagree and Strongly Disagree with corresponding scores of 5, 4, 3, 2 and 1, respectively. For negatively worded statements, the scoring pattern was reversed. The overall perception score of each respondent was obtained by summing the scores of all the statements.

For item analysis, respondents were arranged in ascending order according to their overall perception scores. From this ordered according to their overall perception scores. From this ordered list, the top 25 per cent of respondents with the highest scores and the bottom 25 per cent with the lowest scores were selected. These two groups served as the criterion groups for evaluating the discriminating power of individual statements, as suggested by Edwards. Accordingly, out of 40 farmers to whom the statements were administered for item analysis, 10 farmers with the highest scores and 10 farmers with the lowest scores were identified and used as the criterion groups for evaluating each item. The ratio for each statement was calculated using the *t*-test. The *t*-value indicates the extent to which a particular statement is capable of differentiating between the high perception group and the low perception group. The *t*-value were computed using the formula proposed by Edwards.

$$t = \frac{\bar{X}_H - \bar{X}_L}{\frac{\sqrt{\Sigma(X_H - \bar{X}_H)^2 + (X_L - \bar{X}_L)^2}}{n(n-1)}}$$

Where, ΣX_L = Continuum value (x) × Frequency of responses (f) = fx for lower group, ΣX_H = Continuum value (x) × Frequency of responses (f) = fx for higher group, $\Sigma X^2_L = f(x^2)$ for lower group, $\Sigma X^2_H = f(x^2)$ for higher group, $\bar{x}_L$ = the mean score of the same statement for the low group ($\frac{\Sigma x_L}{n_L}$), $\bar{x}_H$ = the mean score of a given statement for the high group ($\frac{\Sigma x_H}{n_H}$), n = number of respondents in each group

Selection of statements for final scale

After computing the 't' value for all the items, 22 statements with the highest 't' value equal to or greater than 1.75 were selected. Items with a 't' value below 1.75 were strictly rejected according to the guidelines laid out by Edwards in 1957. Following the guideline for selecting items to be kept in the scale, apart from removing those with low discriminating ability and doubtful authenticity, the issue was to include those with the highest discriminating values. Thus, 22 statements were chosen for inclusion in the final scale according to the specified criteria:

1. The 't' value is more than 1.75
2. The statement should present a new idea i.e., the idea not overlapping with that expressed by others
3. The statement should be simple in words and brief.

Standardization of the scale

The validity and reliability of the scale were established to ensure its standardization. Validity was assessed through content validity and criterion validity.

Validity

The content validity of the scale was examined. Content validity refers to the extent to which a measuring instrument adequately represents the content, substance, and subject matter of the construct being measured. Since the items included in the scale comprehensively covered the entire domain of climate change risk in agriculture, based on an extensive review of literature and expert consultation, the scale was considered to possess adequate content validity. Criterion validity refers to the degree to which the results of a particular instrument correspond with those of an established external criterion or standard that measures the same construct. In the present study, the scale items showed appropriate alignment with the theoretical understanding and empirical indicators of climate change risk perception in agriculture. Consequently, the differences in scale values across the statements demonstrated strong discriminating power, supporting the acceptance of the scale as a valid measurement tool.

Reliability

The reliability of the scale was assessed using Cronbach's alpha coefficient with the help of SPSS software 26 (Cronbach, 1951). A Cronbach's alpha value greater than 0.70 was considered indicative of acceptable reliability.

Table 2. Farmers' risk perception about climate change statements analysis and their respective 't' values and Cronbach's alpha (a) values.

Statement	't' value	Cronbach alpha (α)	Status
I perceived that the heavy floods and flash floods in the rainy season are increasing year by year.	5.09434	0.969	Included
I think that crop losses increased due to an increase in temperature.	2.210526	0.752	Included
I do not think that adjusting the sowing date and time is an effective strategy for adapting to climate change.	3.641618	0.821	Included
I think the frequency of droughts, floods, and dry spells increased due to climate change.	2.322581	0.756	Included
I think that the flowering and fruiting times of various crops and fruit trees will change due to climate change.	2.04545	0.712	Included
I perceive that although climate change is occurring in other regions, it is not happening in my own region.	5.436242	0.974	Included
Climate change increases the risk of human life, risk of infectious disease epidemics, and many other risks.	-1.06719	0.321	Excluded
Livestock rearing has become more vulnerable because of climate change.	2.045455	0.711	Included
I think that there is a change in the feeding behaviour of dairy animals due to climate change.	-1.30435	0.314	Excluded
I believe that extreme weather events will happen more frequently in the future.	5.04	0.967	Included
I perceive that the climate is changing year by year.	6.428571	0.983	Included
I do not believe that food security is decreasing due to climate change.	3.103448	0.792	Included
I feel difficulty in adopting climate-smart agriculture practices.	0.947368	0.568	Excluded
I feel that the reduction in certain plant, animal, and bird species is due to climate change.	3.60	0.820	Included
I think that there is a fall in the groundwater level due to climate change.	7.39726	0.986	Included
I think that there is a change in current farm management practices due to climate change.	2.769231	0.763	Included
I think people will not migrate from more vulnerable areas to less vulnerable areas.	5.806452	0.978	Included
I perceive late rainfall records or delays in the onset of rainfall due to climate change.	2.673267	0.758	Included
I believe that the changes in weather patterns are hurting my farm operations.	2.941176	0.769	Included
I don't think that industrialization is responsible for climate change.	5.555556	0.976	Included
I feel that the increase in the cost of cultivation is due to climate change.	6.923077	0.986	Included
I think that climate variability seriously affects the ability to invest in business.	-0.26706	0.423	Excluded
I think climate change is beneficial for farming and will improve our agricultural prospects.	4.864865	0.953	Included
I think that the decrease in natural rangeland/grassland is due to climate change.	-0.78534	0.318	Excluded
I feel that the frequency and extent of heat waves have become a major concern as they affect agricultural production.	2.368421	0.758	Included
I believe that the production and productivity of major crops decline under changing climatic situations.	3.00	0.788	Included
I believe that the extreme cold weather, heavy fog, etc. due to climate change would affect the livelihood.	0.393013	0.521	Excluded
I believe that the increase in the temperature of the Earth due to climate change is very dangerous for the next generation.	5.40	0.972	Included

Note: *Statements having equal to or greater than 1.75 't' value were selected for the final scale

Final administration

The finally selected statements of the scale were randomly arranged and incorporated in the final format of the interview schedule for the farmers.

The finalized scale comprised 22 statements, as presented in Table 3. Responses were recorded on a five-point continuum, ranging from strongly agree (score 5) to strongly disagree (score 1), with intermediate options of agree (score 4), undecided (score 3), and disagree (score 2). The overall perception score of each respondent was obtained by summing the scores across all items. Consequently, the perception scores on this ranged from a minimum of 22 to a maximum of 110. Based on these scores, farmers were categorized into three groups like low, medium and high-risk perception. A higher score indicated a greater perceived level of risk related to climate change, and vice versa.

DISCUSSION

Although several scales have been developed to assess climate-related issues, these tools are largely context specific. As the area covered in the present study differs from those previously examined, there is a need to develop context-appropriate scales or tools to assess climate vulnerability and to identify factors that may threaten the country's food security. In addition, farmers' perceptions of climate change and its adverse effects on agriculture are essential for the effective implementation of mitigation and adaptation strategies. Risk perception is a social construct that represents the relationship between the group exposed to risk and the object at risk. The finalized scale, consisting of 22 carefully selected statements, exhibited strong internal consistency, as indicated by Cronbach's alpha values exceeding 0.70 across all the statements. This high level of reliability suggests that the items consistently measure the intended construct across different respondents. Such findings are in line with established scale development practices in agricultural extension research, where Cronbach's alpha values above 0.70 are considered acceptable (Ray & Mondal, 2011). The result also corresponds with the methodological standards reported in earlier studies, including Arulmanikandan et al. (2025), who developed an assessment tool for farmers' training needs in drone-based technologies using expert validation, item selection criteria and reliability analysis. Like their

approach, the present study employed interquartile range analysis and mean relevancy weightage to refine the pool of statements, ensuring that only statistically significant and contextually relevant items were retained.

The scale encompasses a wide range of risk perception-related items, making it suitable for assessing risk perception across diverse agro-ecological and socio-economic contexts. The inclusion of these items enhances the robustness of the scale and facilitates a comprehensive understanding of constructs that either support or constrain resilience. Such an approach is crucial for developing context-specific interventions and policy measures. Furthermore, the scale development process was aligned with tools developed by Kumar et al. (2015), Shitu et al. (2018), Gupta et al. (2022), Chandra et al. (2024), and Kademani et al. (2025), thereby strengthening its methodological rigor and applicability.

CONCLUSION

Accurate and reliable measurement of farmers' perceptions of the risks and uncertainties linked to climate change and its adverse impacts on agriculture is essential for designing appropriate mitigation and adaptation strategies. Each statement was validated using a Likert scale, and Cronbach's alpha values above 0.70 across all statements indicated a high level of internal consistency. The final form of the scale included 22 statements for evaluating risk perception. Overall, the scale was found to be statistically reliable and valid for assessing farmers' risk perception toward climate change. It can serve as a useful tool for researchers, policymakers, and development agencies to identify the risks and uncertainties perceived by farmers, to prioritize suitable interventions, and to design data-driven and context-specific strategies for strengthening climate resilience.

DECLARATIONS

Ethical approval and consent to participate: The informed consent was sought from the respondents.

Availability of supporting data: Supporting data are available upon request.

Competing interests: No competing interests were declared.

Conflict of interest: No conflicts of interest among the authors.

The authors declare that during the preparation of this work, 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 Tool

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (156-160)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

A Multi-Dimensional Scale for Quantifying Farmers' Adaptation Strategies to Climate Change

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HIGHLIGHTS

- A comprehensive 38-item scale was developed to measure farmers' adaptation strategies to climate change across eight major dimensions.
- All eight dimensions demonstrated strong internal consistency, with Cronbach's alpha values ranging from 0.795 to 0.861.
- The developed scale provides a reliable framework for assessing farmers' adaptation behaviour toward climate change.

ARTICLE INFO

Keywords: Climate change adaptation, Farmers' adaptation strategies, Scale development, Validation study, Climate-resilient agriculture.

https://doi.org/10.48165/IJEE.2026.622RT04

Citation: Mallappa, V. K. H., & Gadde, S. (2026). A Multi-Dimensional Scale for Quantifying Farmers' Adaptation Strategies to Climate Change. *Indian Journal of Extension Education*, *62*(2), 156-160. https://doi.org/10.48165/IJEE.2026.622RT04

ABSTRACT

Climate change poses challenges to agricultural production and the livelihoods of communities, particularly in climate-sensitive regions. Although farmers adopt a range of adaptation practices, the absence of a standardized and validated measurement tool limits the systematic assessment of these strategies. Therefore, the study aimed to develop and validate a scale to measure farmers' adaptation strategies to climate change. The study was conducted in November-December 2025. An initial pool of 53 statements was generated through a literature review and expert consultation. After screening and refinement, 45 statements were subjected to expert judgment using a Likert summated rating approach to establish content validity. Statistical parameters, including Scale Value (S), Interquartile Range (Q), Relevancy Weightage (RW), Relevancy Percentage (RP), and Mean Relevancy Score (MRS) were used to evaluate and select items. Based on these criteria, 38 statements were finalised and organized into eight dimensions: crop adjustment and management, soil management and conservation, water management and conservation, nutrient management, livestock management, flood management, family resource/finance management, and labour use. The internal consistency of the scale was assessed using Cronbach's alpha, with values ranging from 0.795 to 0.861, indicating reliability across dimensions. The findings confirm that the instrument is valid and reliable for assessing farmers' adaptation strategies and informing climate-resilient policy.

INTRODUCTION

Climate change is a major global concern affecting socio-economic, socio-political, ecological, and environmental systems (Filho et al., 2021; Feliciano et al., 2022; Abbass et al., 2022). It is characterized by rising temperatures, irregular rainfall patterns, and an increased frequency of droughts, floods, and cyclones, with particularly severe implications for countries heavily dependent on agriculture (Dawid & Boka, 2025). Climate change is widely recognized as a critical challenge to agricultural production and rural livelihoods, and nations such as India are especially vulnerable due to their large agrarian population and mounting pressure on natural resources (Dupdal et al., 2021; Dupdal et al., 2022). In India, where a substantial share of the population relies on agriculture for livelihood, climate variability significantly affects productivity and limits farmers' capacity to cope with adverse weather conditions (Dawid & Boka, 2025). Bridging the knowledge gap through improvement in communication network has to go a long way in

Received 17-02-2026; Accepted 07-03-2026

supporting farm level decisions and minimize the agricultural production and income loses in adverse climatic and weather conditions (Ravikumar et al., 2015).

Farmers typically respond to climate change through two broad approaches: adaptation and mitigation (Biswas & Rahman, 2023). Climate change adaptation involves implementing strategies that address shifting climatic conditions, including adopting appropriate measures and leveraging potential opportunities arising from climate variability (IPCC, 2022; IPCC, 2014; Biswas & Rahman, 2023). Such adaptation strategies are intended to strengthen the ability of individuals, households, and communities to manage climate risks, sustain livelihoods, and reduce vulnerability (Mucha et al., 2026). However, adaptation processes are influenced by diverse socio-economic and environmental factors that vary across regions (Debisa et al., 2025; Eshetu et al., 2021; Megabia et al., 2022). Consequently, adaptation remains a central policy pathway for addressing ongoing climate challenges.

Adaptation strategies play a crucial role in minimizing the negative impacts of climatic variability on agriculture. Effective adaptation measures enable farming communities to better withstand extreme weather events (Dawid & Boka, 2025). Research on climate adaptation continues to evolve, with new challenges and dimensions emerging, particularly in relation to farming communities (Ginbo et al., 2021; Iyer et al., 2022; Liu et al., 2020; Biswas & Rahman, 2023) and a lack of standardized scale to measure adaptation strategies to climate change. Addressing these gaps requires the development of scientifically robust tools capable of capturing the multidimensional nature of adaptation. Therefore, the present study was undertaken to develop and validate a scale for measuring farmers' adaptation strategies to climate change, to provide researchers and policymakers with a reliable framework for systematic assessment.

METHODOLOGY

The scale was developed through an extensive literature review and expert consultation. The statements were formulated under eight major dimensions like Crop adjustment/management, Soil Management/conservation, Water management/conservation, Nutrient management, Livestock Management, Flood Management, Family Management and Labour Use. The Likert summated rating scale method (Likert, 1932) was adopted to develop a scale for measuring adaptation strategies. The dimensions included crop management practices such as mixed cropping, drought- and disease-resistant varieties, crop rotation, short-duration crops, adjusted planting dates and crop insurance. Soil and water conservation involved mulching, cover crops, reduced tillage, bunds, supplemental irrigation, drip and sprinkler systems, and ridges and furrows. Nutrient management emphasized bio-fertilizers, integrated nutrient management and farmyard manure use. Livestock management covered animal healthcare, vaccination, grazing management, feed supplementation, manure management and insurance. Flood management included structural and non-structural measures like barriers, drainage improvement and hazard insurance. Family resource and labour management focused on reducing expenditures, borrowing food grains, increasing family labour participation and adopting labour-saving implements. The study scale was structured using close-ended questionnaire, which was formed using keywords or concepts regarding adaptation strategies to climate change. Initially, 53 statements were developed to represent the eight dimensions. After refinement and editing for clarity and redundancy, 45 statements were retained. These statements were subsequently subjected to expert judgment for content validation. The statements were shared with 100 experts based on their expertise in climate change, agriculture, KVK and extension scientists all over the country to rate the scale based on the relevance each statement on a five-point Likert scale ranging from (score 1) "Not relevant" to (score 5) "Most relevant". To evaluate the relevancy of each statement, statistical measures like Scale Value (S), Inter-Quartile Range (Q), Relevancy Weightage (RW), Relevancy Percentage (RP) and Mean Relevancy Weightage (MRW) were used and the responses received from 50 judges were used for the final analysis. Statements were included if their median scores were higher than the interquartile range, whereas statements considered less relevant or with more variation were excluded. This process led to the selection of 38 statements across eight dimensions. To reduce the biases a pre-test was conducted with 50 respondents to measure the internal consistency of scale in the non-sample area during November-December 2025, the reliability of the scale was tested by using Cronbach's alpha coefficient through IBM SPSS statistics 27.0.1 (Cronbach, 1951). A Cronbach's alpha value of greater than 0.70 was considered acceptable. In this study, the majority of the dimensions showed high reliability, with alpha values exceeding 0.80, confirming strong internal consistency of the scale.

RESULTS

The development of scale for adaptation strategies to climate change involved screening of 45 statements using expert judgment statistical analysis to ensure validity, relevancy and consistency of statements. A total of fifty experts rated the statements from 1 to 5 based on their relevance and parameters like scale value (S), Inter-Quartile Range (Q), Relevancy Weightage (RW), Relevancy Percentage (RP), and Mean Relevancy Weightage (MRW) were calculated. Based on these statistics 38 statements were finalized and grouped under eight core dimensions such as Crop adjustment/management, Soil Management/conservation, Water management/conservation, Nutrient management, Livestock Management, Flood Management, Family Management and Labour Use. In livestock management Rotational grazing is the moving the livestock through the paddocks on fixed schedule whereas altered pasture grazing is the movement of livestock from paddock to paddock adjusted based on the grass growth rate, weather conditions etc. Six of the eight dimensions showed strong internal consistency, with Cronbach's alpha values exceeding 0.80. For livestock management, alpha value is 0.861, crop adjustment 0.860, flood management 0.856, soil management 0.844, family management 0.834, water management 0.813, nutrient management 0.807 and Labour use 0.795 showed alpha value between 0.70 to 0.80. The results are in line with standard scale development practices reported by Shitu et al. (2018), Chandra et al. (2024) & Arulmanikandan et al. (2025), who emphasised the role of expert validation in instrument construction. Overall, the scale demonstrated good reliability ($\alpha > 0.75$ across dimensions), confirming that the retained 38 indicators are internally

Table 1. Final Selection of Statements in the Adaptation strategies to climate change

S.No.	Statements	Scale value (S)	Inter quartile range (Q)	RW	RP	MRS	Cronbach alpha value
A.	**Crop adjustment/management**						
1	Mixed cropping	1.76	1.03	0.84	84.40	4.22	
2	Drought-tolerant varieties	1.69	1.40	0.82	81.60	4.08	
3	Insects/diseases resistant varieties	1.33	1.12	0.88	88.40	4.42	
4	Less water-intensive crop	1.55	1.15	0.86	86.00	4.30	0.860
5	Crop rotation	1.39	1.23	0.88	88.00	4.40	
6	Cultivating short-duration crops and varieties	1.54	1.00	0.90	89.60	4.48	
7	Change in crop variety (HYV)	1.60	1.18	0.84	84.00	4.20	
8	Adjusting planting dates	1.21	0.85	0.92	91.60	4.58	
9	Crop insurance	1.24	0.90	0.91	91.20	4.56	
B.	**Soil Management/conservation**						
10	Mulching	1.46	1.07	0.89	89.20	4.46	
11	Cover crops	1.83	0.92	0.84	84.00	4.20	0.844
12	Reduced tillage/Zero tillage	1.88	1.03	0.82	82.40	4.12	
13	Construction of bunds to conserve moisture	1.33	1.02	0.91	90.80	4.54	
C.	**Water management/conservation**						
14	Supplemental irrigation through ground water	1.61	0.99	0.89	88.80	4.44	
15	Use of drip irrigation	1.24	0.85	0.94	93.60	4.68	0.813
16	Use of sprinkle irrigation	1.39	1.11	0.89	89.20	4.46	
17	Adopting ridges and furrows for crop cultivation	1.43	1.15	0.88	88.40	4.42	
D.	**Nutrient management**						
18	Bio fertilizer	1.19	0.82	0.92	92.40	4.62	
19	Integrated nutrient management	1.21	0.81	0.94	94.00	4.70	0.807
20	Improve/increase farmyard manure use	1.18	0.71	0.94	94.00	4.70	
E.	**Livestock Management**						
21	Manure management	1.19	0.78	0.93	92.80	4.64	
22	Rotational grazing	2.17	1.82	0.78	78.00	3.90	0.861
23	Better animal health management including surveillance and veterinary services	1.50	1.28	0.85	85.20	4.26	
24	Regular vaccination	1.50	1.16	0.85	85.20	4.26	
25	Extra concentrate minerals supplementation and feed additives to livestock	1.31	1.10	0.90	90.00	4.50	
26	Livestock insurance	1.24	0.90	0.92	92.40	4.62	
27	Altered pasture rotation	1.80	1.27	0.82	82.40	4.12	
F.	**Flood Management**						
28	Construction of Stone breakwater	1.67	1.12	0.86	86.00	4.30	
29	Use of Sandbags for flood protection	1.62	1.05	0.88	87.60	4.38	
30	Use of Hazard insurance	1.50	1.13	0.87	87.20	4.36	0.856
31	Establishing Improved drainage facilities	1.24	1.22	0.87	87.20	4.36	
32	Use of Indigenous options such as walls of wood, stone or coconut leaf and afforestation to overcome flood effects	1.82	1.08	0.84	83.60	4.18	
G.	**Family Resource/ Finance Management**						
33	Reducing expenditure for social functions and festivals	1.97	1.70	0.75	74.80	3.74	
34	Reducing spending on costly food items	2.00	2.01	0.74	74.40	3.72	0.834
35	Borrowing food grains from relatives	2.68	1.78	0.68	67.60	3.38	
H.	**Labour Use**	0.795					
36	Reducing the number of labourers employed on farm	2.14	2.05	0.74	74.00	3.70	
37	Increase the number of family labourers to avoid waged labourers	2.00	1.23	0.78	78.40	3.92	0.795
38	Adoption of labour-saving implements for cultivation	1.26	0.89	0.93	93.20	4.66	

Note: RW= Relevancy Weightage, RP= Relevancy Percentage, MRW= Mean Relevancy Weightage

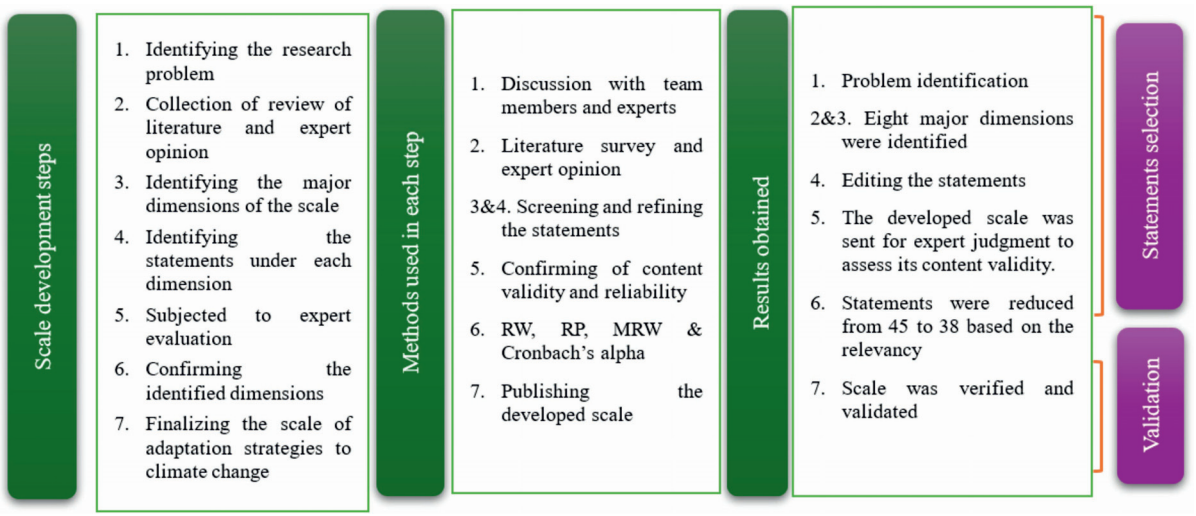

Figure 1. The process of developing adaptation strategies to climate change scale

consistent and suitable for measuring farmers' adaptation strategies to climate change.

DISCUSSION

The study evaluates the reliability and validity of the scale. In the present study Likert scale was employed to reduce ambiguity and make the statement easy to understand. After evaluation, the final scale consisting of 38 statements demonstrated good internal consistency, with Cronbach's alpha values exceeding 0.80 across all dimensions. The high reliability of the scale indicates that it consistently measures the intended construct across respondents; in agricultural extension research, a Cronbach's alpha value greater than 0.70 is generally considered acceptable (Ray & Mondal, 2011). The findings further indicated that the developed scale possesses strong content validity and dimensional consistency, as reflected in the Relevancy Weightage (RW) and Mean Relevancy Score (MRS), suggesting that experts perceived the statements as appropriate for assessing farmers' adaptation strategies to climate change.

Experts were asked to evaluate the relevance of each statement in relation to the study objectives. A total of 100 judges were contacted and the scale was circulated to them, of whom 50 (50%) responded. The responses were used to compute the MRS, while the Scale Value (S) and Interquartile Range (Q) guided the statement selection process. Statements with an S value greater than the Q value and a mean relevancy score above 0.70 were retained. Although the Mean Relevancy Scores for the Family Management dimension was comparatively lower than those of other domains, the Cronbach's alpha value (0.834) remained high, indicating strong internal consistency despite moderate perceived relevance. Similar methodological approaches have been used to establish validity and reliability in earlier studies (Kumar et al., 2015; Kumar et al., 2016; Shitu et al., 2018; Ashoka et al., 2022; Gupta et al., 2022; Vijayan et al., 2023; Chandra et al., 2024).

CONCLUSION

The developed scale demonstrated strong statistical validity and reliability for evaluating farmers' adaptation strategies to climate change. The final scale consists of 38 statements categorized under eight main dimensions i.e., Crop adjustment/management, Soil Management/conservation, Water management/conservation, Nutrient management, Livestock Management, Flood Management, Family Management and Labour Use. Likert scale was used to validate each statement. Cronbach's alpha value was (> 0.70) across all the eight dimensions representing the internal consistency of the dimensions. This scale provides researchers, extension professionals, and policymakers with a scientifically validated instrument to assess adaptation behaviour, identify gaps in resilience, and design targeted interventions for climate-resilient agriculture.

DECLARATION

Ethical approval and consent to participate: Informed consent was sought from the respondents.

Competing interests: No competing interests were declared.

Conflict of interest: No conflicts of interest among the authors.

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

Acknowledgement: The authors gratefully acknowledge the financial support provided by Indian Council of Social Science Research (ICSSR) under Grant ID: File No. ICSSR/RPD/MJ/2023-24/G/95. The authors also sincerely thank all the farmers who participated in the survey across Shivamogga, Udupi, and Chikkamagaluru districts of Karnataka for their valuable time and cooperation.

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Research Tool

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (161-165)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Psychometric Scale Development for the Measurement of Entrepreneurial Behaviour of Vegetable Growers

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HIGHLIGHTS

- A scientifically validated entrepreneurial behaviour scale was developed- 33, standardised psychometric statements were finalised using Likert summated rating techniques
- Scale demonstrated very high reliability and internal consistency, with Cronbach's alpha values of 0.891 and 0.955.
- The tool offers strong potential for research, extension and policy interventions- provides a framework to assess and enhance entrepreneurial skills.

ARTICLE INFO

Keywords: Entrepreneurial behaviour, Vegetable growers, Psychometric scale development, Likert's summated rating technique, Reliability and Validity, Item analysis.

https://doi.org/10.48165/IJEE.2026.622RT05

Citation: Chandra, V., Prusty, A. K., Padhy, C., Raj, R. K., & Ray, S. (2026). Psychometric Scale Development for the Measurement of Entrepreneurial Behaviour of Vegetable Growers. *Indian Journal of Extension Education*, *62*(2), 161-165. https://doi.org/10.48165/IJEE.2026.622RT05

ABSTRACT

The study conducted in the year 2025 developed and standardised a valid and dependable psychometric scale to assess vegetable growers' entrepreneurial behaviour. An initial pool of 76 statements was produced using Likert's summated rating approach. Following editing, 86 experts tested the statements for relevancy using mean relevancy score, relevancy weightage, and relevancy percentage. The crucial ratio (t-value) method was used to analyse the replies of 60 vegetable growers who were chosen from non-sample locations. 33 statements were ultimately chosen to be included in the scale based on discrimination power. The split- half approach was used to determine the instrument's reliability, and the results showed excellent internal consistency and elevated levels of Cronbach's alpha value (0.891 and 0.955) and a satisfactory Guttman Split- half Coefficient (0.720). Expert judgement was used to guarantee content reliability and validity. Researchers, extension specialists, and legislators should find the developed scale to be a helpful tool for evaluating entrepreneurial behaviour and creating need-based interventions to improve the entrepreneurial skills of vegetable growers.

INTRODUCTION

The term "entrepreneurship" describes the process of spotting opportunities, gathering resources, and adding value by starting and growing new businesses. In order to produce economic and societal benefits, it entails creativity, taking calculated risks and making proactive decisions (Bhaskar et al., 2020 & Singh et al., 2024). The creation of jobs, competitiveness, economic progress, and technological advancement are all commonly acknowledged to be significantly influenced by entrepreneurship (Gupta et al., 2020). Vegetables are now considered high- value crops in agricultural systems around the world due to rising demand for them brought on by fast urbanization, population growth, and increased knowledge of balanced meals. Particularly in developing nations where

Received 25-02-2026; Accepted 13-03-2026

smallholder farmers control production systems, vegetable gardening has a substantial contribution to food and nutritional security, job creation, and income enhancement (Food & Agriculture Organization, 2021).

In India, most vegetable growers are small-scale, marginal farmers who mostly use intensive cropping systems and family labour. Vegetable crops offer chances for rapid revenue generation and livelihood diversification due to their short duration and high yield potential (Paine et al., 2025). Vegetable farmers in India, however, have a number of difficulties, such as exorbitant input costs, poor infrastructure for selling and storage, unstable prices, and susceptibility to weather- related pressures. Enhancing the resilience and entrepreneurial potential of vegetable growers requires tackling these issues via technological innovation, capacity building, and market integration (Indian Council of Agriculture Research, 2022).

Understanding the entrepreneurial behaviour of vegetable growers is crucial for several reasons. First, vegetable growers' entrepreneurial behaviour is highly influenced by individual, social and experiential factors (Gupta et al., 2014; Gupta et al., 2023; Patel et al., 2023). Second, examining these behavioural patterns can help identify and study successful entrepreneurs, which in turn can aid in formulating government policies along with designing effective training programs (Kobba et al., 2021; Singh et al., 2024; Kademani et al., 2026).

This study aims to analyze the entrepreneurial behaviour of vegetable growers, focusing on key behavioural dimensions that contribute to enterprise success, such as innovation, risk- taking ability, decision-making skills, achievement motivation and leadership. The findings will be valuable for various stakeholders, including financial institutions, agricultural extension services and policymakers in their efforts to promote and support vegetable entrepreneurship development. Additionally, the study will construct and standardise a comprehensive scale to measure entrepreneurial behaviour by identifying the key behavioural attributes, developing relevant indicators, well as ensuring the reliability and validity of the scale. It will also bridge the gap by developing a psychometrically sound scale that captures dimensions like market orientation, financial management and adaptability to new technology.

METHODOLOGY

Likert scale (Likert's Technique,1932) was used in this study to create the intended scale. The summated rating scale consists of several perception statements, each regarded as having approximately equal perception value. Subjects answer to these claims with varying degrees of agreement or disagreement, each of which is assigned a separate score. This approach was chosen for the current study because it avoids using a single statement to describe concepts in favour of using multiple statements as indicators, each of which represents a different aspect of the concept to provide a more comprehensive view. The following is a discussion of the specific procedures used to restrict the (Likerts, 1932) type scale in order to measure the entrepreneurial behaviour of vegetable growers.

In order to create the psychometric scale, a number of statements about the entrepreneurial behaviour of vegetable growers were collected from books, literature, bulletins, articles, and journals. Additionally, a conversation was held with experts from the field and scientists who had expertise in creating and assisting in the entrepreneurial behaviour areas. A preliminary set of questionnaires was created with consideration for their suitability or applicability to the study's field. After these statements were corrected using the 14 criteria set by (Edwards 1957), (Thurstone & Chave, 1929), and (Edward & Kilpatrick, 1948), 40 of the 76 statements were included in the performa.

The performa that was emailed contained these remarks on a three-point scale that went from "highly relevant (HR), relevant (R), and least relevant (LR)". The judges also received the Google Docs form in person. These judges were experts in their fields who held positions at institutes, universities, and extension education centres. They were asked to change or add any final remarks they felt were necessary. The analysis only considered 86 of the 180 judges who, after properly documenting their findings, supplied the same set of notes. After the study, the statements were changed based on the remarks and criticism from professionals. A total of 40 statements were eventually retained. The "Relevancy percentage," "Relevancy weighted," and "Mean relevancy score" for each statement were calculated by tabulating and analyzing the judges' responses.

RESULTS

The "Very relevant" and "relevant" category ratings were added up and converted to a percentage. Relevancy Percentage computed value was discovered within the range of 10.46 (lowest) to 98.83 (highest). The range between each respondent's actual score and the highest possible score. The computed value of relevancy weightage was assessed to be between 0.37 (lowest) and 0.94 (highest). The range of the computed MRS value was 1.13 (lowest) to 2.83 (highest), and the value of the overall mean relevancy score (OMRS) is 2.06. These three standards were used to evaluate the statements' applicability. Therefore, for the final selection of statements, statements with an overall mean relevancy score > 2.29, a relevancy percentage > 70, and a relevancy weightage > 0.70 were taken into consideration (Thakur and Sharma 2017). As a result, 40 statements were chosen, appropriately altered, and revised in accordance with the experts' feedback.

Sixty farmers from non-sample areas were given a questionnaire with forty items. These farmers were chosen on the basis of their status as farmers or members of the farming community. Five-point Likert scale- strongly agree, agree, undecided, disagree and strongly disagree was used to gauge farmers' level of agreement. A score of 5,4,3,2, and 1, was assigned to each positive statement, whereas the score of each negative statement was 1, 2,3 4, and 5. Each respondent's total entrepreneurial conduct was calculated by summing the scores for each category. The respondents were ordered in descending order. As suggested by Edwards (1957), criterion groups were created for evaluating the individual statements by using the 25% of respondents with the highest total score group as the low group and the remaining 25% as the high group for item analysis. Therefore, out of 60 farmers to whom the items were administered for the item analysis, 15 farmers with the lowest scores and 15 with the highest scores were used as

criterion groups to evaluate various things. The critical ratio, often known as the "t" value, was calculated using the formula put out by Edward (1957). This number shows how well a certain statement distinguishes between the high and low response groups for each statement.

It was determined that the computed t-value was distributed between 0.37 and 9.62. Later, the 33 statements that were quantified in the scale that was finalised were evaluated; their t-values, which are included in the finalised scale, were 2.05 or higher. By demonstrating its validity and reliability, the developed scale was further standardised.

The proposed scale's internal consistency was evaluated using the split- half approach. The sets of statements were given to 60 chosen respondents after the scales were divided in half based on random numbers. As a result, two sets of scores were acquired. Cronbach's Alpha was used in SPSS 24 to obtain the split-half test reliability coefficient. Sets 1 and 2 had alpha values of 0.891 and 0.955, respectively, while the correlation between them was 0. 574. The coefficient of reliability acquired demonstrated the entrepreneurial scale developed for the study's strong internal consistency. The Guttman Split-Half Coefficient, which was similarly determined to be 0.720 (Table 1), was used to further validate the outcome. It may be said that, the scale the is reliable for measuring the entrepreneurial behaviour of the vegetable growers.

The content substance, matter, and themes of a measurement device's representativeness or sampling adequacy are known as

Table 1. Reliability test (Split-half)

Reliability Statistics			
Cronbach's Alpha	Set 1	Value	.891
		N of items	17[a]
	Set 2	Value	.955
		N of items	16[b]
	Total N of items		33
Correlation Between Forms			.574
Spearman-Brown	Equal Length		.729
Coefficient	Unequal Length		.730
Guttman Split- Half Coefficient			.720

The items are: S1, S3, S5, S7, S9, S11, S13, S15, S17, S19, S21, S23, S25, S27, S29, S31, and S33

The items are: S2, S4, S6, S8, S10, S12, S14, S16, S18, S20, S22, S24, S26, S28, S30, and S32

Where: S= Statements

Table 2. Statements Chosen to be part of the final scale

S.No.	Statements	RP	RW	MRS	t
1	Challenging attitude to overcome the loss	89.53	0.84	2.52	3.05
2	Searching successful technologies	89.53	0.84	2.54	2.98
3	Best management to the vocation	90.69	0.84	2.52	3.85
4	Close contact with subject matter experts	89.53	0.82	2.47	5.40
5	Competitive attitude	97.67	0.92	2.77	3.44
6	Optimum utilisation of resources	98.93	0.91	2.74	2.51
7	Close supervision and monitoring of each activity	94.18	0.87	2.63	2.08
8	Close contact with experts	96.51	0.91	2.73	2.46
9	Close relationship with expert for guidance	93.02	0.86	2.59	4.71
10	Timely application of inputs and materials	95.34	0.86	2.6	4.33
11	Collecting information on recent technological developments	96.51	0.88	2.65	3.55
12	Following recommends all cultural practices	98.83	0.89	2.67	2.57
13	Priority to engage skilled personnel	93.02	0.86	2.58	2.77
14	Close contact with traders and business personnel	91.86	0.86	2.60	4.36
15	Production on consumer demand	94.18	0.87	2.62	5.71
16	Regular feedback from the consumers on quality	94.18	0.88	2.65	5.71
17	Aspiration for exporting produce	93.02	0.87	2.62	6.17
18	Rapport establishment with credit organisations	95.34	0.88	2.65	5.87
19	Timely developing required infrastructure	95.34	0.78	2.36	7.73
20	Common decision repayment	96.51	0.91	2.74	7.10
21	Timely repayment of instalment	93.02	0.89	2.68	7.41
22	Approach for fixing instalments as per paying capability	91.86	0.88	2.66	8.26
23	Compulsory insurance coverage	90.69	0.89	2.67	7.73
24	Adopting the advice of the experts	94.18	0.89	2.68	8.28
25	Draw the faith and confidence of the traders and consumers	91.86	0.88	2.66	8.88
26	Motto for quality production	91.86	0.89	2.68	9.62
27	Supplying produce to traders/businessmen at prefixed date and time	94.18	0.91	2.75	7.56
28	Close relation with local people	96.51	0.92	2.77	6.43
29	Financial help for village development	94.18	0.91	2.75	5.87
30	Organising socio-cultural activities in the locality	95.34	0.93	2.79	5.40
31	Regularly look for new ideas to improve the quality of the vegetables	96.51	0.93	2.8	5.40
32	Modify traditional practices to increase productivity or profit	97.67	0.94	2.83	5.14
33	Ready to take financial risks if there is a chance of higher profit	96.51	0.93	2.81	5.14

content validity. 86 judges received all of the revised statements for their professional advice in creating the scale. The scale took into account the experts' recommendations. As a result, the current scale met content validity requirements. In order to prevent biased replies, 33 items were chosen to assess the entrepreneurial behaviour of vegetable producers.

The 33 statements chosen for the final layout of the entrepreneurial scales are placed at random to stay clear of biased responses that can result in the scale's poor validity and reliability. In accordance with Likert (1932), a five-point agreement or disagreement scale was represented by five columns: strongly agree, agree, undecided, disagree, and strongly disagree. The points on the continuum had weights of 5,4,3,2, and 1 for statements. An accurate evaluation of vegetable growers' entrepreneurial behaviour is made possible by this organized scoring procedure, which guarantees that the response is methodically quantified. The five categories of entrepreneurial behaviour used in the study are: Strongly agree (SA), Agree (A), Undecided (UN), Disagree (D), and strongly disagree (SD). The lowest possible score was 33 (scoring 1 on each of the 33 items), and the highest score was 165 (ranking 5 on each of the 33 items), as shown in Table 2.

DISCUSSION

The scale, which is developed comprising 33 statements, was examined using the split-half reliability technique in order to assess the internal consistency and stability of the instrument. The statements were separated into two groups according to odd and even numbering, with Set 1 consisting of 17 statements (S1, S3, S5, …, S33) and Set 2 consisting of 16 statements (S2, S4, S6, …, S32).

The results revealed that Cronbach's Alpha for Set 1 was 0.891, indicating a high degree of internal consistency among the statements included in this set. Similarly, set 2 exhibited a very high Cronbach's Alpha value of 0.955, suggesting excellent homogeneity among its statements. The items in each half are consistently measuring the same underlying construct, as shown by these high alpha coefficients (Shirur et al., 2015; Gupta et al., 2022). The slightly higher reliability coefficient for set 2 indicates comparatively stronger inter- item consistency, although both sets exceed the acceptable reliability threshold.

A moderate but acceptable correlation between the two forms is indicated by the correlation of 0.574 between the two parts of the developed scale. This suggests that even though the products in each half are not identical, they are sufficiently related and contribute meaningfully to the measurement of the same construct. Such a correlation is desirable in split- half reliability analysis, as it reflects balance between item diversity and construct consistency.

To account for the unequal number of items in the sets, the Spearman- Brown reliability coefficient was applied. The resulting reliability coefficients were 0.729 for equal length and 0.730 for unequal length, both of which are above the minimum recommended value of 0.70. Additionally, the coefficient of Guttman split-half was calculated as 0.720, further reinforcing the reliability and stability of the scale. The instrument would continue to have sufficient reliability even if it were given as a full- length test, according to these revised coefficients.

The results show that the scale has satisfactory to exceptional dependability. The instrument is reliable for measuring the desired construct, as evidenced by the robust split-half coefficients, adequate inter-form correlation, and strong internal consistency within each set. As a result, the scale that was established can be regarded as psychometrically sound and is appropriate for use in further statistical analyses, result interpretation, and the drawing of legitimate conclusions in the current study (Deepika et al., 2024)

CONCLUSION

The study was effective in creating and standardising a valid and trustworthy scale to measure vegetable growers' entrepreneurial behaviour. It provides a structured approach for assessing entrepreneurship in vegetable farming by incorporating key behavioural dimensions. A final collection of 33 assertions was kept after methodical item production, expert validation, and item analysis, guaranteeing sufficient content coverage and discrimination ability. The instrument's stability and dependability were confirmed by the split- half reliability results, which showed great internal consistency. Overall, the scale is psychometrically sound and suitable for use in research, extension, and policy-oriented studies aimed at assessing and enhancing entrepreneurial behaviour among vegetable growers.

DECLARATION

Ethical approval and consent to participate: Informed consent was sought from the respondents.

Competing interests: No competing interests were declared.

Conflict of interest: No conflicts of interest among the authors.

The authors declare that during the preparation of this work, 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 Tool

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (166-172)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Development of A Standardized Scale to Assess Marketing Effectiveness of Farmer-Producer Organisations (FPOs)

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HIGHLIGHTS

- The scale consists of 48 items across nine dimensions assessing the marketing effectiveness of FPOs.
- Relevancy testing, item analysis, EFA, split-half reliability, Cronbach's alpha, composite reliability and convergent validity together confirmed validity of the scale.
- The scale can be further used to assess, compare, and improve FPO marketing performance across regions and interventions.

ARTICLE INFO

Keywords: Farmer Producer Organizations (FPOs), Marketing effectiveness, Exploratory Factor Analysis (EFA), Average Variance Extracted (AVE), Composite Reliability (CR), Convergent validity, Scale development.

https://doi.org/10.48165/IJEE.2026.622RT06

Citation: Tripathy, H., Somanath, G., Thomas, A., & Smitha, S. (2026). Development of A Standardized Scale to Assess Marketing Effectiveness of Farmer-Producer Organisations (FPOs). *Indian Journal of Extension Education*, *62*(2), 166-172. https://doi.org/10.48165/IJEE.2026.622RT06

ABSTRACT

The study was undertaken to develop a standardized instrument capable of accurately assessing the marketing effectiveness of Farmer-Producer Organisations (FPOs) through the summated rating technique. Initially, 18 dimensions were identified through literature review and expert consultation. Nine dimensions were chosen based on an Item–Content Validity Index of ≥ 0.80. Based on a comprehensive review of literature and consultations with stakeholders of FPOs, 156 statements related to marketing effectiveness were identified. Following extensive editing, 112 statements were selected, out of which 82 statements with relevancy scores greater than 0.85 were retained. Based on the t-test results, 48 statistically significant statements ($t > 2.145$, $p < 0.05$) were retained for scale development. A nine-dimensional structure with factor loadings greater than 0.60 was verified by exploratory factor analysis. With a strong split-half reliability coefficient (0.941) and Cronbach's alpha (0.944), the completed instrument demonstrated excellent reliability. The instrument exhibited strong convergent validity, as evidenced by a high overall Average Variance Extracted of 0.864 and an excellent Composite Reliability value of 0.996. The final 48 items were grouped under nine dimensions. For positive items, scores ranged from 5 (Strongly Agree) to 1 (Strongly Disagree), whereas negative items were evaluated using reverse scoring.

INTRODUCTION

Farmer-Producer Organisations have emerged as an important institutional innovation that enables marginal and small-scale growers in India to strengthen their involvement in agricultural markets. They function as member-owned collectives that enable farmers to aggregate produce, improve bargaining power, access input and output markets, and engage in value addition activities (Trebbin, 2014). Government organisations like the NABARD & SFAC have promoted FPOs as a critical strategy over the past ten years to combat the information gap, diversified landholdings, and poor market connections that have socially excluded smallholders

Received 10-03-2026; Accepted 19-03-2026

(Government of India, 2013; Mitra, 2015). As a result, FPOs are now viewed as critical institutional mechanisms for enhancing market participation, improving price realization, and fostering rural entrepreneurship.

A key determinant of the success and sustainability of FPOs is their marketing effectiveness, which refers to their ability to optimise resources, expand market reach, secure better prices, and enhance member satisfaction (Kumari et al., 2022; Kumar et al., 2023; Singh et al., 2023). Studies have shown that FPOs engaged in diversified activities–including production, processing, manufacturing, and marketing–tend to exhibit higher levels of effectiveness compared to organizations focusing on a single function. For example, research indicates that FPOs involved in integrated operations demonstrate an effectiveness rate of 68.40%, emphasizing the importance of comprehensive strategies in achieving market performance (Anand et al., 2023). By aggregating produce and streamlining supply chains, FPOs not only facilitate better access to institutional buyers and retail markets but also improve overall market efficiency, reduce wastage, and foster sustainable agri-entrepreneurship (Parthiban et al., 2015; Waghmode et al., 2025).

Despite these achievements, FPOs face multiple challenges that hinder their marketing effectiveness. Structural issues such as inadequate storage and transport facilities, limited access to credit, and gaps in technical marketing expertise continue to constrain growth (Ghadge et al., 2023). Moreover, the absence of a centralized monitoring and tracking system for FPO operations has led to inefficiencies and uneven performance across regions. The organizational efficiency of FPOs, financial literacy among members, adoption of branding and packaging strategies, and utilization of digital marketing tools also play a crucial role in determining marketing success. Evidence suggests that FPOs with structured marketing plans, strong member engagement mechanisms, and effective negotiation strategies achieve higher financial sustainability and market competitiveness (Muniyoor & Pandey, 2024).

Evaluating the marketing effectiveness of FPOs through a standardized scale is therefore critical for both research and policy-making. Such an assessment provides measurable insights into operational strengths and weaknesses, identifies areas for improvement, and informs targeted interventions aimed at enhancing market outcomes for smallholder farmers (Jose et al., 2023). Ultimately, improving marketing effectiveness not only elevates the incomes and livelihoods of farmer members but also strengthens India's agricultural supply chain by ensuring quality, reducing wastage, and promoting efficient resource utilization. Developing and applying a robust marketing effectiveness scale is thus essential for supporting FPOs in realizing their full potential as drivers of agri-entrepreneurship and rural economic development.

The present study was undertaken with the objective of developing a standardized scale to assess the marketing effectiveness of Farmer Producer Organizations (FPOs).

METHODOLOGY

The present study was conducted during the period 2024-2025 with the objective of developing and standardizing a scale to measure the marketing effectiveness of FPOs. The scale was constructed using the summated rating technique proposed by Likert (1932) and Edwards (1969), a widely accepted method for developing reliable measurement instruments. Initially, eighteen dimensions related to the marketing effectiveness of FPOs were identified through an extensive review of literature and consultation with subject matter experts. These dimensions were circulated among 120 experts through a Google Form using a five-point continuum ranging from strongly agree to strongly disagree. Within two months, 64 responses were received. Based on a relevancy score criterion of ≥0.80, nine dimensions were retained.

$$\text{Relevance score (\%)} = \frac{\text{Total scores obtained on each items}}{\text{Maximum possible score}} \times 100$$

Subsequently, 156 statements corresponding to the nine dimensions were generated through literature review and expert consultation. Following the guidelines suggested by Likert (1932) and Edwards (1969), these statements were refined and reduced to 112 items. The refined statements were again circulated to the same group of experts through Google Forms, and 64 responses were obtained. Applying the relevancy threshold of ≥ 0.80, a total of 82 statements were selected for further analysis.

Item analysis was carried out using the Index of Discrimination (t-value) method suggested by Edwards (1969). The 82 statements were pre-tested with 60 Board of Directors (BOD) members from non-sample FPOs in Kerala and Odisha. Using purposive sampling, 10 FPOs from each state were selected based on the criterion that the organizations had completed at least three years since registration. From each selected FPO, three Board of Directors (BOD) members were randomly chosen as respondents, resulting in a total sample of 30 respondents from Kerala and 30 from Odisha. Each statement was measured on a five-point Likert scale, where positive statements were scored from 5 (strongly agree) to 1 (strongly disagree) and negative statements were reverse scored. Based on the discrimination analysis, 48 statements with significant t-values ($t > 2.145$, $p < 0.05$) were retained for the final scale. The reliability of the standardized scale was assessed using Cronbach's alpha and split-half reliability (Spearman–Brown coefficient), while convergent validity was used to establish the validity of the instrument. The results indicated that the developed scale possesses acceptable reliability and validity for measuring the marketing effectiveness of FPOs.

RESULTS

Determination of key dimensions

Based on the assessment of content validity, the key dimensions underlying the marketing effectiveness of FPOs were identified. This was carried out using the summated rating approach, which was designed by Likert (1932) and Edwards (1969). Based on an extensive review of relevant literature and consultations with professionals working with FPOs, eighteen dimensions related to the marketing effectiveness of FPOs were initially identified. To examine their relevance, a Google Form was circulated to 120 subject-matter experts from Deemed Universities, State Agricultural Universities, and national institutions such as ICAR and MANAGE. The experts were requested to rate each dimension using a five-point scale. Within

a period of two months, responses were received from 64 experts, and their feedback was analyzed to evaluate the relevance and reliability of each dimension. Dimensions that showed low reliability or poor relevance were excluded, and only those with a relevancy score of 0.80 or higher were retained following the criteria suggested by Polit and Beck (2006). Based on the relevancy score result nine key dimensions were finally identified for assessing the marketing effectiveness of FPOs: Production Scheduling, Procurement and Aggregation, Marketing Channel, Marketing Costs, Value Addition, Branding, Grading, Product Promotion, and Market Access.

Relevancy of the statements

Based on nine identified dimensions, a total of 156 statements related to the marketing effectiveness of Farmer-Producer Organisations (FPOs) were initially generated through an extensive review of literature and consultations with FPO experts. These statements were then carefully examined and refined using the 14 criteria suggested by Likert (1932) and Edwards (1969) for scale construction. During this preliminary editing process, repetitive and unclear statements were removed or modified. As a result, 112 statements that were clear & relevant were retained for further analysis.

The refined pool of 112 statements was then assessed to determine their significance in accurately representing the marketing effectiveness of FPOs across the nine dimensions. A Google Form was used to score each topic on a five-point relevance scale by 120 topic-specific experts from Deemed Universities, State Agricultural Universities, and national institutions like ICAR and MANAGE. Within a period of two months, responses were received from 64 experts, and their feedback was analyzed to evaluate the relevancy of each statement. Statements that demonstrated low reliability or limited relevance were removed. Only those items with a relevancy score of 0.80 or above were retained, following the guidelines suggested by (Polit & Beck, 2006; Edwards, 1969; Raj & Thomas, 2022) and followed in similar cases (Kumar et al., 2016; Shitu et al., 2018; Gupta et al., 2022: Kademani et al., 2025). Following this validation process, 82 statements were finalized and organized under nine dimensions for further analysis.

Item analysis (Index of discrimination)

The Index of Discrimination reflects how well an item distinguishes high- and low-effectiveness entrepreneurs. To analyze the discriminatory power of the items, the critical ratio (t-value) method recommended by Edwards (1969) was employed. A total of 82 statements developed to measure the marketing effectiveness of Farmer Producer Organizations (FPOs) were pre-tested with 60 Board of Directors (BOD) members from non-sample FPOs in Kerala and Odisha. The respondents were equally divided between the two states, with 30 BOD members from each. Through purposive sampling, 10 FPOs were selected in each state, and three BOD members from each FPO participated in the pre-test, making a total of 30 respondents per state. Each statement was rated on a five-point Likert scale, with positive statements scored from 5 to 1 and negative statements reverse-scored. After arranging respondents' total scores from highest to lowest, the upper 25 per cent and lower 25 per cent were selected for statement discrimination. These extreme groups offer a clearer contrast, enabling more precise identification of statements that effectively distinguish between high and low marketing effectiveness. The middle 50 per cent was excluded because their overlapping scores reduce sensitivity and weaken discrimination. To identify statements that effectively differentiated between higher- and lower-scoring respondents, t-values were computed for each statement using the standard critical ratio formula. After statistical analysis, 48 statements with t-values exceeding 2.145 at the 0.05 significance level were retained under nine key dimensions of FPO marketing effectiveness.

Scale standardization

To standardize the scale, both its validity and reliability were systematically tested and confirmed. Reliability of the scale was established to ensure consistency and stability of measurement. Internal consistency was assessed using Cronbach's Alpha, indicating the extent to which items measured the same construct. Additionally, split-half reliability was computed using the Spearman–Brown coefficient, confirming the dependability and reproducibility of the instrument. The results demonstrated that the instrument exhibited exceptional reliability. The measurement tool displayed remarkable internal consistency, with a Cronbach's alpha of 0.944. This finding is further supported by impressive split-half reliability coefficients, including Spearman–Brown at 0.941 and Guttmann at 0.930.

Validity is important for ensuring that a research instrument reliably measures the desired construct, allowing for meaningful and consistent outcomes (Singh, 2019). Convergent validity was established by conducting exploratory factor analysis using principal component extraction with varimax rotation, which clearly confirmed the underlying dimensions of marketing effectiveness among FPO members. Convergent validity, which is an important aspect of construct validity, refers to how well the items intended to measure the same concept are related to one another, showing that they reflect a common underlying idea. The scale is considered adequate when items show strong factor loadings ($\geq$0.50, preferably $\geq$0.70), AVE (Average Variance Extracted) exceeds 0.50, and CR is above 0.70, indicating reliable measurement of the construct (Cronbach & Meehl, 1955; Campbell & Fiske, 1959; Fornell & Larcker, 1981). The statements showed strong factor loadings (>0.70), with an Average Variance Extracted (AVE) of 0.864 and composite reliability of 0.996, exceeding the recommended thresholds for convergent validity (Hair et al., 2020). Therefore, the results confirmed good convergent validity, and the scale was finalised with 48 statements.

The bar chart shows the AVE scores over all of this nine dimensions of marketing effectiveness in FPOs, and all dimensions cross the 0.60 benchmark, which indicates that the scale has excellent convergent validity.

DISCUSSION

Strong validity and reliability has been demonstrated by the instrument. An excessive Cronbach's Alpha value of 0.944

Table 1. Descriptive statistics on FPOs' marketing effectiveness

S. No.	Statements	t-value	Extra-ction	R^2	AVE
I.	Production Scheduling (Planning and organizing the timing and quantity of agricultural production to optimize output and meet market demands efficiently.)				
1.	The production schedule is prepared before each crop season.	5.196*	.964	0.930	
2.	I believe that through effective production scheduling, our market competitiveness has increased.	5.000*	.961	0.923	
3.	Through advance production scheduling, we are able to seize the market opportunities.	3.655*	.990	0.979	0.931
4.	Our FPO undertakes regular scheduling of production activities.	5.000*	.969	0.939	
5.	The members of our FPO have received training in production scheduling.	4.898*	.940	0.883	
II	Procurement and Aggregation (The process of sourcing agricultural products from individual farmers and consolidating them into larger quantities for sale or distribution by Farmer Producer Organisations.)				
1.	I believe that aggregation helps our FPO negotiate better prices.	5.196*	.948	0.898	
2.	Our FPO has been able to provide timely payments to the farmers.	4.898*	.963	0.928	
3.	Our FPO has developed its own infrastructure for procurement and aggregation.	3.576*	.889	0.790	0.842
4.	Our FPO has designated collection centers.	3.576*	.866	0.749	
5.	Our FPO has a systematic mechanism for procurement of produce from the farmers.	3.655*	.929	0.863	
6.	Shared storage facilities provided by the FPO helps in reducing post-harvest losses.	3.464*	.908	0.824	
III	Marketing Channels (A marketing channel is the pathway through which goods or services flow from producers to consumers, encompassing various intermediaries such as wholesalers, retailers, and agents.)				
1.	The number of intermediaries in the marketing channel is few in our FPO.	5.196*	.900	0.810	
2.	Our FPO actively undertakes online marketing of the produce.	3.666*	.976	0.953	
3.	Our FPO employs multi-channel marketing strategies.	3.666*	.953	0.909	0.896
4.	Our FPO usually participates in exhibitions and trade fairs for marketing.	3.665*	.936	0.877	
5.	Our FPO undertakes door-to-door selling of produce.	4.898*	.964	0.929	
IV	Marketing Costs (The expenses incurred in promoting and selling products or services to customers by a FPO.)				
1.	I believe that the marketing costs incurred by our FPO are high.	4.700*	.870	0.756	
2.	Our FPO provides trainings for improving the marketing skills.	3.655*	.963	0.928	
3.	We collaborate with retail chains and wholesalers which cut our marketing costs.	5.000*	.989	0.978	0.896
4.	My FPOs allocate marketing budgets based on the anticipated sales.	5.000*	.967	0.935	
5.	Marketing budgets for our FPO is determined by assessing the market competition.	4.898*	.940	0.883	
V	Value addition (The numbers & types of value added products marketed by the FPOs.)				
1.	We undertake the production of value added products on a large scale.	3.665*	.874	0.764	
2.	Value added products have increased the profitability of the members.	3.576*	.963	0.928	
3.	I feel that value added products helps FPOs to meet specific market demands and preferences.	6.000**	.937	0.877	0.868
4.	The value added products helps us in capturing higher margins in competitive markets.	3.576*	.954	0.911	
5.	Value addition has enhanced the overall resilience of our FPO against market shocks.	4.898*	.936	0.876	
6.	Value addition has helped us in reducing post-harvest losses.	4.898*	.923	0.852	
VI	Branding (Creating a distinct identity for FPO products to differentiate them from competitors.)				
1.	Through a brand name, we are able to stand differentiated in the competitive market.	7.00**	.925	0.855	
2.	Branding facilitates effective communication of the FPO's mission and goals.	4.898*	.954	0.911	
3.	Branding has helped to command better pricing and improve our profitability.	3.655*	.936	0.875	0.810
4.	Branding has helped us in navigating many regulatory challenges and gaining government support.	3.665*	.914	0.835	
5.	Branding has fostered our collaboration with other stakeholders and industry partners.	3.665*	.756	0.572	
VII	Grading (Classifying farm products based on quality standards to meet consumer preferences and market requirements.)				
1.	Grading has enabled us to secure various certifications.	5.000*	.868	0.754	
2.	The pooled products are sorted and graded before marketing.	5.000*	.946	0.894	
3.	Grading has helped in maintaining consistency in quality, which builds trust with consumers.	5.196*	.964	0.930	0.862
4.	Grading has helped us in securing better prices for our produce in the market.	7.000**	.946	0.894	
5.	Grading has incentivized us to produce better quality produce.	4.898*	.915	0.837	
VIII	Product promotion (Promoting FPO products through various activities to increase awareness and drive sales.)				
1.	We undertake promotional activities to increase the visibility of the FPO products in the market.	3.655*	.861	0.741	
2.	We have been able to retain customers and ensure repeat purchases.	5.196*	.959	0.919	
3.	Through the promotional events, we have been able to gather feedback and insights from consumers.	4.898*	.936	0.876	0.830
4.	We align the promotional events with seasonal of high demand thereby maximizing the sales opportunities.	5.196*	.957	0.915	
5.	I believe that product promotion undertaken in our FPO has contributed to its marketing effectiveness.	4.898*	.837	0.701	

Table 1 contd...

S. No.	Statements	t-value	Extra-ction	R^2	AVE
IX	Market access (Availability of transportation and distribution facilities to ensure that the FPO products reach the target market efficiently.)				
1.	Access to different markets helps us to negotiate better terms with buyers and wholesalers.	5.196*	.900	0.811	
2.	Good market access has enabled us in achieving economies of scale.	4.898*	.911	0.830	
3.	Access to multiple markets provides us with real-time market intelligence and trends.	5.196*	.889	0.790	0.837
4.	Online marketing has expanded our market beyond local boundaries.	5.000*	.934	0.873	
5.	Online marketing is cost-effective marketing compared to the traditional methods.	5.196*	.940	0.884	
6.	We also use online platforms for product promotion and advertising.	4.370*	.900	0.811	
	Overall AVE = (0.931+0.842+0.896+0.896+0.868+0.810+0.862+0.830+0.837)/9 = 0.864				

Table 2. Reliability Statistics

Reliability Statistics			
Cronbach's Alpha	Part 1	Value	.927
		N of Items	24[a]
	Part 2	Value	.962
		N of Items	24[b]
	Total N of Items		48
Correlation Between Forms			.888
Spearman-Brown Coefficient		Equal Length	.941
	Unequal Length		.941
Guttman Split-Half Coefficient			.930

a. The items are: V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_{10}, V_{11}, V_{12}, V_{13}, V_{14}, V_{15}, V_{16}, V_{17}, V_{18}, V_{19}, V_{20}, V_{21}, V_{22}, V_{23}, V_{24}.
b. The items are: V_{25}, V_{26}, V_{27}, V_{28}, V_{29}, V_{30}, V_{31}, V_{32}, V_{33}, V_{34}, V_{35}, V_{36}, V_{37}, V_{38}, V_{39}, V_{40}, V_{41}, V_{42}, V_{43}, V_{44}, V_{45}, V_{46}, V_{47}, V_{48}.

demonstrated its outstanding internal consistency, indicating that the items cooperate to capture the desired construct. Split-half reliability showed remarkable internal consistency, with Spearman-Brown (0.941) and Guttman coefficients (0.930) well above the established benchmarks (DeVellis, 2017). These results align with recent studies (Lade et al., 2024), adding further confidence to the robustness of the instrument. The factor analysis confirmed meaningful item-dimension relationships across nine factors, with loadings consistently above 0.60. The AVE value for each dimension was as follows: Production Scheduling (0.931), Procurement and Aggregation (0.842), Marketing Channels (0.896), Marketing Costs (0.896), Value Addition (0.868), Branding (0.810), Grading (0.862), Product Promotion (0.830), and Market Access (0.837). All dimensions demonstrated strong convergent validity, as indicated by loadings of factors above 0.70, an aggregate AVE of 0.864, & a CR of 0.996, exceeding recommended benchmarks & aligning with the findings of Meethal and Thomas (2024).

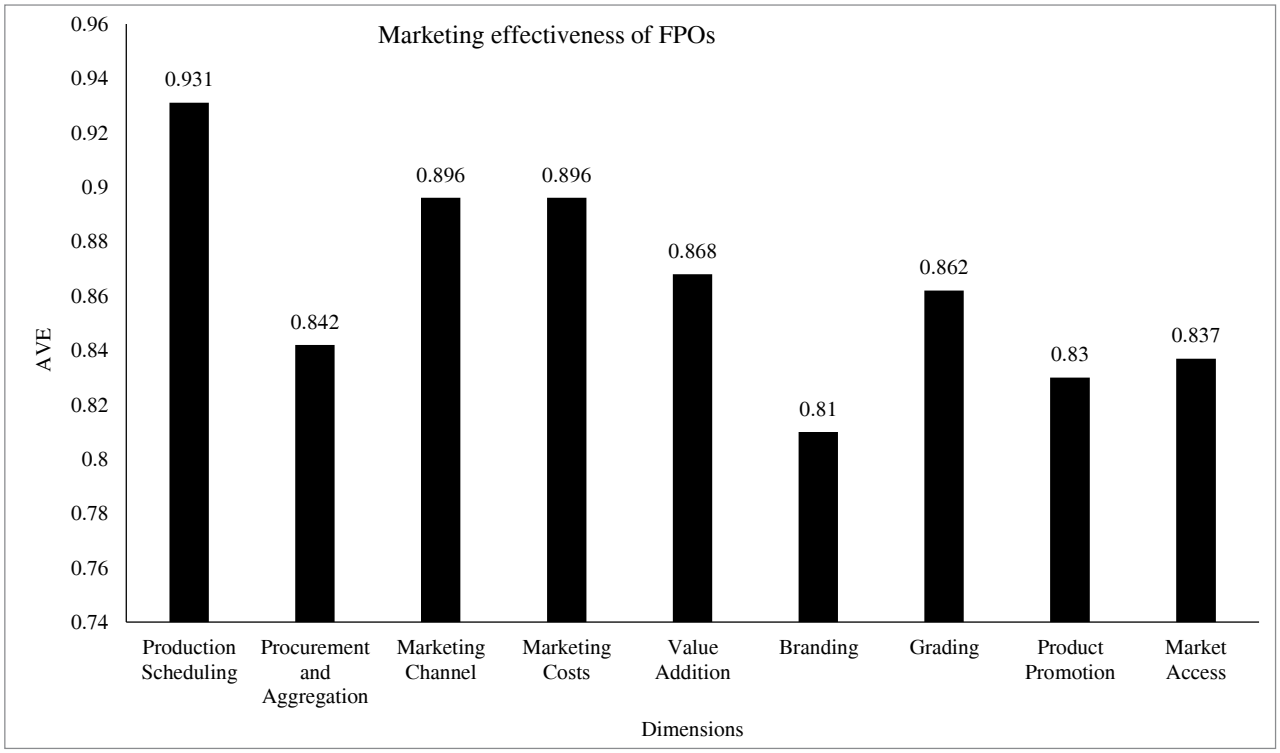

Figure 1. AVE values reflecting all nine dimensions associated with the marketing effectiveness of FPOs.

The final instrument consists of 48 carefully developed items designed to measure the marketing effectiveness of FPOs across nine key dimensions: Production Scheduling (5 items), Procurement and Aggregation (6 items), Marketing Channels (5 items), Marketing Costs (5 items), Value Addition (6 items), Branding (5 items), Grading (5 items), Product Promotion (5 items), and Market Access (6 items). The items were carefully validated using factor analysis, expert judgment, and reliability and validity tests, ensuring the scale is conceptually meaningful and empirically strong.

The designed instrument used to evaluate the marketing effectiveness of Farmer Producer Organizations (FPOs) is a useful tool for systematically reviewing and improving their marketing performance. By capturing members' experiences and perceptions in a structured manner, it enables researchers, policymakers, and FPO leaders to assess the efficiency and effectiveness of marketing practices, identify strengths and weaknesses, and make informed, data-driven decisions. The standardised measure allows for benchmarking across different FPOs, monitoring progress over time, and comparing results across regions, while also highlighting areas for improvement. Moreover, it supports the evaluation of training programs, capacity-building initiatives, and policy interventions aimed at strengthening FPOs' marketing capabilities. By keeping farmers' perspectives at the centre, the scale not only facilitates research but also provides practical insights to guide organisational development, improve competitiveness, and enhance the sustainability of FPOs in the agricultural market.

CONCLUSION

The study was carefully designed and validated to evaluate the marketing effectiveness of Farmer-Producer Organisations (FPOs). The developed scale covers nine key dimensions, namely Production Scheduling, Procurement and Aggregation, Marketing Channels, Marketing Costs, Value Addition, Branding, Grading, Product Promotion, and Market Access, providing a comprehensive assessment of FPO marketing functions. The results indicate that the measurement instrument demonstrates very high internal consistency, with a Cronbach's Alpha of 0.944 and strong split-half reliability coefficients (0.941 using the Spearman–Brown formula and 0.930 using the Guttmann method). In addition, the scale exhibits excellent convergent validity, supported by high factor loadings (above 0.70), a strong Average Variance Extracted (AVE = 0.864), and Composite Reliability (CR = 0.996). Among the dimensions, Production Scheduling, Marketing Channels, and Marketing Costs emerged as particularly influential. Overall, the validated scale serves as a reliable and practical tool to assess marketing performance, supporting policy decisions, organizational improvements, and member-focused strategies to strengthen FPO sustainability.

DECLARATION

Ethical approval and consent to participate: Informed consent was sought from the respondents.

Competing interests: No competing interests were declared.

Conflict of interest: No conflicts of interest among the authors.

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

Acknowledgement: I sincerely thank all those who offered their support, guidance, and valuable insights throughout the development of this scale. Together, the first and second authors designed the study, carried out the statistical analysis, read the literature, and wrote the paper. The third and fourth authors provided valuable editorial inputs. Before submission, the final paper had been reviewed and approved by all authors.

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Research Note

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (173-178)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

What Constrains Agripreneurship? A Factor Analytical Study of Vegetable Growers in South Odisha

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HIGHLIGHTS

- Identified major institutional, financial, technological, and market constraints limiting vegetable growers' entrepreneurial performance.
- Factor analysis revealed a multidimensional structure of constraints, with four components explaining 71.44% total variance.
- Farmers prioritised market reform, flexible credit, post-harvest infrastructure, and organisational support for enterprise sustainability.

ARTICLE INFO

Keywords: Extension strategies, Entrepreneurship, Livelihood enhancement, Market integration, Post-harvest management.

https://doi.org/10.48165/IJEE.2026.622RN01

Citation: Chandra, V., Prusty, A. K., Padhy, C., Raj, R. K., & Ray, S. (2026). What Constrains Agripreneurship? A Factor Analytical Study of Vegetable Growers in South Odisha. *Indian Journal of Extension Education*, *62*(2), 173-178. https://doi.org/10.48165/IJEE.2026.622RN01

ABSTRACT

The study analysed the constraints of entrepreneurial behaviour of vegetable growers in South Odisha and identified priority interventions for agripreneurial development. Using an exploratory design, the data collection was carried out from 240 vegetable growers using the structured interview method in 2025. Constraint severity and suggestion priority were calculated with weighted mean scores and ranking, and seven components to explain 100% variance were extracted by P.C.A., with the first three components explaining 57.2%. Results showed that the biggest constraints were untimely availability of inputs (Mean = 2.154), non-sanction of credit required (2.146), low price in market in the presence of market glut (2.079), and inadequate training (2.033). Major supports as suggested by farmers were insurance coverage in bad situations (2.279), organising vegetable growers (2.233). The findings revealed that the performance of agripreneurs is limited by the interlinked market, financial, technology, and institutional factors. Strengthening the coordination of market regulation, flexible credit systems, post-harvest infrastructure, and organisation of farmers is crucial in improving entrepreneurial capacity and the sustainability of income for vegetable growers.

INTRODUCTION

Agriculture remains a core economic activity in Odisha and food security system, engaging nearly half of the state's workforce and contributing significantly to rural livelihoods. The sector drives crop diversification and income generation among small and marginal farmers. Vegetables are an important high-value, cash crop segment with Odisha's cropping pattern because they provide year-round income opportunities compared with seasonal crops, increase farmers' marketable surplus, support nutrition security for rural households, encourage agri- industrial linkages (Government of Odisha, 2025a). Vegetable production in the state increased from 97.34 lakh metric tonnes (MT) in 2019-20 to 109.3 lakh MT in 2023-24, reflecting steady growth and adoption of diversified crops, including vegetables. In this period, Odisha ranked 7th among Indian

Received 20-01-2026; Accepted 25-02-2026

states in vegetable production, contributing about 5.5 per cent of the country's total output (Government of Odisha, 2025b).

Vegetable farming in Odisha is currently facing crisis that has emerged due to persistent market failures, inadequate post-harvest infrastructure, production constraints and climatic risk (Amar et al., 2025). Farmers often receive low farm-gate prices due to weak marketing linkages and price volatility, quantities of produce are lost due to the lack of adequate cold storage and processing facilities, and climatic changes like floods, erratic rainfall frequently damage perishable crops. These factors reduce profit, discourage investment in vegetable cultivation, and undermine the economic sustainability of small and marginal farmers (Das et al., 2025). While Odisha is rich in vegetable production potential, but weak in infrastructure, especially in post-harvest infrastructure and market access, have created distress among vegetable growers, turning what should be a high-value enterprise into a high-risk, low-return endeavour (Government of Odisha, 2025b).

Entrepreneurship in agriculture has become an important factor in India's rural development, economic robustness and livelihood diversification. Despite its declining contribution to national GDP in the last few decades, agriculture continues to employ major part of the rural human resources around 52 per cent of the population highlighting the socio-economic significance of agriculture and the potential for agripreneurial growth to uplift the rural incomes (Trivedi & Patel, 2024). Vegetable production, in particular, is a high-value and employment-intensive sector, providing an important source of income generation, risk reduction and market access for smallholder farmers. However, the extent to which vegetable growers behave in an entrepreneurial manner is mediated by a complex interaction of personal, institutional, technological and market constraints (Kumar & Nain, 2012; Chopra & Rathore, 2024; Bhuriya & Gour, 2025). Understanding the binding constraints faced by growers is important in determining extension strategies that can be used to boost agripreneurship (Saha et al., 2024). Research on agripreneurial constraints reveals wide-ranging constraints across the scope of lack of availability of inputs, poor financial services, lack of infrastructure, lack of market linkage and socio-cultural norms inhibiting risk-taking and innovation (Bathini et al., 2021; Raza et al., 2025). The study explores constraints perceived and remedies suggested by farmers among vegetable growers in South Odisha, focusing specifically on the relationships of these barriers to entrepreneurial behaviour.

METHODOLOGY

The current investigation was an ex post facto research design, which is suitable for research into already existing behavioural patterns and constraints under no manipulation of variables. The study was carried out in Ganjam and Koraput of South Odisha which is known for increasing vegetable production and new agripreneurial activities. In the first stage, the major vegetable growing blocks were identified from the two selected districts on the basis of area under vegetable cultivation and participation in the market. From Ganjam District two blocks were taken i.e. Sorada and Khalikote and from Koraput district two blocks were taken i.e. Semiliguda and Koraput. Villages were randomly selected from Sorada and Khalikote blocks of Ganjam district. Twelve villages were selected, six from each block. From Sorada block, six villages were taken: Gopalpur, Nuagada, Borada, Ekalalpur, Gangapur & Sarabadi and from Khalikote block, six villages were taken: Bagalpur, Nuapalli, Chikili, Danapur, Chakasingh & Dimiria. From Semiliguda block six villages were taken: Charangul, Khudi, Dudhari, Sadam, Muthai & Choragan and from Koraput block six villages were taken: Bagara, Chakili, Dakara, Ekataguda, Jerati & Kalchur. Proportionate random sampling was followed for a total sample of 240 vegetable growers. Primary data was gathered in personal interviews with the use of a pre-tested, structured interview schedule developed in consultation with extension experts and subject matter specialists. The dimensions that the instrument addressed were those related to administration, technology, availability of inputs, credit and finance, production, marketing, and socio-cultural constraints and the interventions suggested by farmers, respectively.

Weighted mean scores, gap percentages and ranks were calculated to identify the severity and priority of constraints and suggestions. To examine the underlying structure in a case of multiple constraint variables and simplify the dimensional complexity, the Principal Component Analysis (PCA) using varimax rotation was applied. Factors with eigenvalues greater than one, and variables with high factor loadings were kept, and latent dimensions that have an impact on agripreneurial constraints were interpreted. Descriptive statistics such as frequency, percentage, mean, and standard deviation were used to summarise the data. Inferential and multivariate analyses were conducted using standard statistical software. Content validity of the instrument was established through expert review, and reliability was ensured through pilot testing and necessary refinements prior to final data collection.

RESULTS

Distribution of perceived constraints amongst vegetable growers

Among the administrative constraints, lack of control on traders and input suppliers ranked highest (Mean = 2.025) followed by poor liaison in the local vegetable trade system with traders and input suppliers (Mean = 1.967) reflecting poor institutional linkage and governance in the local vegetable trade system. Under the technological constraints, insufficient training for knowledge and skill competency ranked first (Mean = 2.033) and literatures not supplied for reference ranked second (Mean = 1.958), reflecting lack of access of growers to need-based technical knowledge and advisory support. With regard to input availability, inputs not timely available turned out to be the most critical constraint (Mean = 2.154) followed by inadequate distribution of mini-kits (Mean = 2.063), suggesting gaps in the supply chain and institutional input delivery mechanism. In the category of credit and finance, required amount not sanctioned was the biggest constraint (Mean = 2.146), with no relaxation in fixing repayment instalments coming at second position (Mean = 2.104), which reflected the financial rigidity and procedural hindrances faced by vegetable growers. Among the production constraints, there is a lack of knowledge on quality maintenance ranked first (Mean = 2.079), followed by inadequate attempt to develop management competency (Mean = 2.071)

Table 1. Distribution of Perceived Constraints Influencing Entrepreneurial Behaviour of Vegetable Growers in South Odisha

S.No.	Constraint	Strongly agree	Agree	Disagree	Mean	Rank
a.	Administrative constraints					
i	Poor liaison with traders and input suppliers	55	122	63	1.967	II
ii	No control over traders and input suppliers	61	124	55	2.025	I
iii	Less credibility of the extension functionaries	49	121	70	1.913	III
b.	Technological constraints					
i	Inadequate training for knowledge and skill competency	65	118	57	2.033	I
ii	Inadequate demonstration to enrich knowledge	54	120	66	1.950	III
iii	Literatures not supplied for reference	55	120	65	1.958	II
c.	Input availability					
i	Inputs not timely available	81	115	44	2.154	I
ii	Inadequate distribution of mini- kit	68	119	53	2.063	II
iii	Input not available on credit system	65	116	59	2.025	III
d.	Credit and finance					
i	Harassment in processing of documents	70	119	51	2.079	III
ii	Required amount not sanctioned	78	119	43	2.146	I
iii	Lack of relaxation in fixing repayment instalments	72	121	47	2.104	II
e.	Production Constraints					
i	Lack of knowledge about quality maintenance	68	123	49	2.079	I
ii	Insufficient attempt to develop management competency	67	123	50	2.071	II
iii	Lack of idea to control stored grain pests	68	120	52	2.067	III
f.	Marketing constraints					
i	Exploitation by the traders and businessmen	67	119	54	2.054	II
ii	Low sale price in plea of market glut by the businessmen	71	117	52	2.079	I
iii	Lack of control of the government on traders and businessmen	62	121	57	2.021	III
g.	Socio-cultural constraints					
i	Lack of community support to use common resources	68	122	50	2.075	III
ii	Lack of cooperation of the villages and local people	73	123	44	2.121	II
iii	Possibility of cattle menace	77	119	44	2.138	I

suggesting that there is a need for capacity building in post-harvest and farm management practices. With respect to marketing constraints, low sale price under the plea of market glut by businessmen emerged as the major constraint (Mean = 2.079) followed by exploitation by traders and businessmen (Mean = 2.054), which shows the vulnerability of the farmers to price fluctuation and the domination of middlemen. Under socio-cultural constraints, possibility of cattle menace scored highest (Mean = 2.138) whereas non-cooperation of villages and local people scored second (Mean = 2.121), showing that social and community related factors also play a very significant role in entrepreneurial decision-making.

Perceived suggestions from vegetable growers

Among the organisational support measures, good coordination and cooperation among extension officials (Mean = 2.088) topped the list followed by good linkage with related departments (Mean = 2.071), indicating the need for better institutional convergence for extension delivery. Under technological backstopping, reasonable demonstration to build confidence (Mean = 2.133) emerged as the topmost suggestion followed by adequate training to raise knowledge and competency of skills (Mean = 2.129) reflecting preference of the growers for practical and hand-on learning approaches. In terms of input availability support, authenticity in quality (Mean = 2.083) ranked at the top followed by liaisoning with traders for availability and timely supply of inputs (Mean = 2.075) implying the importance in quality assurance and reliable input supply chains. In the category of credit and finance; flexibility in mortgage (Mean = 2.138) followed by availability of required amount (Mean = 2.133) was the most preferred support which highlights the need for credit policies for the farmers. Under post harvester management support, competency development on grading (Mean = 2.183) was ranked first followed by community drying yard facility (Mean = 2.150) which showed the demand of improved post harvester handling infrastructure and skills from the growers. With respect to marketing support, insurance coverage in adverse situations (Mean = 2.279) was considered most essential followed by minimum support price of the produce (Mean = 2.217) implying the need for risk mitigation and price security mechanisms. Under socio-cultural support, organising vegetable growers (Mean = 2.233) ranked first, followed by establishing coordination and cooperation among vegetable growers (Mean = 2.225) which shows the importance of collective action in strengthening the entrepreneurial behaviour.

The factor analysis of constraints

Principal Component Analysis (PCA) was conducted to identify the major dimensions of constraints faced by the respondents (Table 3). Although seven components were extracted, only three components were retained for interpretation following

Table 2. Farmer-Perceived Priority Support Measures for Strengthening Entrepreneurial Behaviour of Vegetable Growers in South Odisha

S.No.	Support	More Essential (3)	Essential (2)	Less Essential (1)	Mean	Rank
a.	Organisational support					
i	Good linkage with related departments	69	119	52	2.071	II
ii	Immediate solving of field problems	63	119	58	2.021	III
iii	Good coordination and cooperation among extension officials	71	119	50	2.088	I
b.	Technological backstopping					
i	Adequate training to enhance knowledge and skill competency	72	127	41	2.129	II
ii	Reasonable demonstration to develop confidence	76	120	44	2.133	I
iii	Adequate facilities for soil testing	71	122	47	2.100	III
c.	Input availability support					
i	Available with fair price	69	118	53	2.067	III
ii	Liasoning with traders for timely supply	69	120	51	2.075	II
iii	Authenticity on quality	71	118	51	2.083	I
d.	Credit and finance					
i	Timely availability of credit	71	118	51	2.083	III
ii	Flexibility in mortgage	77	119	44	2.138	I
iii	Availability of the required amount	77	118	45	2.133	II
e.	Post-harvest management support					
i	Skill competency for quality maintenance	73	118	49	2.100	III
ii	Competency development on grading	84	116	40	2.183	I
iii	Community drying yard facility	78	120	42	2.150	II
f.	Marketing of the produce					
i	Cold store facility to store during market glut	85	119	36	2.204	III
ii	Minimum support price of the produce	86	120	34	2.217	II
iii	Insurance coverage in an adverse situation	95	117	28	2.279	I
g.	Socio-cultural support					
i	Organising vegetable growers	90	116	34	2.233	I
ii	Establishing coordination and cooperation among vegetable growers	88	118	34	2.225	II
iii	Cooperative system in the disposal of produce	79	117	44	2.146	III

Table 3. Factor Loading / Principal Component analysis of constraints

Variables	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
Administrative	-0.195	0.509	-0.442	-0.327	-0.382	0.001	0.505
Technical	0.108	0.133	0.680	-0.564	0.230	-0.199	0.312
Input Availability	-0.211	0.611	-0.153	-0.005	0.519	-0.306	-0.442
Credit & Finance	0.496	0.405	0.070	-0.067	0.035	0.741	-0.173
Production	-0.536	0.130	0.267	0.463	0.294	0.388	0.417
Marketing	0.593	0.042	-0.244	0.353	0.384	-0.268	0.493
Socio-cultural	0.142	0.409	0.428	0.481	-0.544	-0.308	-0.082
Eigenvalue	1.455	1.424	1.124	0.997	0.764	0.694	0.541
Variability (%)	20.788	20.346	16.064	14.241	10.915	9.917	7.729
Cumulative %	20.788	41.134	57.199	71.439	82.354	92.271	100.00

the Kaiser criterion (Eigenvalue >1). These three components together explained 57.20% of the total variance, indicating a satisfactory representation of the data. The first principal component (PC1) recorded the highest eigenvalue (1.455) and accounted for 20.79% of the total variance, with strong loadings on Marketing (0.593), Credit & Finance (0.496), and Production (–0.536); hence, it was interpreted as Market–Production Constraints, representing economic and output-related barriers. The second component (PC2), with an eigenvalue of 1.424, explained 20.35% of the variance and exhibited high loadings on Input Availability (0.611), Administrative (0.509), and Socio-cultural (0.409) constraints, and was therefore designated as Administrative–Input Constraints, reflecting institutional and access-related limitations. The third component (PC3) possessed an eigenvalue of 1.124 and contributed 16.06% of the total variance, with dominant loadings on Technical (0.680) and Socio-cultural (0.428) constraints, and was labeled as Technical–Socio-cultural Constraints, indicating knowledge-based and social impediments. The remaining components had eigenvalues below unity and were not considered for further interpretation.

DISCUSSION

The investigation gave a holistic insight into the constrained environment within which the agripreneurial behaviour of the vegetable growers in South Odisha. Among the administrative constraints, the greatest severity was attached to the lack of control in traders and input suppliers and poor liaisoning brought out the structural weaknesses in the market governance and the extension-market interface. Similar results were obtained by Gupta et al. (2014) and Anamika et al. (2023). The comparatively low ranking of "non-cooperative officials" implied that growers had been freer of interpersonal relationships with officials and more limited by the lack of effective regulatory and coordination mechanisms. Technological limitations, especially the lack of reasonable demonstration to develop confidence, highlighted acute shortcomings in the extension delivery system. These results reinforced the proposition that entrepreneurial behaviour in vegetable cultivation had relied heavily on access to knowledge and learning by experience (Kumar et al., 2013; Das et al., 2014). The intense input availability and credit constraints shown in this study, particularly due to delayed input supply and unsanctioned required credit, meant that financial as well as supply chain constraints have not been key impeding factors for enterprise expansion (Suman et al., 2025; Kiran et al., 2025). Marketing constraints such as low sale price at time of glut in market and exploitation by traders came out as the most acute challenges. Among the production constraints, lack of knowledge about quality maintenance and Insufficient attempt to develop management competency, similar result was obtained by (Ajaykumar et al., 2024). Among socio-cultural constraints possibility of cattle menace, lack of cooperation of the villages and local people and lack of community support to use common resources, a similar result was obtained by (Kobba et al., 2020; Khan et al., 2024).

The suggestions revealed that farmers strongly emphasised the need for good coordination and cooperation among extension officials to ensure timely guidance and effective problem resolution at the field level. Reasonable field demonstrations were identified as the most important technological support, as they enhance farmers' confidence and promote adoption of improved vegetable production practices. Ensuring authenticity and quality of agricultural inputs was considered essential for improving crop performance and minimising production risks. In terms of financial support, flexibility in mortgage requirements for credit access emerged as a crucial factor in enabling small and marginal farmers to invest in cultivation activities without financial constraints. For post- harvest management, competency development on grading was prioritised, as it helps farmers secure better market prices through quality differentiation. Insurance coverage in adverse situations was the top marketing- related suggestion, highlighting farmers need for protection against climate variability and market uncertainties. Organising vegetable growers into groups or collectives was viewed as vital socio-cultural support, as it strengthens collective action, improves market access, and facilitates knowledge sharing, thereby enhancing the overall entrepreneurial capacity of vegetable farmers.

The PCA explained three major components with eigenvalues greater than one. In PC1, the strong positive loadings of marketing and credit indicated that better financial access and market orientation tended to move together, while the negative loading of production suggested that production constraints intensified where these economic linkages were weak. This inverse relationship implied that inadequate commercialisation support may have translated into lower productive efficiency, reinforcing the economic nature of this component. PC2 showed uniformly positive loadings for input availability, administrative, and socio-cultural factors, indicating that these variables operated as a mutually reinforcing system; effective institutional support was closely associated with improved access to inputs and socially accepted practices. In PC3, the high positive loading of technical factors alongside socio-cultural influence suggested that technology adoption depended not only on technical feasibility but also on farmers' awareness and social readiness.

CONCLUSION

The study concluded that agripreneurial development of vegetable growers in South Odisha had been seriously constricted due to institutional, technological, financial, input and market-related bottlenecks. Market exploitation, insufficient training and demonstration, delayed supply of inputs, poor access to credit and poor post harvesting infrastructural were found to be the most critical impediments. Factor analysis confirmed that these constraints were multidimensional and interlinked, necessitating integrated extension interventions. Based on the findings, it is suggested that the extension agencies should consider prioritising strengthening the market governance, ensuring timely and quality delivery of input as well as expanding need-based training and field demonstration, and improving access to flexible and timely credit. Development of post harvesting infrastructure like grading, storage mechanisms and risk mitigation mechanisms is vital. Promoting farmer organisations and improving coordination between extension institutions will further strengthen agripreneurial capacity and income sustainability of vegetable growers in the region.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the farmer respondents of the study during the course of the research.

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 author declares that they have 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 Note

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (179-182)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Environmental Awareness and Behavioural Gap among High School Students in East Champaran, Bihar

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HIGHLIGHTS

- Awareness levels were higher than behavioural adoption and showed a measurable awareness–action gap.
- Climate change awareness showed a significant behavioural association.

ARTICLE INFO

Keywords: Environmental awareness, Pro-environmental behaviour, High school students, Environmental education, Chi-square test.

https://doi.org/10.48165/IJEE.2026.622RN02

Citation: Kritika & Pandey, R. (2026). Environmental Awareness and Behavioural Gap among High School Students in East Champaran, Bihar. *Indian Journal of Extension Education*, *62*(2), 179-182. https://doi.org/10.48165/IJEE.2026.622RN02

ABSTRACT

The study was conducted in 2026 in the East Champaran district of Bihar to examine the relationship between environmental awareness and behavioural adoption among high school students. A descriptive survey design was employed, and primary data were collected from 300 students of Classes IX and X selected through stratified random sampling from four secondary schools. A structured questionnaire was used to measure environmental awareness, understanding of environmental issues and behavioural adoption using a five-point Likert scale. The results revealed that students possessed a moderate level of environmental awareness (Mean = 3.60) and understanding (Mean = 3.42), whereas behavioural adoption was comparatively lower (Mean = 3.25). The paired t-test indicated a statistically significant difference between awareness and behavioural adoption scores ($p < 0.01$), confirming the presence of an awareness–action gap. Chi-square analysis showed that demographic variables such as gender and class level were not significantly associated with environmental awareness. In contrast, climate change awareness was significantly associated with carbon reduction behaviour. The findings suggest that awareness alone is insufficient to ensure consistent environmental practices. Strengthening experiential and participatory environmental education at the school level may help translate environmental knowledge into sustained behavioural engagement.

INTRODUCTION

Environmental challenges such as pollution, climate change, and resource depletion are becoming increasingly visible in everyday life, particularly in Bihar's rural regions. In areas such as East Champaran, environmental concerns are closely intertwined with agriculture, public health, and local livelihoods. Within this context, schools play a critical role in shaping environmental consciousness among adolescents. Environmental education has expanded significantly in recent years, emphasising sustainability, climate awareness, and responsible citizenship (Wals & Benavot, 2017; Hicks & Holden, 2019). Research indicates that young people today are more exposed to environmental information than previous generations. However, access to environmental information does not always translate into consistent behavioural engagement. Studies in environmental psychology and education consistently report a divergence between awareness and action, often referred to as the awareness–action gap (Otto & Pensini, 2017; Ardoin et al., 2020). While students may express concern about environmental degradation, consistent engagement in pro-environmental practices remains uneven. Recent empirical investigations show that

Received 26-02-2026; Accepted 12-03-2026

environmental behaviour is influenced by multiple factors, including emotional connection to nature, peer influence, social identity, and contextual reinforcement (Fielding & Hornsey, 2016; Collado et al., 2017; Geng et al., 2019). Adolescents who perceive environmental issues as personally relevant or socially valued are more likely to adopt sustainable practices. At the same time, behavioural adoption depends on experiential learning opportunities rather than purely theoretical instruction (Stevenson et al., 2017).

Within the Indian context, extension education models increasingly emphasise participatory and community-linked strategies to strengthen behavioural engagement among rural youth. Environmental awareness among adolescents is often moderate, but behavioural consistency improves when school-based initiatives are integrated with local environmental activities (Singh & Verma, 2022; Kumar et al., 2023; Yadav & Patel, 2024). These findings suggest that bridging the awareness–action divide requires structured experiential reinforcement.

Although environmental concern among youth is rising globally, studies indicate that behavioural adoption remains selective and context-dependent (Zsóka et al., 2017; Whitmarsh et al., 2020). In districts such as East Champaran, where environmental realities are immediate and visible, examining the relationship between awareness and behaviour becomes particularly relevant. However, systematic empirical evidence focusing on this relationship at the secondary school level in Bihar remains limited.

The present study, therefore, examines environmental consciousness among high school students in East Champaran district with specific attention to the relationship between awareness and behavioural adoption. It aims to determine whether higher levels of environmental awareness are associated with stronger pro-environmental engagement. Based on existing environmental education scholarship, the study hypothesises that awareness levels are significantly higher than behavioural adoption levels, indicating a measurable awareness–action gap.

METHODOLOGY

The present study adopted a descriptive survey research design to examine the relationship between environmental awareness and behavioural adoption among high school students. A descriptive design was considered appropriate because it enables systematic collection of information from a large number of respondents to describe existing levels of awareness, understanding and environmental practices without manipulating the study variables. The study was conducted in the East Champaran district of Bihar, a predominantly rural region where environmental education initiatives are increasingly important in school curricula. Two administrative blocks of the district were selected purposively to represent typical rural educational settings and to facilitate efficient field data collection. From each selected block, secondary schools were identified and included in the sampling frame.

A stratified random sampling technique was employed to ensure adequate representation of students across relevant categories. Stratification was carried out on the basis of class level and gender, enabling balanced participation of students from Classes IX and X and capturing possible variation in environmental awareness and behavioural practices. From the selected schools, a total of 300 students were randomly chosen as respondents for the study. Primary data were collected through a structured questionnaire designed to measure key dimensions of environmental awareness and behaviour among students. The questionnaire consisted of items related to environmental issues such as pollution, climate change, waste management, biodiversity conservation and energy conservation. Responses were recorded on a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5).

The key variables of the study were environmental awareness, environmental understanding and behavioural adoption. Environmental awareness refers to students' knowledge and perception of major environmental problems and their causes. Environmental understanding represented students' conceptual comprehension of environmental processes and their broader ecological implications. Behavioural adoption referred to the extent to which students reported practising environmentally responsible behaviours in daily life, such as conserving resources, reducing waste and participating in environmental activities. Composite scores for each variable were calculated using the mean responses of the respective questionnaire items.

Prior permission for data collection was obtained from the school authorities, and student participation was voluntary. Responses were recorded anonymously to maintain confidentiality.

RESULTS

The analysis of the collected data focused on examining students' level of environmental awareness, environmental understanding and behavioural adoption of sustainable practices. Descriptive statistics were used to summarise the responses, while inferential statistical techniques were employed to identify significant differences and relationships among the study variables. The results are presented and interpreted in the following sections.

The responses regarding the most pressing environmental concerns perceived by the respondents are presented in Table 1. The students demonstrated a moderate level of environmental awareness, as evidenced by their mean score of 3.60 (SD = 0.876). Students appeared to have a reasonable understanding of environmental concepts, as indicated by the mean understanding score of 3.42 (SD = 0.884). However, behavioural adoption recorded a comparatively lower mean of 3.25 (SD = 0.912), pointing to less consistent engagement in environmentally responsible practices. For interpretation of mean scores, the following classification was used: 1.00–2.33 = low level, 2.34–3.66 = moderate level, and 3.67–5.00 = high level. The comparatively lower adoption score, when viewed alongside awareness and understanding, suggests that behavioural responses have not advanced in proportion to students' cognitive knowledge.

The results of the paired-sample t-test used to examine the awareness–action gap are presented in Table 2. The analysis

Table 1. Mean scores of environmental constructs

Variable	Mean	SD
Awareness	3.60	0.876
Understanding	3.42	0.884
Adoption	3.25	0.912

Note: Scale: 1 = Strongly disagree to 5 = Strongly agree

Table 2. Paired comparison of awareness and adoption

Variable Pair	Mean Difference	t-value	p-value
Awareness – Adoption	0.35	4.96	0.002

Note: Significant at $p < 0.01$

indicated a statistically significant difference between awareness and behavioural adoption scores ($t = 4.96$, $df = 299$, $p < 0.01$), with a mean difference of 0.35. This result suggests that although students demonstrate a reasonable level of environmental awareness, the translation of this awareness into consistent environmental behaviour remains comparatively limited.

The chi-square analysis examining associations between demographic variables and environmental indicators is presented in Table 3. The findings revealed no significant association between gender and environmental awareness ($p > 0.05$) or between class level and awareness ($p > 0.05$), indicating that levels of awareness were broadly similar across these demographic groups. On the other hand, a statistically significant correlation ($p < 0.05$) was found between carbon-reduction behaviour and climate-change awareness. This suggests that students with a deeper understanding of climate change were more likely to engage in specific eco-friendly activities.

Table 3. Chi-square association between awareness and behaviour

Independent Variable	Dependent Variable	χ^2	df	p-value
Gender	Environmental Awareness	3.21	2	0.071
Class Level	Environmental Awareness	2.87	2	0.089
Climate Change Awareness	Carbon Reduction Behaviour	4.21	1	0.040

Note: Significant at $p < 0.05$

DISCUSSION

The findings of the present study indicate that although high school students in East Champaran possess a moderate level of environmental awareness, the level of behavioural adoption remains comparatively lower. The statistical difference observed between awareness and behavioural adoption confirms the presence of an awareness–action gap. This pattern suggests that environmental knowledge alone does not automatically lead to consistent pro-environmental behaviour among adolescents. While students appear to understand environmental issues such as pollution and climate change, translating this knowledge into everyday environmental practices remains limited. The comparatively higher mean score for environmental awareness in the present study indicates that students are increasingly exposed to environmental information through school curricula, media, and public discourse. However, the lower behavioural adoption score suggests that awareness by itself may not be sufficient to influence routine environmental practices. This finding reinforces earlier research in environmental education, which highlights that behavioural change requires not only cognitive understanding but also practical engagement, motivation, and supportive social environments.

The absence of a significant association between demographic variables, such as gender and class level, and environmental awareness further suggests that environmental information is reaching students relatively uniformly across the school system. However, the significant association observed between climate change awareness and carbon reduction behaviour indicates that issue-specific understanding may encourage more concrete environmental actions. Students who better understand the implications of climate change may be more inclined to adopt practices such as reducing energy consumption, avoiding wasteful resource use, or supporting environmentally responsible habits. These findings highlight the importance of experiential and participatory learning approaches in environmental education. Classroom-based instruction alone may create awareness, but behavioural engagement is more likely to develop when students are actively involved in environmental activities. School-based initiatives such as environmental clubs, tree-planting drives, waste-segregation campaigns, and community clean-up programmes can provide students with opportunities to translate environmental knowledge into practical action. Participation in such activities strengthens students' sense of responsibility and encourages long-term environmental commitment.

From a policy perspective, the results suggest that environmental education programmes at the secondary school level should place greater emphasis on action-oriented learning rather than solely theoretical instruction. Educational policies may encourage integration of project-based environmental learning, field activities, and community participation within school curricula. Schools may also collaborate with local institutions and community organisations to provide students with opportunities to engage directly with environmental issues affecting their local surroundings. The findings also carry important implications for extension education and environmental outreach programmes. Extension agencies working in rural areas can collaborate with schools to promote youth-centred environmental initiatives such as awareness campaigns, village sanitation drives, water conservation programmes, and climate-responsive practices. Such initiatives can create stronger linkages between formal education and community-based environmental action. By involving students in local environmental improvement activities, extension programmes can help bridge the gap between awareness and behavioural adoption.

Overall, the results emphasise that environmental awareness forms an important foundation for sustainable behaviour, but it must be reinforced through practical engagement, community participation, and supportive institutional frameworks. Strengthening experiential environmental education and extension-based environmental initiatives may therefore play a crucial role in transforming environmental awareness into consistent behavioural practice among adolescents.

CONCLUSION

Students possess a moderate level of environmental awareness and understanding of environmental issues, which does not always translate into consistent pro-environmental behaviour. The statistically significant difference observed between awareness and behavioural adoption confirms the presence of an awareness–action gap among adolescents. The significant association observed

between climate change awareness and carbon reduction behaviour suggested that issue-specific understanding can encourage more concrete environmental actions. Environmental education at the secondary school level should emphasise experiential and participatory learning approaches. Activities such as school environmental clubs, tree-planting programmes, waste management initiatives, and local environmental campaigns can provide students with opportunities to apply environmental knowledge in real-world contexts. Such initiatives can strengthen students' sense of environmental responsibility and encourage the development of sustainable behavioural practices. Extension agencies, educational institutions, and community organisations can collaborate to organise environmental awareness drives, community-based environmental projects, and youth-led sustainability activities and can create stronger linkages between formal education and community-level environmental action.

DECLARATIONS

Ethics approval and informed consent: Prior permission for data collection was obtained from the school authorities, and student participation was voluntary. Responses were recorded anonymously to maintain confidentiality.

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.

The authors express their sincere gratitude to the participating schools and students for their cooperation during data collection. The authors also acknowledge the academic guidance and institutional support received from the Department of Home Science, Patna University, during the course of this research.

Acknowledgement: The authors are grateful to the ACIAR-funded "Transforming Smallholder Food Systems in the Eastern Gangetic Plain (RUPANTAR) Project" for funding this PhD Fellowship. In addition to the project's financial support, the authors thank everyone who helped accomplish this research.

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Research Note

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (183-188)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Undergraduates' Perceptions and Engagement in Practical Agriculture: A Case of Landmark University, Nigeria

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HIGHLIGHTS

- Undergraduates showed positive perceptions of practical agriculture, especially hands-on learning and entrepreneurship skills.
- Factor analysis identified five dimensions shaping engagement: value, resources, mentorship, workload, and aspiration misfit.
- Academic workload/time constraints were the only significant negative predictor of perceived practical agriculture value.

ARTICLE INFO

Keywords: Practical agriculture education, Undergraduate perceptions, Student engagement, Food security, Sustainable Development Goals (SDGs).

https://doi.org/10.48165/IJEE.2026.622RN03

Citation: Owolabi, A. O., Ayeni, M. D., Prusty, A. K., Masso, W. Y. A., Mishra, N., & Akpan, S. E. (2026). Undergraduates' Perceptions and Engagement in Practical Agriculture: A Case of Landmark University, Nigeria. *Indian Journal of Extension Education*, *62*(2), 183-188. https://doi.org/10.48165/IJEE.2026.622RN03

ABSTRACT

The article explores the perceptions and participation of undergraduates in practical agriculture education in Landmark University, Nigeria, and hypothesises whether the constraints associated with participation are significantly related to the perceived value of practical agriculture by students. Primary data were gathered using a structured questionnaire and analysed using descriptive statistics and exploratory factor analysis (PCA with oblimin rotation) on 329 undergraduates in four colleges. The respondents indicated positive involvement in practical agriculture and a positive attitude towards practical agriculture, with the highest scores on hands-on experience, acquisition of entrepreneurial skills, and perceived employment opportunities in the agricultural sector. Factor analysis produced five consistent elements, including perceived career value/personal relevance, institutional resourcing and technology deficits, mentorship/instructional support gaps, academic workload/time constraints, and status/aspiration misfit, explaining 62.55 per cent of total variance (KMO = 0.809; Bartlett's χ^2 significant). The results indicate that to enhance practical agriculture performance, it is necessary to protect practical time, strengthen instructional and mentorship support, and increase integration of resources and technology to maintain student engagement and align practical agriculture with diverse aspirations.

INTRODUCTION

In most developing nations, agriculture has been core to economic growth, food security and livelihood of the rural population, as it still forms a source of employment and revenue to a significant percentage of the population. The World Bank (2023) highlights that agricultural sector growth is especially efficient in poverty reduction and raising rural incomes whereas the International Labour Organisation (2022) forecasts that almost 1 billion individuals across the world are involved in agriculture, which

Received 17-02-2026; Accepted 13-03-2026

highlights its further labour-consumption ability. As population grows, dietary patterns shift, and pressure on natural resources increases, global food systems are becoming increasingly challenged, and sustainable and innovation-based agriculture practices are needed (Food and Agriculture Organisation (FAO), 2025). The Organisation for Economic Co-operation and Development (OECD) & Food and Agriculture Organisation of the United Nations (FAO) (2025) also point out that the future agricultural growth would be significantly reliant on future productivity gains, facilitated by technological adoption, skills acquisition, and the use of evidence-based decisions throughout the agrifood sector.

The experiential method of learning, especially the practical exposure method, is deemed effective in bringing theoretical knowledge into practical competencies in the real world (Kolb, 1984). It has been empirically proven that applied learning settings increase the level of student engagement, skills acquisition and problem-solving skills in comparison to traditional lecture-based instruction (Freeman et al., 2014). Farm practical training programmes in Nigeria have demonstrated that students appreciate exposure to experience, but the effectiveness is limited due to logistical, infrastructural, and instructional constraints (Adefalu et al., 2021). Youth often perceive agriculture as labour-intensive or less prestigious compared to white-collar professions, particularly where exposure to modern technologies and agribusiness opportunities is limited (Obayelu & Fadele, 2019). Similarly, Nwankwo (2015) reported that students' attitudes toward agriculture strongly affect their interest in agricultural programmes and related career pathways. When agriculture is viewed as relevant, innovative, and opportunity-oriented, students are more likely to engage actively and consider agripreneurship as a viable livelihood option (Owoade, 2020).

Landmark University, Nigeria, established with a strong agrarian philosophy, integrates compulsory practical agriculture into its curriculum to build entrepreneurial and technical competencies among undergraduates. The success of such institutional programs, however, is largely determined by the nature of the perceptions and interactions of students with these practical experiences. There is little empirical data on undergraduate perceptions of the value of practical agriculture in such a setting and specifically in terms of the participation barriers of the resource availability, mentorship, academic load, and alignment of aspirations. The knowledge of these factors is critical in enhancing experiential learning systems and processes, curriculum delivery, and the preparation of graduates to play a significant role towards achieving sustainable agriculture, food security and rural development targets that meet SDGs 1 and 2. Hence, the current research was conducted to determine the perceptions of the undergraduates on the issue of practical agriculture, to establish the extent of their involvement, and to determine the most important things that they consider when participating in the practical agricultural education.

METHODOLOGY

The research was carried out in Landmark University, Omu-Aran, in the Irepodun Local Government Area in Kwara State, Nigeria. Living Faith Church Worldwide founded the university in 2011 and is an agrarian-based institution that has a call to ensure agricultural transformation in the form of education, innovation and development of entrepreneurship. Practical agriculture is a mandatory part of the curriculum, meaning that students are subjected to crop production, livestock management and other field-based activities that aim at giving them hands-on experience and acquisition of skills. All undergraduates pursuing the universal practical course on agriculture that is compulsory at the university, regardless of their field of study, formed the population of the study. The sampling method used was stratified in order to have a proportional representation of students at the four colleges, namely, Agricultural Sciences, Business and Social Sciences, Pure and Applied Sciences, and Engineering. Out of a sample size of 329 (10%) out of 3281 students (the total population of undergraduates of the institution) was sampled proportionally. Simple random sampling was used to select respondents within each stratum in order to achieve the research objective and reduce sampling bias. As a study variable, a well-designed questionnaire was used to gather primary data that consisted of socio-demographic variables of the students, perceptions of practical agriculture, participation level and the factors that limit participation were used to collect the data. The tool was a combination of closed-ended Likert-scale questions and categorical questions about the research objectives. Before the questionnaire was administered, it was also face validated by subject-matter experts in Agricultural Economics and Extension in order to ascertain that the questionnaire is clear, relevant, and contains enough content. The instrument was tested with the help of the test-retest method in order to check the reliability of the instrument. The collected data were analysed through descriptive and inferential statistical methods. The frequency, percentage, mean, and standard deviation were selected to present descriptive statistics to summarise the characteristics and the level of perception of respondents. The underlying dimensions that affected the engagement of students in practical agriculture were identified using the Exploratory Factor Analysis based on Principal Component Analysis (PCA) with oblimin rotation. To ensure the appropriateness of the data for factor analysis, the Kaiser- Meyer-Olkin (KMO) and Bartlett Test of Sphericity measures were used.

RESULTS

Perception of practical agriculture

Table 1 shows that the overall high valuation of practical agriculture is observed and the endorsed highest were around experience, opportunity, and enterprise. In particular, there was a high ranking of the hands-on opportunity of real-life farming challenges (M = 4.42, SD = 0.72), then entrepreneurial skills in agribusiness (M = 4.40, SD = 0.82), and perceived employment opportunities in the growing agricultural industry (M = 4.37, SD = 0.78). This tendency means that students primarily perceive practical agriculture not as an abstract academic imperative but as an instrumental, competence, productivity and income-generating activity. The finding aligns with the larger argument of experiential learning that learning-by-doing enhances skill development and competence that is relevant to employment (Kolb, 1984), and with the empirical data that active and applied learning is more effective than passive learning in improving student outcomes (Freeman et al., 2014).

Table 1. Perception of practical agriculture

Variables	Mean	Standard Deviation
Practical agriculture education enhances my employability after graduation	4.0424	1.02166
The modules taught in practical agriculture match the needs of the job market	3.8788	0.90448
My peers will consult and respect me if I obtain a degree in agriculture	3.5364	1.08045
Practical agriculture provides hands-on experience needed for real-world farming challenges	4.4212	0.71978
The skills acquired in practical agriculture can be applied to other fields beyond farming	3.8606	1.06561
It helps me acquire entrepreneurial skills for agribusiness	4.4000	0.81625
Practical agriculture will help me become self-employed after graduation	4.2273	0.88890
Practical agriculture is suited to my abilities and career aspirations	3.4273	1.22133
I believe there are employment opportunities in the growing agricultural sector	4.3667	0.77701
I want to learn agricultural innovations to develop sustainable farming practices.	3.9697	1.06861

There was also a high level of agreement among students that practical agriculture can help them to be self-employed upon graduation (M = 4.23, SD = 0.89) and improve employability (M = 4.04, SD = 1.02). These results are consistent with previous education research in Nigeria that suggests that good practical agriculture education is linked to better work preparedness and self-employment orientation (Okelola & Adeyolanu, 2024). In the same way, the moderately high score on transferability of skills outside of farming (M = 3.86, SD = 1.07) supports the perspective that practical agriculture imparts generic skills that facilitate intersectoral mobility - a perspective also supported by practical training research that students find value in farm practical exposure but wish it to be more organized and extensive across units (Adefalu et al., 2021).

Nevertheless, two outcomes lead to the critical perception frictions that may reduce the sustained engagement despite the student recognition of benefits. To begin with, the claim that modules are aligned with job-market requirements was only moderately agreed with (M = 3.88, SD = 0.90), which suggests that students see partial, but not full, correspondence between the practical content and the current labour-market demands. Second, the least rated was aspiration/fit (suited to my abilities and career aspirations; M = 3.43, SD = 1.22), and a moderate score was peer respect (M = 3.54, SD = 1.08). These items have relatively large standard deviations, which means that they are heterogeneous: although a large number of students feel fit and social value, a significant proportion of students feel doubt, stigma, or poor identity alignment. This aspiration-identity difference is reminiscent of broader Nigerian youth data that agriculture could be considered a hard vocation and not as appealing as other avenues, especially when agriculture is not presented as modern, technology-driven, and socially desirable (Obayelu & Fadele, 2019). It is also consistent with the results that misperceptions and social discourses may influence the readiness to engage even in the presence of opportunities (Owoade, 2020).

Misconception about agriculture

Table 2 shows that the respondents did not accept the stereotypes about agriculture to a large extent. The mean scores were always low on such statements like agriculture is only in rural areas (M = 1.75, SD = 1.04), farming is only in the less educated (M = 1.59, SD = 0.96), agriculture is a low-status occupation (M = 1.75, SD = 1.07), and agricultural work is only in the less educated (M = 1.65, SD = 0.99). Taken together, these reactions indicate a decreasing acceptance of conventional stigma discourses and an increasing awareness of agriculture as a valid professional and economic avenue. This trend is significant since previous youth-related research in Nigeria often reports status issues and aspiration mismatch as limitations to the decision to pursue agriculture as a profession (Obayelu & Fadele, 2019; Owoade, 2020). The relatively higher rejection of these stereotypes in the present sample could be due to the institutional orientation of Landmark University and the exposure to practical agriculture as a structured learning experience.

Nevertheless, two myths demonstrate lingering doubt instead of strong opposition. To begin with, the respondents were not as dismissive of the statement that modern technology has rendered agriculture less relevant (M = 2.10, SD = 1.29), which could be an indication of incomplete knowledge of how digitisation is transforming farm decision-making instead of making agriculture less relevant. As a matter of fact, agriculture is becoming more and more defined by the innovations of Agriculture 4.0, i.e., IoT-based sensors, data analytics, and precision technologies that facilitate real-

Table 2. Misconceptions about agriculture

Variables	Mean	Standard Deviation
Agriculture is only for people in rural areas	1.7455	1.04113
Agriculture is not a financially rewarding career	1.7333	0.99929
Farming is only for the less educated	1.5866	0.96237
Agriculture is a low-status profession	1.7545	1.06779
Modern technology has made agriculture less relevant	2.1000	1.28553
Agriculture cannot be practiced in urban areas	1.9455	1.10404
Agriculture is not a field for innovators and entrepreneurs	1.6242	1.03349
Agriculture work is boring and repetitive	2.2394	1.33697
Agricultural work is only for those who cannot get a white-collar job	1.6545	0.99332
Practical agriculture requires a lot of land	2.7909	1.34884

time monitoring of soil conditions and crop performance and enhance resource efficiency (FAO, 2025).

Second, the statement that practical agriculture needs much land got the most misconception score (M = 2.79, SD = 1.35), as well as that agriculture work is boring and repetitive (M = 2.24, SD = 1.34). These findings indicate that although students do not subscribe to status-based stereotypes, there is still a partial constraint-based framing of agriculture as land-intensive and routine. This is becoming less consistent with modern trends in urban and controlled-environment agriculture, where modular hydroponics, vertical farming, and other space-saving systems allow production in small areas, including urban areas (Senthamizh & Anbarasan, 2025).

Exploratory factor analysis of perceptions and constraints

To determine the latent dimensions that support the perceptions and engagement of students in practical agriculture, an exploratory factor analysis was performed using Principal Component Analysis (PCA) with oblimin rotation, which permits the extracted components to correlate. The sampling adequacy and factorability were satisfactory (KMO = 0.809) and the test of sphericity was significant (kh2(190) = 2721.78, p <.001), which confirmed that the inter-item correlation structure was suitable to extract factors. One five-component solution was retained and explained 62.55% of the total variance, which means that the extracted structure explained a significant portion of shared variance among the observed items.

The rotated solution (Table 3) generated conceptually consistent components that were aligned with the logic of measurement in the study. Factor 1 (Perceived career value and personal relevance) combined items reflecting employability, transferability of skills, perceived social recognition, and aspiration-fit (loadings 0.66-0.88), which is the extent to which students perceive practical agriculture as valuable and relevant to their future. Factors 2-4, in contrast, represented constraint domains that can prevent participation despite high perceived value. Factor 2 (Institutional resourcing and technology deficits) was a measure of inadequate equipment, poor adoption of modern technology, and inadequate financial support (loadings 0.50-0.66). Factor 3 (Mentorship and instructional support gaps) grouped instructor availability, mentorship, and access to demonstration resources (loadings 0.78-0.87). Factor 4 (Academic workload and time constraints) represented competing academic demands that restrict time to be spent on practical activities (loadings 0.60-0.72). Collectively, these constraint-related elements offer a differentiated explanation of why participation can be inhibited by resource shortages, ineffective instructional/mentorship support, and time pressure.

Factor 5 (Status/aspiration misfit: inverse opportunity orientation) was defined by items that defined opportunity- and innovation-oriented perceptions, but these measures were negatively loaded (0.63 to 0.81). Substantively, the negative loadings suggest that students who strongly support agriculture as opportunity-rich and innovation-driven are less prone to status/

Table 3. Rotated Factor Matrix Showing Components Affecting Students' Perception and Participation in Practical Agriculture

Factor	Label	Key indicators	Loading range	Interpretation
1	Perceived career value and personal relevance	Employability after graduation; peer respect/recognition; skills transferable beyond farming; suited to abilities and career aspirations	0.66–0.88	Higher scores reflect stronger belief that practical agriculture is valuable, career-relevant and personally meaningful, which should support participation.
2	Institutional resourcing and technology deficits	Lack of modern equipment/facilities; limited financial incentives/scholarships; poor integration with modern technology	0.50–0.66	Higher scores reflect structural/infrastructural barriers that reduce the quality and feasibility of participation.
3	Mentorship and instructional support gaps	Inadequate number of trained instructors; lack of mentorship opportunities; limited access to demonstration farms/ experimental plots	0.78–0.87	Higher scores indicate weak human support and learning scaffolding, likely reducing sustained engagement.
4	Academic workload and time constraints	High workload from other courses limiting time for practical agriculture *(plus any time-related cross-loaders, if applicable)*	0.60–0.72	Higher scores reflect crowding-out effects, students want to participate but time and academic pressure constrain involvement.
5	Status/aspiration misfit (inverse opportunity orientation)	Hands-on experience; entrepreneurial skills; self-employment potential; employment opportunities in agriculture; interest in innovations for sustainable practices	0.63–0.81 (negative)	These items loaded negatively, meaning that stronger endorsement of opportunity/ innovation is associated with lower status/ aspiration misfit. Practically: this factor captures a stigma/misfit dimension, where *opportunity orientation* operates in the opposite direction.

Note: Extraction Method: Principal Component Analysis, Rotation Method: Oblimin with Kaiser Normalisation, Only Loadings ≥0.30 are reported. Negative loadings show inverse relationships. KMO = 0.809; Barlett's Test: χ^2 (190) = 2721.78, p < 0.001, Total Variance explained by the five components: 62.55%

aspiration misfit or stigma-based disengagement. To use the factor in further modelling and hypothesis testing, the factor was thus considered a misfit/stigma dimension, and sign-flipping (or reverse-coding) was used such that higher factor scores always indicate higher misfit/stigma.

The given component correlation matrix in Table 4 presented some initial evidence in the context of H01. In particular, the perceived value component (Factor 1) was moderately negatively correlated with the misfit/stigma component (Factor 5; r = 0.498), which means that a higher perceived value of practical agriculture is likely to be accompanied by lower status/aspiration misfit. This correlation justifies the next step of formal hypothesis testing to establish whether the observed relationship is statistically significant and whether other elements of the constraint (institutional resourcing/technology deficits, mentorship gaps, and academic workload/time constraints) have systematic relationships with perceived value.

Table 4. Component Correlation Matrix

Component	1	2	3	4	5
1	1	0.052	–0.022	–0.105	–0.498
2	0.052	1	“0.203	0.311	0.017
3	–0.022	–0.203	1	–0.148	0.046
4	–0.105	0.311	–0.148	1	0.081
5	–0.498	0.017	0.046	0.081	1

Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalisation.

DISCUSSION

The results show that there is an overall positive attitude of the undergraduates towards applied agriculture, especially in terms of its practical exposure, its orientation towards entrepreneurship and its prospects of employment. This kind of orientation is preferable from an agricultural extension perspective, given that it indicates that the students are not perceiving practical agriculture as an obligatory course requirement, but as an avenue to competence building and livelihood preparedness. This is consistent with experiential logic of learning, as repeated learning-by-doing improves perceived utility and competence (Kolb, 1984), and with the fact that active and applied learning positively affect student outcomes and involvement (Freeman et al., 2014). Student satisfaction and learning experience have been prioritised in such assessments of higher education programmes in the same way, and this is why capacity-building intervention should be designed to support skill-focused learning through supportive institutional processes (Tripathi et al., 2024).

Aspirational-fit and peer recognition items were less stable and more dispersed, indicating that although quite a number of students find the concept of usefulness of practical agriculture, there is still a group that is more hesitant to connect the concept of agriculture to themselves and their career opportunities of choice. Other related studies on youth engagement indicate that the decision to participate in livelihoods involving agriculture is deeply influenced by aspiration and future orientation, with the propensity to abandon agriculture in favour of different opportunities that seem to be less lucrative or oriented towards the preferred futures (Sai et al., 2024). Career-aspiration research also reveals evidence that hesitation and perception can affect the career preferences and assurance of students, which means that agricultural education associated with extensions needs to convey professional paths and social usefulness that are credible (Kriti et al., 2025).

Another extension implication is the misconception profile. The fact that generally students rejected the old stereotypes of agriculture only being rural, less educated, or inherently of low status, supports the idea that stigma can be negated successfully with the help of structured exposure and institutional focus. However, a greater correspondence to the concept of land-intensity and repetitiveness suggests that even the fall of status-based myths does not lead to the disappearance of constraint-based ones. In the case of extension education, this dictates that practical learning should be able to depict on the surface the modern agriculture protected cultivation, small-space production systems, and technology-facilitated decision making so that students can easily see the way agriculture can be innovative, scalable, and professionally differentiated.

The factor structure is also a good diagnostic that can be used to strengthen participation conditions. The dimensions obtained divide the perceived value and separate institutional resources/technology, mentorship/instructional support, academic workload/time pressure, and aspiration misfit domains that represent the success of the extension learning settings when motivation is coupled with facilitating support. Analogous student-centred research shows that the results of skill development require the help of structured training, such as communication and professional skills, to supplement the technical education (Sikdar & Prakash, 2025), as well as the fact that modern higher education tends to demand more widespread consideration of skills of the 21st century and less disciplinary knowledge (Yadav & Vatta, 2025). The research on student time-use behaviours highlights that poor time management and procrastination may undermine learning engagement and therefore takes a strong position in advocating controlled and properly planned practical time blocks (Malavika et al., 2025).

CONCLUSION

The practical agriculture at the Landmark University was a high-value experiential learning course, since students were fully linked with practical agriculture to real-life skills, entrepreneurship preparedness and job opportunities. Simultaneously, the relatively low scores on aspiration-fit and peer recognition suggested that practical agriculture did not necessarily turn out to be career-defining to all students; some students still abstained to consider agriculture to be identical to their own career goals or self-perception. Though students were much more open to the old stigma-based stereotypes, the fact that the beliefs like the fact that agriculture takes up a lot of land and that it is boring/repetitive indicated that the sector was still conventionally perceived in part. Therefore, the programme’s next improvement needed not only more practical sessions, but better-designed practical exposure to smart, modern, technology-enabled and vertical agriculture, linking practical tasks to clear agribusiness and innovation pathways, and strengthening mentoring and career guidance.

DECLARATIONS

Ethical approval and informed consent: Informed consent was ensured from the respondents of the study during the course of the research. Also, the consent from administration of the Landmark University, Omu-Aran, regarding the conduct of the study was sought.

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 personal 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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Seminar Report

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026, (189-191)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Report on Indian Society of Extension Education National Seminar-2026 "*Digital Technologies for Sustainable Food Systems and Atmanirbhar Bharat*" held at Goa, India during 29-31 January, 2026

India stands at a pivotal juncture where agriculture must evolve beyond traditional paradigms to embrace intelligent technologies that can ensure sustainability, inclusivity, and enhanced productivity. Agricultural extension services, once reliant solely on human intermediaries and field demonstrations, now have the potential to be revolutionised through digital tools, AI-driven decision-making, precision agriculture, and Internet of Things (IoT) applications. However, integrating these technologies into extension education demands critical reflection, strategic policy design, and cross-sectoral collaboration.

The ISEE National Seminar 2026 on *Digital Technologies for Sustainable Food Systems and Atmanirbhar Bharat* aimed to bring together academia, research institutions, policymakers, grassroots practitioners, Agri Tech startups, and farmers to explore how intelligent technologies can meaningfully transform agricultural extension education and services was inaugurated by Shri **Digambar Kamat**, the Minister for Public Works (PWD) in Goa, on **January 29, 2026**. It recognises that while access to technologies has expanded, their effective use is hindered by digital divides, contextual misalignments, and knowledge asymmetries. The event focused not merely on showcasing innovations but on building inclusive, scalable models that connect traditional agricultural wisdom with contemporary digital tools. Organised in collaboration with University of Agricultural Sciences, Dharwad; Goa College of Agriculture, Goa; ICAR-Agricultural Technology Application Research Institute, Bengaluru and Pune; Goa Chambers of Commerce and Industries, Panjim, Goa, and Centre For Multi-Disciplinary Development Research (CMDR), Dharwad, the seminar served as a vibrant platform for senior extension professionals, policy leaders, academicians, researchers, and students to deliberate on the transformative role of digital technologies in agriculture and allied sectors. The event witnessed keynote addresses, lead papers, oral and poster presentations reflecting strong engagement across generations of extension professionals. The seminar covered nine major themes and provided a platform for deliberations on the achievements and a way forward by more than 250 scientists and delegates during three-day deliberations. A total of 310 abstracts were received, which were published in the form of a book of abstracts containing 460 pages. The major take-home emerged from presentations and discussions:

Intelligent Technologies in Digital Extension for Next Generation Agriculture–Progress and Possibilities

The deliberations emphasized the growing potential of intelligent technologies in next-generation agriculture and underscored the need for systematic capacity building of extension personnel, along with effective integration of these intelligent systems within public extension institutions for wider reach and impact.

Digital Extension and Education to Empower Farmers for *Atmanirbhar Bharat* – Challenges and Opportunities

The discussions focused on key challenges such as digital literacy, access gaps, language localisation, and last-mile connectivity, while also exploring emerging opportunities in digital advisory services. The deliberations emphasised the need to strengthen digital extension curricula and promote blended advisory models combining digital and conventional approaches to enhance farmer empowerment and inclusiveness.

Digital Tools to Ensure Sustainable Food Systems–Opportunities and Challenges

The deliberations highlighted the role of digital tools in enhancing transparency, improving resource efficiency, and supporting sustainable and nutrition-sensitive agricultural practices. The discussions emphasized the adoption of digital technologies for systematic monitoring and assessment of sustainability indicators across food systems.

Opportunities and Advances in Digital Extension and Education – Global and Local Experiences

The deliberations highlighted the diversity of global innovations and emphasized the importance of contextualizing and adapting these best practices to local agro-ecological conditions and socio-economic realities to enhance their effectiveness and scalability.

Digital Applications in Start-ups and Entrepreneurship Development for *Atmanirbhar Bharat*

With emphasis on agri-startups, incubation ecosystems, fintech innovations, agritech platforms, and market-linked digital solutions supporting entrepreneurship development, the deliberations

highlighted the growing role of digital applications in fostering innovation-led enterprises and underscored the importance of strengthening collaboration among academia, industry, and start-ups to promote rural entrepreneurship and contribute to Atmanirbhar Bharat.

Gender Concerns in Application of Digital Tools – Achievements and Action Points

The discussions focused on issues related to digital inclusion of women farmers, access to digital devices, relevance of content, and skill development. The deliberations emphasized the need for gender-responsive digital extension strategies and targeted capacity-building programmes to ensure equitable access and effective use of digital technologies.

Intelligent Technologies and Sustainable Food Systems

Covering smart farming systems, data-driven planning approaches, and sustainability analytics for strengthening food systems, the deliberations highlighted the potential of intelligent technologies in improving efficiency, resilience, and sustainability across agricultural value chains, and emphasized the integration of these technologies for effective and sustainable food system management.

The deliberations further highlighted the role of digital climate advisory services, early warning systems, weather-based decision support tools, and carbon-smart practices in strengthening adaptation, mitigation, and risk management. The sessions also emphasized the importance of price forecasting, e-NAM, digital marketing platforms, blockchain, and real-time market information systems in enhancing farmers' market participation through reliable and transparent digital intelligence. Further, discussions on quality control and food safety underscored the use of digital traceability tools, sensors, block-chain, and ICT-enabled quality assurance systems to improve food safety standards, transparency, and consumer confidence across agri-food value chains.

The ISEE Awards

Various awards instituted by the Indian Society of Extension Education were conferred on the extension professionals/ educationists in recognition of their meritorious works & services to the following recipients:

Life Time Achievement Award

- Dr. S. Prabhu Kumar, Former Director, ICAR-ATARI, Ludhiana

Dr. D. K. Mishra Memorial Award

- Dr. Sheikh N. Meera, Director, ICAR-ATARI, Hyderabad

Dr. K. N. Singh Memorial Award

- Dr. R. Venkattakumar, Principal Scientist & Head, Division of Extension Systems Management (XSM), ICAR-NAARM, Hyderabad

Dr. Y. P. Singh Memorial Award

- Dr. Milind C Ahire, Professor, Department of Agricultural Extension Education, MPKV, Rahuri
- Dr. Joginder Singh Malik, Professor, Professor, Extension Education, CCSHAU, Hisar

Dr. O. P. Dahama Memorial Award

- Dr. Kalyan Ghadei Professor & Head , Institute of Agricultural Sciences, Department of Agricultural Extension Banaras Hindu University, Varanasi Uttar Pradesh
- Dr. Surya Rathore, Principal Scientist, ICAR-NAARM, Hyderabad

Dr. G. S. Vidyarthi Memorial Award

- Dr. Alok Kumar, Principal Scientist & Head, Division of Social Sciences, ICAR-Central Potato Research Institute, Shimla-171001, H.P.

ISEE Fellow Award

- Dr. Umesh Ramkrishna Chinchmalatpure, Deputy Director, Directorate of Extension Education, Dr. Panjab Rao Deshmukh Krishi Vidyapeeth, Akola-444104, Maharashtra, India
- Dr. M. Ramasubramanian, Professor, Professor (Agricultural Extension), Nammazhvar Organic Farming Research Centre, Tamil Nadu Agricultural University Coimbatore-641003
- Dr. Itigi Prabhakar, Assistant Professor, Assistant Professor (Agricultural Extension), Department of Social and Allied Sciences, College of Horticulture, UHS Campus, GKVK Bengaluru-650056, Karnataka
- Prof. K. K. Jha, Professor & Head, Professor & Ex Head, Department of Agricultural Extension Education, SAS, Nagaland University.
- Dr. Patil Sandip Dhanaraj, Assistant Professor, Govt. College of Agriculture, Muktainagar, Tal. Muktainagar, Dist. Jalgaon-425306, MS, India
- Dr. S. R. Bishnoi, Scientist, ICAR Scientist, Agril. Extension, ICAR-IARI, New Delhi
- Dr. Daya Ram, Professor (Extension Education) College of Agriculture Central Agricultural University, Imphal-795004 Manipur, India
- Dr. Brijesh Kumar Gupta, Assistant Professor (Senior Scale), Department of Agricultural Extension, College of Agriculture, Banda University of Agriculture and Technology, Banda-210001, Uttar Pradesh, India
- Dr. D. K. Bose, Principal Scientist, SHUATS, Prayagraj, Uttar Pradesh, India
- Dr. P. K. Tiwari Assistant Professor, MBD CHRS, GPM Pin - 495117, Chhattisgarh
- Dr. D. Puthira Prathap, Principal Scientist (Agricultural Extension) #3, ICAR-Sugarcane Breeding Institute, Coimbatore – 641 007, Tamil Nadu, India
- Dr. Vipan Kumar Rampal, Professor & Head, Department of Extension Education, PAU, Ludhiana, Punjab, India

Young Scientist Award

- Dr. Rahul Kumar Singh, SMS (Agril. Extension), Krishi Vigyan Kendra, Varanasi-221307, Uttar Pradesh, India
- Dr. Anil Kumar Rohila, Assistant Professor (Agril. Extension Education), Extension Education Institute, CCS Haryana Agricultural University, Nilokheri-132117, Haryana

- Dr. Moumita Dey Gupta, Programme Coordinator, and Subject Matter Specialist (Agricultural Extension), WBCADC Krishi Vigyan Kendra, Sonamukhi, Bankura-722202, West Bengal
- Dr. Pankaj Kumar Ojha, Associate Professor, Department of Agricultural Extension, College of Agriculture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh
- Dr. Usha Das, Scientist, Agricultural Extension, ICAR- Indian Institute of Wheat and Barley Research, Karnal-132001, Haryana
- Dr. Satya Prakash, Associate Professor (Agril. Extension), Department of Agricultural Extension Education, PGCA, RPCAU, Pusa, Samastipur, Bihar
- Dr. Manohar Bhaurao Dhadwad, Associate Professor (Agril. Extension), Department of Agricultural Extension Education, Mahatma Phule Krishi Vidyapeeth, Rahuri, District Ahilyanagar-413722 , Maharashtra, India
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- Dr. J. B. Dobariya, Senior Scientist and Head, Senior Scientist and Head, Krishi Vigyan Kendra, Navsari Agricultural University, Ahwa Road, NAU Campus, Waghai, Dist. Dangs,
- Dr. Dipika Hajong, Scientist Sr Scale, Scientist Senior Scale (Agricultural Extension) Division of TOT and Training, CAZRI Road, Jodhpur-342003, Rajasthan

Best KVK Scientist Award

- Dr. G. Prasad Babu, Sr Scientist & Head, Senior Scientist & Head ICAR-NIRCA-Krishi Vigyan Kendra-Kandukur Prakasam Dist-523105, Andhra Pradesh
- Dr. Vairagar Vishal Gulab, Sr Scientist & Head, Krishi Vigyan Kendra Mohol Tal Mohol Dist Solapur-413213, Maharashtra, India
- Dr.Sudhir Keshavrao Deshmukh, Subject Matter Specialist, Extension Education-KVK Washim, Mahananda Colony, Loni Road, Risod Tq. Risod Dist. Washim-444506, Maharashtra, India
- Dr. Jagdeesh Morya, Scientist, Scientist Krishi Vigyan Kendra Jhabua, RVSKVV, Gwalior, Madhya Pradesh, India
- Dr. Surya Kanta Roy, Scientist, ICAR-ATARI, Kolkata, Bhumi Vihar Complex, 1st Cross Rd, GB Block, Sector 3, Bidhannagar, Kolkata-700097, West Bengal
- Dr. (Smt) Geeta Singh, Scientist, Agril. Extension KVK, Dindori-481880, Madhya Pradesh, India
- Dr. Narendra Prasad, Subject Matter Specialist, Krishi Vigyan Kendra, Shahjahanpur, Village & Post-Niyamatpur, Shahjahanpur-242001, Uttar Pradesh, India
- Dr. Sarvesh Kumar, Assistant Professor, Deptt. of Agril Extension, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh

General impressions

The seminar was attended by students, researchers, academicians, scientists, extension professionals, NGOs, FPOs, financial institutions, research organizations and policy makers, etc. and overall the national seminar provided an excellent platform for extension professionals and professional engagements who came from all over the country. The presence of Dr. Ashok Dalwai, former CEO, National Rainfed Area Authority, MOA & FW, GoI, Dr. Ranjay Kumar Singh, ADG (Agril Extension), Dr. V. V. Sadamate (former advisor, Planning Commission), Dr. M. M. Adhikary, Dr. G. Eswarappa, Dr. Veerbhadaria, Dr. P. L. Patil (VC, UAS Dharwad), Dr. U. S. Gautam (Former DDG and President, ISEE), and Ms. Pratima Dhond (President, GCCI), Dr Mahesh Patil, Chairman of Agri and Food Committee helped to shape the seminar proceedings. Important issues for professional improvement were deliberated in the Annual General Body Meeting held on 29.01.2026 evening, and the decisions that would further strengthen the ISEE functioning were arrived at.

Indian Journal of Extension Education
Vol. 62, No. 2 (April–June), 2026
ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

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The **ABSTRACT** is a mini version of full paper. Abstract should contain year of study, brief account of principal objective(s), methods used, principal results, and main conclusion in understandable form so that the reader need not refer to the whole article except for details.. It should be written in simple past tense, in complete sentences, limited to 150-200 words. It should not have references to literature, illustrations, and tables. The year of research endeavor must be part of it.

The **KEYWORDS** best describes the nature of the research after the abstract. Provide a list of 5 to 8 keywords (indexing terms). The first letter of each keyword should be in upper case or capital letter. As major words in the title are not used in the subject index, appropriate words from the title (or synonyms) should be listed as keywords.

The **INTRODUCTION** provides rationale for the study, written in present tense, refers to established knowledge in literature. It should contain nature and scope of the problem, review of relevant literature, hypothesis, approach and justification for this approach. No trade name should be used and Industrial products should be referred to by their chemical names (give ingredients in parentheses) at first mention. In the absence of a common name, use the full name or a defined abbreviation, in preference to a trade name. It should be between 450-500 words.

The **METHODOLOGY** describes what was done- experimental model or field study. It should be an exhaustive one (in logical order, sufficient details to reproduce the procedure) without tables and figures (approximately 300-400 words). The subheadings must be avoided as far as possible in methodology. It should be written in simple past tense. Where the methods are well known, the citation of standard work is sufficient. All modifications of procedures must be explained. Experimental materials and statistical models should be described clearly and fully. Calculations and the validity of deductions made from them should be checked and validated. Units of measurement, symbols, and standard abbreviations should conform to international standards. Metric measurements are preferred, and dosages should be expressed entirely in metric units (SI units). Give the meaning of all symbols immediately after the equation in which they are first used.

The **RESULTS AND DISCUSSION** should be written separately and avoid repetition of the results in the discussion.

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Published by Dr. U.S. Gautam, President, Indian Society of Extension Education, Division of Agricultural Extension, ICAR-IARI, Pusa Campus, New Delhi-110012
Printed by ACS Publisher, Delhi on behalf of Indian Society of Extension Education, New Delhi