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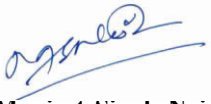
EDITORIAL

Global agriculture is experiencing significant localised shifts due to erratic weather patterns and shifting climate conditions. Argentina's 2025/26 wheat harvest is expected to reach a record of between 27.1 and 27.8 million tons, exceeding the previous 2021/22 record of 22.4 million tons by up to 25%. The Kharif season in India has been the most disrupted in recent years due to an erratic and prolonged southwest monsoon (108% of the long-period average) and October led to widespread submergence, fungal outbreaks, and nutrient leaching in crops like cotton, soybean, and maize. Rising temperatures and humidity in late 2025 have accelerated the spread of invasive pests like the fall armyworm and locusts, as well as fungal diseases such as wheat rust. Reports in 2025 highlight that elevated atmospheric CO_2 levels are actively reducing the concentrations of protein, iron, and zinc in staple crops like wheat and rice, threatening food security for vulnerable populations. The agricultural sector faces a "perfect storm" of rising inflation and economic stagnation, leading to flat commodity prices and lower farm incomes despite higher input costs.

The current issue (January-March, 2026) comprises a total of 37 manuscripts, including eight research tools, seven research notes, and twenty-two full-length research papers. Social Network Analysis of Role of Institutions in Agriculture and Food Security; Understanding Ecology–Economy Interface; Unveiling Regional Disparities in Makhana Farming; Attitude towards NGOs; Effect of Soybean Digital Farmer Field School; Bibliometric Analysis of Global Research on Nutraceutical Crop; Socio-Economic Determinants of Agriculture Households in Punjab; Labour Bank-Karshika Karma Sena on the Livelihood of Agricultural Labour Households; Farmers' Perceptions of Genetically Improved G3 Rohu Fish Culture; Big Five Personality Predictors of Career Readiness among Agricultural Graduate Students; Composite Fertilizer Management Index among Major Field Crop Growers; Occupational Health Hazards among Women Fish Vendors; Perceived Training Needs of Farm Women on Modern Crop Technologies; Small-scale Farmers' Willingness to Pay for Extension Services; Farmers' Knowledge on Nutrition and Nutrition-Sensitive Agriculture; Dietary Diversity and Nutritional Status of the Tribal Women; Factors Associated with Perception and Knowledge about Stubble Management; Coverage of Agricultural Issues in Leading Indian Hindi Dailies; Critical Factors Hindering the Millet Entrepreneurial Sector; Marketing Efficiency and Major Constraints of Protected Cultivation; Climate Change Adaptation Strategies among Livestock Rearers; Bibliometric Analysis of Global Research on Digital Platforms in Rural Knowledge Transfer were covered in Research Article section. In the research note section- Perceptions on the Selection of Seed Varieties for Paddy Farming; Factors Influencing Farmers' Adaptive Capacity to Climate Change; Farmer Preparedness and Constraints for Agribusiness Opportunities; Mapping Determinants of Beneficiary Knowledge in TSP; Prioritising Backyard Poultry Bottlenecks; Constraints Faced by Developmental Personnel Concerning Livelihood Programmes and Constraints Affecting the Adoption of Low-Carbon Agricultural Technologies were covered. Additionally, research tools for Entrepreneurial Orientation, Knowledge Test on Papaya Ring Spot Virus Management Practices, Nutrition Literacy Scale, Digital Learning Engagement Scale, Farmers' Attitude scale towards ICT-Based Agro-Advisory Services, Scale to Assess Dairy Farmers' Attitudes toward Climate-Resilient Dairy Farming, AgTech-Enabled Market Access Scale for Hi-Tech Agriculture, and Knowledge Test on Pesticide Safety were included. The Scopus cite score during the quarter increased from 1.7 to 2.1 (https://www.scopus.com/sourceid/21100846015).

I, on behalf of the editorial board, extend my sincere thanks to all those who directly or indirectly assisted the editorial board. We acknowledge the contribution made by the reviewers by including their names. We acknowledge Ms. ACS publisher for maintaining the timeline. All the expert members of the editorial board and willing contributors are sincerely acknowledged. The support extended by the Executive Council is duly acknowledged. Special thanks are extended to Dr. U.S. Gautam, Dr. J.R. Mishra, Dr. Keshava, Dr. Basvaprabhu Jirli, and Dr. Bhanu P. Mishra for their insightful thoughts and guidance.



(Manjeet Singh Nain)
Chief Editor

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Research Article

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Role of Institutions in Agriculture and Food Security: A Social Network Analysis of the Bonda Tribal Communities of Odisha, India

Dwity Sundar Rout[1], Atanu Deb[2], Swati Suman[1], Preetha Bhadra[3], Ajay Kumar Prusty[2] and Avisweta Nandy[4]*

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HIGHLIGHTS

- Social capital, local leadership, and community trust were critical mediators of institutional effectiveness.
- Institutional interventions focused on input delivery but lacked cultural sensitivity and participatory governance.
- Cross-institutional convergence and community-led approaches were essential for building resilient tribal food systems.

ARTICLE INFO

Keywords: Bonda, Agriculture, Food security, Culture, Institution.

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ABSTRACT

The study focuses on the Bonda tribe, a Particularly Vulnerable Tribal Group (PVTG) residing in the ecologically fragile Bonda Hills of Odisha, India. It explores the transformative role of institutions in agriculture and food security across three altitudinally distinct villages, Kadamguda, Badbel, and Andrahal, using a sequential exploratory mixed-method approach. Tools like focus group discussions, participatory rural appraisal, household surveys, and social network analysis were employed to map institutional presence and community interaction. Findings reveal varying levels of social cohesion and institutional embeddedness. Kadamguda demonstrates strong intra-village ties and effective institutional linkages, while Badbel and Andrahal reflect weaker community networks despite broader institutional outreach. The Bonda Development Agency (BDA) emerges as a pivotal actor connecting tribal households with service providers such as Integrated Tribal Development Agency (ITDA), Watershed Support Services and Activities Network (WASSAN), Madhyam, and the Agriculture Department, Government (Govt.) of Odisha. The study highlights that institutional presence alone is insufficient; local leadership, social capital, and community trust critically shape outcomes. For institutions to be effective, 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.

INTRODUCTION

Institutions play a pivotal role in transforming agriculture and ensuring food security, particularly in regions marked by socio-economic vulnerabilities and ecological fragility (Nicoletis et al., 2019; Tambo et al., 2023). Across the globe, institutions ranging from state departments, cooperatives, and non-governmental organisations to grassroots organisations serve as vital channels through which farmers access inputs, credit, knowledge, infrastructure, and markets. (Kindness & Gordon, 2001).The institutions adopt a diverse set of priorities, acknowledging the multifaceted nature of entrepreneurial support (Kademani et al., 2024). Institutions have a synergising effect and effect on common programmes and activities (Singh et al., 2014). Institutions act as

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innovation mediators and facilitators of long-term resilience (Li et al., 2024). Their effectiveness, adaptability, and coordination determine the extent to which marginalised communities are empowered to overcome constraints and achieve food and livelihood security (Reid, 2017). The significance becomes even more pronounced in tribal and remote regions, where structural challenges such as geographic isolation, limited extension outreach, low literacy, and poor infrastructure hinder the flow of development benefits (Yoganandham, 2024; Lahiri et al., 2024). In such settings, institutional interventions serve as transformational mechanisms that bridge the divide between tradition and modernity (Adefila et al., 2024; Su et al., 2023), their ability to engage meaningfully with communities determines the success of agriculture-based livelihood interventions (Rout et al., 2020; Tambe, 2022; Chandegara et al., 2024).

In India, tribal communities continue to face chronic food insecurity despite a range of welfare schemes and agricultural programmes (Patel, 2025; Pindus & Hafford, 2019). Odisha, home to 13 Particularly Vulnerable Tribal Groups (PVTGs) (Das & Bose, 2015), offers a relevant setting to explore the role of institutions in addressing these issues (Panda et al., 2015). Many tribal communities rely on subsistence farming, shifting cultivation (*podu*), and forest-based livelihoods (Prateek & Punia, 2025; Rath, 2015; Hazari et al., 2023), and often integrated farming systems (Suman et al., 2025). These systems, though locally adapted, are increasingly stressed by environmental degradation (Das et al., 2022) and lack of institutional support (Aggarwal et al., 2009). Addressing food security in such areas demands institutions that are locally responsive and culturally appropriate (Brooks & Loevinsohn, 2011; Pothukuchi, 2004; Sari & Muslim, 2024).

The Bonda tribe, residing in the remote hills of Malkangiri district in southern Odisha, represents one such PVTG (Bhoi & Acharya, 2024) that depends on traditional agricultural practices, backyard farming, and non-timber forest products for its livelihoods (Altieri & Koohafkan, 2008; Pandey et al., 2016; Sahoo et al., 2023; Venugopal et al., 2019). Several government and non-governmental institutions operate in the region, including the Bonda Development Agency (BDA) (Anuradha, 2019), Integrated Tribal Development Agency (ITDA) (Bose et al., 2008), Agriculture and Horticulture departments, Govt. of Odisha, and NGOs such as WASSAN (Viswanath, 2021) and Madhyam (Madhyam Foundation, 2024) have introduced millet promotion and nutrition-sensitive farming interventions. However, disparities in outreach, consistency, and cultural integration raise concerns about the actual impact of these efforts on agricultural sustainability and food security (Renzaho & Mellor, 2010; Pavana Kumar et al., 2024). Despite a visible institutional presence, limited research has explored how these linkages function in practice and how communities perceive and interact with them (Kilpatrick et al., 2003).

METHODOLOGY

The study was conducted in the Bonda Hills of Khairaput block in Malkangiri district, Odisha, where the Bonda tribe, a Particularly Vulnerable Tribal Group (PVTG), resides in geographically isolated and culturally distinct hilltop villages. A sequential exploratory mixed-method research design was adopted, in which qualitative insights gathered during the initial phase guided the development of quantitative tools. The study area was purposively selected due to its ecological diversity and socio-cultural uniqueness. Three villages (hamlets) were chosen to represent varying altitudinal zones (i.e., 900 metres, 1000 metres and 1050 metres respectively) with different levels of resource access and institutional support: Kadamguda (Lower Bonda Hills), Badbel (Middle Bonda Hills), and Andrahal (Upper Bonda Hills). The sampling frame with the population size of 270 was developed in consultation with local stakeholders, including Panchayats, Self-Help Groups (SHGs), and the Bonda Development Agency (BDA), to ensure that different household types (e.g., male- and female-headed, migrant and non-migrant) were represented. A total of 270 households were surveyed, with 90 respondents from each hamlet, allowing for ecological and institutional comparison across the zones. Data collection involved both primary and secondary sources. Primary data were collected using structured household surveys to gather information on agricultural practices, food security, and institutional interactions, Participatory Rural Appraisal (PRA) techniques (Resource map, seasonal diagram, mobility map, Spider diagram for decisive roles) to explore community resource use and seasonal patterns, Focus Group Discussions (FGDs) to capture group-level insights, and Key informant interviews with village elders, institutional representatives and extension officials to understand governance and support structures. Secondary data were sourced from government publications, census and statistical handbooks, academic literature, and reports from organisations like FAO, UNDP, and ICAR to supplement and validate the field findings. Data were analysed using social network analysis (SNA) through UCINET software. This mixed-method and multi-source approach enabled a holistic understanding of how institutions influence agriculture and food security in the context of the Bonda tribal community. It investigates whether institutions are effectively contributing to agricultural transformation and food security or whether systemic gaps remain in their design and delivery. Through a context-specific case study, the research seeks to provide empirical evidence that can guide more inclusive, participatory, and sustainable development strategies in tribal regions.

RESULTS

The sociograms (Figures 1, 2 & 3 along with Table 1) represent the social and institutional network structures for 90 respondents each from the Bonda tribal villages of Kadamguda (Lower Bonda Hill), Badbel (Middle Bonda Hill) and Andrahal (Upper Bonda Hill) (Kumari et al., 2024). Each graph shows that every individual is socially connected and they are linked to key institutions working to promote agriculture and food security.

Network structure and interpretation

Kadamguda (Lower bonda hill): In Kadamguda, the village-level social network exhibits a well-connected institutional ecosystem. The village node, represented in green (Table 1), maintains direct connections with several key institutions, including the Bonda Development Agency (BDA), marked in red, which serves as the central authority for tribal development, the Integrated Tribal

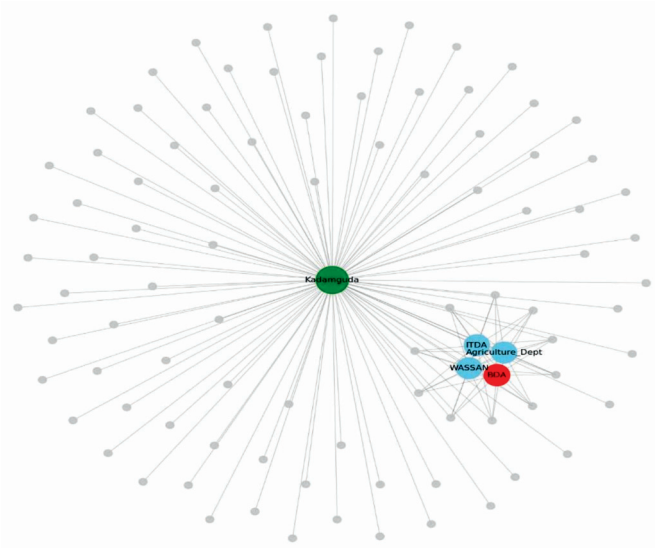

Figure 1. Social Network Analysis: Institutional role in promoting agriculture & ensuring food security in Kadamguda (Lower Bonda Hill)

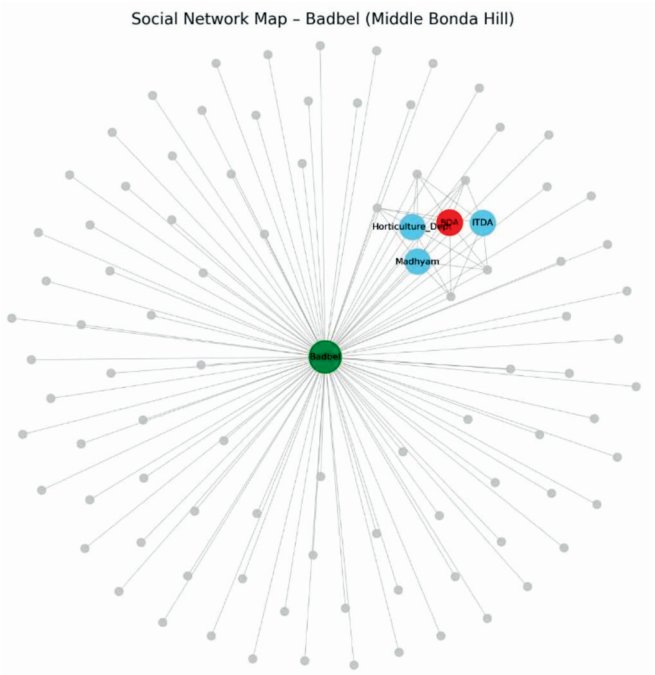

Figure 2. Social Network Analysis: Institutional role in promoting agriculture and ensuring food security in Badbel (Middle Bonda Hill)

Table 1. Nodes and colour coding (Figures 1, 2 & 3)

Colour	Represents
Green	Village centre node (Kadamguda, Badbel, Andrahal)
Red	BDA (Bonda Development Agency)–key institution
Sky Blue	Other institutions (ITDA, Agriculture Dept (Govt. of Odisha), etc.)
Light Grey	Individual respondents (P1 to P90 in each village)

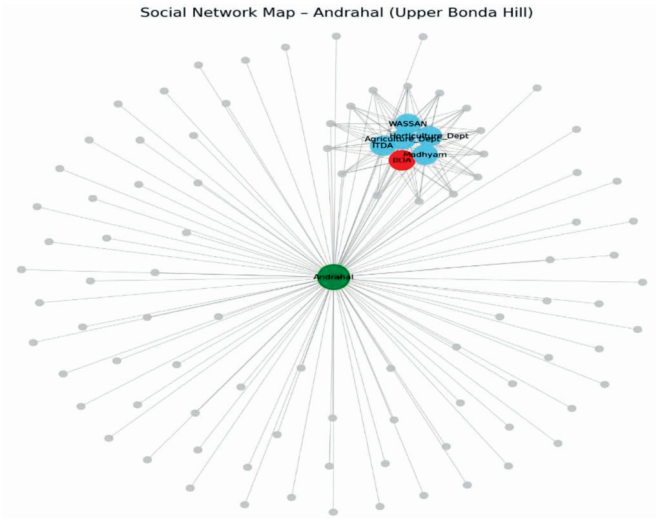

Figure 3. Social Network Analysis: Institutional role in promoting agriculture and ensuring food security in Andrahal (Upper Bonda Hill)

Development Agency (ITDA), responsible for implementing infrastructure projects and various tribal welfare schemes, the Department of Agriculture, which provides seeds, inputs and extension services and WASSAN, a civil society organization focused on promoting sustainable agricultural practices and millet-based farming (Table 2). Within the village, approximately 90 individuals are interconnected in a dense intra-village network, each person maintaining 2 to 5 social links. Many individuals also have direct ties with institutions, especially BDA and WASSAN, indicating active community participation in institutional programmes. This configuration reflects a well-functioning institutional interface, with BDA and WASSAN being particularly embedded in the community social ecosystem, enabling effective outreach and program delivery in agricultural development.

Badbel (Middle bonda hill): The institutional linkages in Badbel include BDA, ITDA, the Horticulture Department, Govt. of Odisha and the NGO Madhyam. The Horticulture Department, Govt. of Odisha is engaged in promoting backyard gardens and fruit tree cultivation, while Madhyam focuses on participatory communication and community awareness (Table 2). The village network comprises 90 individuals who are organised in natural clusters based on kinship and neighbourhood ties. Compared to Kadamguda, the institutional connections in Badbel appear less deep. Although BDA maintains a central role, the Horticulture Department, Govt. of Odisha and Madhyam show limited penetration across the broader population, suggesting either lower community awareness of these institutions or sporadic outreach efforts. This indicates that while there are communication and horticultural interventions present, the overall effectiveness and integration of institutions in Badbel may be constrained by uneven institutional visibility and engagement.

Andrahal (Upper bonda hill): Among the three villages, Andrahal exhibits the highest institutional link density. It is connected to all six key institutions identified in the study, that is, BDA, ITDA, the Departments of Agriculture and Horticulture (Govt. of Odisha),

WASSAN and Madhyam, highlighting targeted outreach efforts, likely due to the village's heightened vulnerability and remote location. Direct institutional ties with villagers are particularly strong for BDA, WASSAN, and Madhyam, reflecting active involvement in programmes such as Self-Help Groups (SHGs), millet promotion projects, and community awareness initiatives (Table 2). However, despite this strong institutional presence, the interpersonal network among the 90 respondents appears relatively loose, indicating lower levels of social cohesion. This fragmentation may be due to physical inaccessibility arising from challenging terrain or other socio-cultural factors. The weaker social ties could hinder collective action and affect the long-term sustainability of externally introduced programs. Nevertheless, institutions like WASSAN and Madhyam seem to be playing crucial bridging roles, helping to connect dispersed individuals and facilitate program participation in the absence of strong community bonding.

Based on the detailed centrality scores, provided for the three Bonda villages, Andrahal, Badbel, and Kadamguda, the role of key institutions and the level of embeddedness of the village node in each network are interpreted and analysed. These scores are organised under Table 2 and offer valuable insights into how information, services, and interventions flow within each community. Andrahal shows a highly institutionalised network, with five institutions equally central in terms of direct connectivity (degree centrality = 0.1146). The presence of both government (BDA, ITDA, Agriculture Department) and non-governmental actors (WASSAN, Madhyam) reflects a strong top-down and lateral outreach. However, the village node itself (Andrahal) has lower centrality, suggesting that while interventions exist, community-level cohesion or leadership engagement may be weak. This highlights a structural dependency on institutions, potentially limiting sustainability unless social capital within the village is strengthened. In Badbel, institutional involvement is more sectoral, focusing on horticulture and communication (Madhyam). Both WASSAN and the Agriculture Dept., Govt. of Odisha have no presence, indicating programmatic gaps in food systems sustainability. While all engaged institutions are equally central in terms of degree, Madhyam has the highest betweenness, implying a significant role in knowledge mediation and communication. The village node itself remains peripheral, pointing to a top-heavy structure where interventions are institutionally driven, but not necessarily community-embedded. Kadamguda reflects a more agriculture-focused network, with strong engagement from BDA, ITDA, Agriculture Dept (Govt. of Odisha), and WASSAN. The Agriculture Department shows the highest betweenness, signifying its influence in bridging various actors and possibly playing a key role in promoting improved cultivation practices and input delivery. Although the village node is not as central as the institutions, it has slightly higher centrality than in Badbel, indicating moderate internal connectivity. The absence of Horticulture and Madhyam suggests a lack of emphasis on nutrition gardens and communication-based capacity building.

Table 2. Centrality scores

Node	Degree Centrality	Betweenness Centrality
Andrahal		
BDA	0.1146	0.0282
ITDA	0.1146	0.0276
Agriculture Dept	0.1146	0.0291
WASSAN	0.1146	0.029
Madhyam	0.1146	0.0272
Andrahal	0.0521	0.0047
Horticulture Dept	0.0	0.0
Badbel		
BDA	0.1146	0.0259
ITDA	0.1146	0.0298
Horticulture Dept	0.1146	0.0294
Madhyam	0.1146	0.031
Badbel	0.0417	0.0027
Agriculture Dept	0.0	0.0
WASSAN	0.0	0.0
Kadamguda		
BDA	0.1146	0.028
ITDA	0.1146	0.0275
Agriculture Dept	0.1146	0.0305
WASSAN	0.1146	0.0249
Kadamguda	0.0417	0.0026
Horticulture Dept	0.0	0.0
Madhyam	0.0	0.0

DISCUSSION

The Social Network Analysis (SNA) of the Bonda tribal villages: Kadamguda, Badbel, and Andrahal, reveals critical insights into how institutional structures, particularly the Bonda Development Agency (BDA), shape the dynamics of agriculture development and food security in remote, vulnerable tribal geographies. The BDA, created specifically under the Integrated Tribal Development framework of the Government of Odisha, emerges as the most structurally central and influential actor in all three sociograms, with consistently high degree and betweenness centrality scores, functioning as a bridge between various departments (e.g., Agriculture, Horticulture, ITDA) and the tribal population. In line with Anuradha (2020) and the PVTG development strategy of the Ministry of Tribal Affairs, Govt of India, BDA's mandate includes ensuring access to basic services, livelihood support, and participatory planning in areas where mainstream institutions often falter due to logistical or cultural disconnects.

Table 3. Cross-village comparison: Institutional reach and network dynamics

Factor	Kadamguda	Badbel	Andrahal
Institutional Diversity	Moderate (4)	Moderate (4)	High (6)
BDA Centrality	High	High	High
Individual-Institution Links	Strong	Moderate	Highest
Intra-village Social Cohesion	High	Moderate	Low to Moderate
Focus Institutions	BDA, WASSAN	BDA, Madhyam	BDA, WASSAN, Madhyam

In Kadamguda, BDA's position as a central node directly connected to a large number of individual respondents signifies effective last-mile institutional delivery, particularly in agricultural input distribution, Public Distribution System (PDS) facilitation, and program awareness. This direct linkage is crucial in tribal regions where formal education is limited and dependency on oral communication and community influence is high. BDA's ability to embed itself within the social fabric enhances the uptake of millet promotion programs, kitchen garden schemes, and input subsidies, corroborating the findings of WASSAN's millet mission reports (Sreekanth, 2021), which highlight institutional proximity as a key factor for tribal farming revival. The role of BDA becomes more complex in Badbel and Andrahal. In Badbel, while BDA retains its formal centrality, the community-institution interface is more fragmented, with limited inter-individual ties. This may reflect a partial engagement model, where institutional presence is visible but community participation is mediated by local leaders or influencers, a phenomenon explored in Narayan's (2002) concept of "mediated trust." In Andrahal, located in the upper reaches of the Bonda hills and known for its socio-geographic isolation, BDA exhibits the broadest institutional connectivity, including collaboration with ITDA, Agriculture Department, WASSAN, and Madhyam. Yet, its impact appears diluted due to sparse community cohesion. This paradox aligns with Scoones' (1998) Sustainable Livelihoods Framework, which argues that institutional capital alone cannot guarantee sustainable outcomes if social capital (community trust, networks, and participation) is weak. The BDA, despite its effort to engage more actors and deliver multi-sectoral support, faces limitations in catalysing behavioural change or collective action without a corresponding strengthening of intra-community bonds.

In all three villages, BDA's influence is amplified or constrained by its relationship with knowledge partners like WASSAN and communication-focused NGOs like Madhyam. In Andrahal, where WASSAN's presence in agroecology and Madhyam's role in participatory awareness are more pronounced, BDA appears to serve as a platform for convergence, facilitating integrated and context-specific interventions. This layered interaction mirrors Klerkx & Leeuwis's (2009) concept of innovation intermediaries, where institutions like BDA become not just service providers but enablers of innovation networks. Yet, the success of such a role depends heavily on how embedded BDA is within the social networks of the community, not just administratively but relationally. The BDA's position as a high-centrality actor must be viewed not just through its quantitative network metrics but through its qualitative role as a boundary-spanner linking formal state mechanisms with informal tribal governance, aligning top-down schemes with bottom-up priorities. When BDA manages to maintain frequent interaction, inclusive planning, and responsive grievance redressal, it strengthens not only programme delivery but also community trust and collective efficacy, essential for food security outcomes. But when its engagement becomes transactional or superficial, even a structurally central position may yield minimal transformative change, as seen in villages with weak horizontal ties.

CONCLUSION

The vital but complex role that institutions play in transforming agriculture and guaranteeing food security was highlighted. The social fabric and community dynamics of each village have a significant impact on the effectiveness of agricultural interventions, even though organisations like the Bonda Development Agency, ITDA, and NGOs like WASSAN and Madhyam are essential, and BDA is the indispensable institutional backbone for agriculture and food security interventions. Cohesive social networks and solid institutional ties have improved programme delivery in *Kadamguda*, however, *Badbel* and *Andrahal e*xhibited limited community engagement despite having a larger institutional presence due to weaker intra-village ties and fragmented social cohesion, hence, coordination ought to be handled by the Bonda Development Agency. ITDA and NGOs like Madhyam and WASSAN may promote social cohesion and offer technical assistance. The agriculture and horticulture departments must make sure that funds are distributed, and encourage farming methods that can withstand climate challenges.

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 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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Ecology–Economy Interface: Understanding Protected Area Awareness Among Forest-Fringe Dairy Farming Communities in Kerala

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HIGHLIGHTS

- Enhancing farmer awareness regarding surrounding protected areas holds a significant role in aligning biodiversity conservation with sustainable agricultural development.
- Dairy farming communities in the forest-fringe areas of Kerala had a medium level of protected area awareness.
- Variables such as gender, education, social participation, and information-seeking behaviour exhibited a strong association with protected area awareness.

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Keywords: Awareness scale, Dairy farmers, Ecology, Human–wildlife conflict, Land use restrictions, Ordinal logistic regression, Protected area.

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ABSTRACT

Dairy farming communities near protected areas (PAs) face challenges such as land-use restrictions, displacement, and human–wildlife conflict, often leading to negative attitudes and hindering sustainable agricultural development. Increasing awareness regarding PAs is essential to improve perceptions and promote coexistence with wildlife. This study assessed PA awareness and its determinants among 300 dairy farmers living near Silent Valley National Park, Wayanad Wildlife Sanctuary, and Karimpuzha Wildlife Sanctuary in Kerala, India, during 2023-24. Awareness was measured using a structured scale, and determinants were analysed with an ordinal logistic regression model. Farmers generally demonstrated moderate awareness of ecological roles but limited understanding of regulatory provisions and livestock-wildlife health concerns. Most farmers from Silent Valley, Wayanad, and the overall sample had a medium level of awareness, while a higher level of awareness was more common in Karimpuzha. Key predictors of awareness included gender, education, social participation, and information-seeking behaviour. The results highlight the need for targeted, gender-inclusive awareness programmes that promote community engagement, strengthen rural education, and encourage proactive information access.

INTRODUCTION

The ecosystem services provided by natural resources such as air, soil, water, wetlands, grasslands, forests, and mountains are crucial for the survival of mankind, and they contribute significantly to the wealth of a nation (Hettiarachchi et al., 2023). Protected areas (PAs), in particular, are essential for the preservation of biodiversity and supporting life systems due to their ecological and cultural significance (Saviano et al., 2018). Protected areas serve as essential foundations of national and international conservation strategies (Mathur et al., 2019). India's tremendously rich biodiversity is safeguarded legally through the Wildlife Protection Act of 1972, by which a network of 1,014 PAs was created throughout the country, comprising National Parks, Wildlife Sanctuaries, Community Reserves, and Conservation Reserves, categorised based on management objectives and differential levels

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of protection (Press Information Bureau, 2025). These PAs are designated to preserve natural ecosystems, provide safe habitats for species, sustain ecosystem balance, and maintain cycles and processes that are often disrupted in intensively managed landscapes (Dudley, 2008). The PAs are surrounded by eco-sensitive zones that serve as buffer regions, where specific activities are prohibited, regulated, or promoted to minimise ecological disturbances (Khanduri & Sharma, 2025).

Designating a region as a PA presents several challenges to local communities, including land use restrictions, potential displacement, and human–wildlife conflict (Maan & Chaudhry, 2019). Specifically, land use zoning limits access to essential forest resources such as fodder, fuelwood, and non-timber forest products on which forest-dependent communities rely for their sustenance (Savita & Kushwaha, 2018). Dairy farming is particularly affected, as livestock grazing is often banned or severely restricted within PAs. Their vulnerability is further exacerbated by human–wildlife conflict (HWC), which can result in economic losses due to livestock depredation, crop damage, property damage, and even human injury (Nyhus, 2016; Meena et al., 2023). Together, these challenges often contribute to negative attitudes among local farming communities towards PAs and low tolerance towards wildlife, which can lead to non-cooperation, illegal grazing, unauthorised extraction of forest resources, encroachment, or even retaliatory actions against wildlife (Karanth & Nepal, 2011).

In India, where agriculture constitutes the backbone of the rural economy and many PAs are located near or within agrarian landscapes, awareness among farmers regarding nearby PAs is critical for balancing conservation goals with socio-economic development (Macura et al., 2011; World Economic Forum, 2020). According to Model of Responsible Environmental Behavior (Hines et al., 1987), pro-environment actions emerge when individuals possess sufficient environmental knowledge, relevant action skills, favourable attitudes, and a strong sense of responsibility. Consequently, farmers who recognise the ecological and economic interdependence of their livelihoods and embrace a conservation-oriented stewardship are more likely to adopt sustainable practices that reduce HWC and promote coexistence (Bhatia, 2021). While several studies in India have examined community and stakeholder attitudes towards PAs (Badola et al., 2011; Karanth & Nepal, 2011; Talukdar & Gupta, 2017), research focusing on awareness remains limited (Heinen & Shrivastava, 2009; Patankar, 2019).

METHODOLOGY

The fieldwork for this study was carried out during 2023-24 along the fringes of Silent Valley National Park (SVNP), Wayanad Wildlife Sanctuary (WWLS), and Karimpuzha Wildlife Sanctuary (KWLS) in the Nilgiri Biosphere Reserve region of the South Indian state of Kerala. Using proportionate stratified random sampling, 10 local governing bodies adjacent to the PAs were selected: 5 from SVNP (out of 9), 3 from WWLS (out of 7), and 2 from KWLS (out of 4). A random sample of 30 farmers was drawn from each. Selection criteria required farmers to reside within 5 km of the PA boundary, own at least 2 dairy animals, and have 10 years of dairy farming experience. Thus, the study involved interviews of 300 farmers, comprising 150 from the forest-fringe communities of SVNP, 90 from WWLS, and 60 from KWLS.

Protected area awareness was measured using a "protected area awareness scale" designed as a summated rating scale (Likert, 1932). A list of the statements derived from literature and subject matter specialist consultation was tested for relevancy, and those with a weightage below 0.70 were excluded (Kumar & Popat, 2009). The retained statements were administered to 80 dairy farmers from non-sample areas, and based on the t-values above 1.75 (Edwards, 1969), 16 statements were finalised for the scale. Scale reliability was supported by an ordinal alpha of 0.86 (Gadermann et al., 2012). Careful statement selection, sample adequacy, and expert validation via relevancy testing were employed to ensure scale validity. The scale was administered on a five-point continuum (5 = extremely aware to 1 = not at all aware), and farmers were classified into low, medium, and high levels of awareness using the cumulative square root of frequency method.

To assess the overall awareness level of farmers on each item of the protected area awareness scale, weighted mean scores (WMS) were computed using the formula:

$$WMS = \frac{\Sigma^{k}_{i=1} f_i \times w_i}{N}$$

where, f_i denotes frequency of farmers in the ith response category, w_i is the weight assigned to that category, k represents the number of response categories, and N is the total number of respondents. The WMS range from 1.00 to 5.00 and are interpreted using midpoint-based class intervals, where 1.00 to 1.49 indicate 'not at all aware' and 4.50 to 5.00 indicate 'extremely aware.' The WMS facilitated ranking and comparison of statements, as well as meaningful interpretation of the relative strength of farmers' awareness.

To identify the determinants of dairy farmers' PA awareness, an ordinal logistic regression was employed on the overall sample, with awareness level as the dependent variable (Maiti et al., 2014). The ordinal logistic regression approach assumes the existence of an underlying latent variable Y^* representing the "true" awareness score. The relationship between Y^* and the observed awareness categories is defined by two threshold parameters (μ_1 and μ_2):

$Y = 1$, if $Y^* \leq \mu_1$ (Low)
$Y = 2$, if $\mu_1 < Y^* \leq \mu_2$ (Medium)
$Y = 3$, if $Y^* > \mu_2$ (High)

It is assumed that the latent variable Y^* follows a linear relationship with the explanatory variables, modelled as:

$$Y^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k + \varepsilon$$

where, β_0 is the intercept term on the latent scale, $\beta_1 \ldots, \beta_k$ represents coefficients to be estimated,

$X_1, X_2, \ldots, X_k$ are the explanatory variables, and ε denotes the random error.

Systematic data analyses were carried out using MS Excel and R version 4.4.3 (R Core Team, 2024). Ordinal alpha coefficient was estimated with *psych* and *polycor* (Fox, 2022; Revelle, 2025), ordinal logistic regression with *MASS* (Venables & Ripley, 2002), the Brant test with *brant* (Brant, 1990), Variance Inflation Factor (VIF) with *car* (Fox & Weisberg, 2019), and average marginal effects with the *margins* package (Leeper, 2024) in R.

RESULTS

The majority of farmers were middle-aged (63.67%), and males comprised 56% of the sample. Secondary education was attained by 43.33% of respondents. Additionally, 47% maintained small herds and 68% owned marginal land. The mean distance to the nearby forest boundary was 1.28 km. They exhibited low social participation (41%) and information-seeking behaviour (37.33%). Over half of the farmers (62.33%) used social media as an information source.

Protected area awareness

The scale items were administered to each farmer upon confirmation regarding their familiarity with the term "protected area," to which all answered "yes." Table 1 presents the WMS along with their awareness levels for the 16 statements of the protected area awareness scale. The WMS values ranged from 1.95 to 3.70, indicating considerable variation in the level of awareness among farmers. The statement on the recreational value of PAs ranked first (WMS = 3.70), reflecting a moderate level of awareness. This was followed by statements on the provision of ecosystem services (WMS = 3.68), bequest value (WMS = 3.60), preservation of ecosystem processes (WMS = 3.59), microclimate regulation (WMS = 3.59), and conservation of biodiversity (WMS = 3.54), suggesting that farmers were moderately aware of the key ecological functions of PAs. Farmers also exhibited moderate awareness regarding restrictions on trespassing (WMS = 3.51) and encroachment into PAs (WMS = 3.50). In contrast, they were only somewhat aware of prohibitions on the removal of forest produce without permission (WMS = 3.42) and damaging wildlife habitat (WMS = 3.37), as well as of the existence of eco-sensitive zones (ESZ) around PAs (WMS = 2.94) and restrictions on livestock grazing within them (WMS = 2.87). Awareness was slight with respect to activities in ESZs, including the requirement of approval for cutting trees and introducing non-native species (WMS = 2.23), prohibition of commercial mining and firewood use (WMS = 2.06), and permission for continuation of ongoing agricultural operations (WMS = 2.05). The least ranked item was awareness regarding vaccination practices to control communicable diseases shared between livestock and wildlife (WMS = 1.95).

As indicated in Table 2, the level of awareness among farmers regarding PAs varied across the three study sites. In the SVNP area, over one-third of the farmers (38%) demonstrated a medium level of awareness, followed by low (32%) and high (30%) levels. In the WWLS region, slightly under half of the farmers (44.44%) fell into the medium category of awareness. The remaining farmers were equally divided between low (27.78%) and high (27.78%) levels of awareness. Conversely, in the KWLS area, a slight predominance of high levels of awareness was observed (36.67%), followed closely by low (35%) and medium (28.33%) levels. Across the overall sample, the largest proportion of farmers belonged to the medium awareness category (38%), with nearly equal proportions in the low (31.33%) and high (30.67%) awareness categories.

Determinants of protected area awareness

Before conducting the regression analysis, the proportional odds assumption, a prerequisite for ordinal logistic regression, was

Table 2. Differential levels of protected area awareness

Study area	Low 16.00 to 40.27#	Medium 40.28 to 58.35#	High 58.36 to 80.00#
SVNP (n = 150)	32.00	38.00	30.00
WWLS (n = 90)	27.78	44.44	27.78
KWLS (n = 60)	35.00	28.33	36.67
Overall (n = 300)	31.33	38.00	30.67

Range = 16.00 to 80.00; Mean = 49.59
#Range of scores for level of classification

Table 1. Item-wise farmers' protected area awareness (n = 300)

S. No.	Statements	Weighted Mean Score	Awareness Level
1	Protected areas provide recreational and natural experiences for people.	3.70	Moderately aware (3.50 to 4.49)
2	Protected areas provide natural services, such as habitat for insects that pollinate local crops.	3.68	
3	Protected areas have bequest value for future generations.	3.60	
4	Protected areas preserve ecosystem processes.	3.59	
5	Protected areas regulate the microclimate of landscapes.	3.59	
6	Protected areas conserve biodiversity.	3.54	
7	Trespassing into a protected area is a punishable offence.	3.51	
8	Encroachment into a protected area is a punishable offence.	3.50	
9	Removal of any forest produce from a protected area cannot be carried out without due clearance.	3.42	Somewhat aware (2.50 to 3.49)
10	The habitat of any wild animal shall not be destroyed, damaged, or altered.	3.37	
11	The protected areas are surrounded by an eco-sensitive zone, which serves as a transition zone from highly protected areas to areas involving less protection.	2.94	
12	Livestock grazing is not permitted in protected areas, with exemptions based on local conditions.	2.87	
13	In eco-sensitive zones, cutting down trees and introducing non-native species requires approval from forest authorities.	2.23	Slightly aware (1.50 to 2.49)
14	Activities such as commercial mining and commercial use of firewood are prohibited in the eco-sensitive zones.	2.06	
15	Ongoing agricultural activities are permitted in eco-sensitive zones.	2.05	
16	Immunisation of livestock kept near protected areas is essential for safeguarding against communicable diseases.	1.95	

Table 3. Ordinal regression estimates for protected area awareness

Variable	Estimated Coefficient	Standard Error	p value	Marginal Effect#
Age	0.007	0.018	0.696	-0.001
Gender: Female	-0.853	0.323	0.008**	0.092
Education: No formal education	-2.243	0.819	0.006**	0.235
Education: Primary	-1.820	0.597	0.002**	0.191
Education: Secondary	-1.322	0.491	0.007**	0.138
Education: Higher secondary	-0.373	0.531	0.482	0.039
Herd size	-0.030	0.026	0.239	0.003
Farm size	-0.015	0.210	0.945	0.002
Distance from forest boundary	-0.069	0.133	0.604	0.007
Social participation	0.124	0.037	0.001***	-0.013
Information-seeking behaviour	0.301	0.042	0.000***	-0.032
Social media use	0.486	0.369	0.189	-0.051

Observations = 300; #Average marginal effects, other variables held constant;
** = significant at 0.01 level (2-tailed test); *** = significant at 0.001 level (2-tailed test);
Reference categories: Gender = Male, Education = Graduate and above

tested using the Brant test. The omnibus test was non-significant ($\chi^2 = 13.47$, df = 12, p = 0.34), indicating that the assumption was met overall. Pseudo R^2 statistics were calculated to assess model fit. The McFadden's R^2 value was 0.446, indicating a good model fit. Additionally, maximum likelihood pseudo-R^2 was 0.623, and the Cragg-Uhler (Nagelkerke) pseudo-R^2 value was 0.702, further supporting the explanatory power of the model. The predictors showed no evidence of multicollinearity, as reflected in VIF values under 5.

The ordinal logistic regression results (Table 3) indicate that being a female dairy farmer, along with lower education, limited social participation, and weaker information-seeking behaviour, were associated with significantly lower odds of being in higher PA awareness categories. Average marginal effect analysis revealed that female farmers had a 9.2% higher probability of being in lower awareness categories than males, after controlling for other variables. Formal education attainment had a pronounced influence: compared to graduates, farmers with no formal education had a 23.5% higher predicted probability of low awareness; those with primary-level education had a 19.1% higher predicted probability; and those with secondary-level education had a 13.8% higher predicted probability, ceteris paribus. In contrast, no significant difference was observed between higher secondary and graduate education levels. Behavioural factors played a critical role; greater information-seeking behaviour reduced the probability of low awareness by 3.2 percentage points, while increased social participation reduced this probability by 1.3 percentage points, holding other variables at their observed values. Age, herd size, farm size, distance from forest boundary, and social media use had statistically insignificant effects on farmers' PA awareness levels.

DISCUSSION

The study aimed to empirically assess the PA awareness and its determinants among dairy farmers in the forest-fringe communities. The results show that farmers had moderate awareness of the ecological significance of PAs. They especially recognised the recreational value, provision of ecosystem services, and biodiversity conservation functions of PAs. This aligns with earlier studies that found higher recognition of direct and visible benefits of PAs compared to indirect or regulatory aspects (Karanth & Nepal, 2011). Moderate awareness of restrictions on trespassing and encroachment also suggests that farmers are familiar with rules that affect their day-to-day access to resources. In contrast, awareness of prohibitions on forest-produce extraction, habitat damage, and the existence of ESZs was only somewhat developed. This points to a limited understanding of regulatory mechanisms that are less visible in everyday life. Awareness was particularly low regarding activities which are prohibited, restricted, and even those that are permitted, such as ongoing agriculture. This has contributed to misconceptions among farmers and fostered negative attitudes that authorities intend to curtail farming and claim their land (Kuttappan, 2023). The lowest awareness was observed for strategies to prevent communicable diseases from passing between livestock and wildlife. This highlights a significant knowledge gap in areas central to integrated health and conservation approaches. A medium level of awareness was found in two out of three regions and the overall sample. This suggests that there is ample scope for strategic efforts to improve awareness among dairy farming communities.

Findings of the regression analysis show that gender significantly influenced farmers' awareness levels, indicating similarities with the results of Xun et al. (2017). Female farmers had low awareness levels due to limited access to forest officials, NGO workers, or extension officers, as well as reduced participation in awareness campaigns or political activities in comparison to male farmers. Multiple responsibilities such as household chores, childcare, and farm activities hinder women from attending such programmes, similar to the findings by Paul et al. (2025). So, it is imperative to create conscious opportunities for women in social events such as training programmes to ensure their equitable inclusion, as such initiatives are observed to substantially enhance knowledge levels of women participants (Roy et al., 2024; Kumari et al., 2025). A positive correlation was observed between education and awareness, highlighting the essential role of formal education in improving the ecological and legal awareness among farmers (Xun et al., 2017; Hariohay et al., 2018).

The statistically significant and positive effect of social participation on PA awareness posits that farmers involved in a higher number of social networks, community groups, or local institutions, particularly in leadership roles, are more likely to fall into higher awareness categories. This suggests that social interaction has a crucial role to play in facilitating the flow of information related to the importance and laws related to PAs. Farmers showing active participation in community activities are likely to be better informed, either through formal discussions, peer exchanges, or access to awareness programmes channelled through these networks. A similar finding was reported by Munasib and Jordan (2006) while examining the effect of social capital on farmers' environmental awareness. Strengthening community-based platforms can therefore improve awareness and farmer involvement in PA management. Similarly, farmers who actively seek information through peers, training programmes, or mass media are more likely to understand ecological value and regulations of PAs. This aligns with Pongener and Jha (2024), who found that information source utilisation significantly influenced farmers' awareness of recommended practices in Nagaland. Identifying farmers' information-seeking behaviour and supporting it through accessible communication channels is crucial for enhancing conservation awareness (Reimer, 2025).

Overall, the socio-demographic and behavioural dimensions collectively shape not only farmers' awareness levels but also their adaptive capacity to manage livelihood risks near PAs. Among forest-fringe dairy farmers in Kerala, higher PA awareness can enhance economic resilience by encouraging adaptive practices such as fodder cultivation, stall-feeding, and livestock immunisation. Lack of awareness was found to be a major barrier to the adoption of climate-resilient dairy practices among farmers in Haryana (Reddy et al., 2024). Awareness also promotes livelihood diversification through agri-tourism and facilitates effective engagement with institutional support mechanisms like compensation schemes (Hridya & Meena, 2024). Moreover, it fosters appreciation of ecosystem services that sustain long-term dairy productivity, thereby reinforcing both ecological coexistence and livelihood sustainability at the ecology–economy interface.

CONCLUSION

The study revealed that while farmers were moderately aware of the ecological roles of protected areas, their understanding of eco-sensitive zone regulations and livestock-wildlife health concerns remained limited. A considerable proportion of forest-fringe farmers from Silent Valley National Park, Wayanad Wildlife Sanctuary, and the overall sample showed a medium level of protected area awareness, whereas high levels predominated among farmers from Karimpuzha Wildlife Sanctuary. Gender, education, social participation, and information-seeking behaviour emerged as significant determinants of awareness. These findings highlight the need for integrated strategies that are gender-inclusive, promote education, leverage community-based platforms, and encourage active information-seeking among farmers. Awareness-building efforts should be complemented by capacity-building and financial incentives to help farmers sustain their livelihoods in forest-fringe areas. Collectively, such targeted interventions are vital to conserve protected area ecology, sustain the agrarian community economy, and foster harmonious farmer–wildlife coexistence in agricultural landscapes near protected areas.

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

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Unveiling Regional Disparities in Makhana Farming: A Multidimensional Analysis from Bihar

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HIGHLIGHTS

- Landholding size and perception levels significantly differentiate *Mithlanchal* and *Simanchal* Makhana growers.
- Multidimensional profiling using Multiple Correspondence Analysis (MCA) explained nearly half of the variance (49.38%), confirming robust separation between traditional and emerging Makhana production areas.
- Policy relevance emerges from the evidence-based identification of regional strengths and gaps, suggesting tailored interventions on resource enhancement in *Simanchal* and perception and technology orientation in *Mithilanchal* to promote balanced and inclusive sectoral development.

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Keywords: Makhana cultivation, Regional disparities, Mann-Whitney U test, Multiple correspondence analysis, Permutation test, Bihar.

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ABSTRACT

Makhana (*Euryale ferox)* cultivation in Bihar accounts for 85% of India's total production of Makhana, exhibiting pronounced regional disparities driven by agro-ecological, socio-economic, and institutional factors. This study compares traditional (Darbhanga/ Madhubani) and emerging (Purnea/Katihar) Makhana-growing zones to elucidate differences in farming practices, resource endowments, and socio-behavioural attributes. In a comparative cross-sectional design, 120 Makhana growers (60 per region) were surveyed using a structured interview schedule covering landholding size, income level, training, age, education level, perception, knowledge and attitude level of farmers. Mann-Whitney U tests ($\alpha = 0.05$) examined univariate regional differences; Multiple Correspondence Analysis and permutation testing (B = 999) assessed multidimensional separation and statistical significance of regional groupings. Univariate analysis revealed significant regional differences in landholding size, larger in traditional zones, perception scores higher in emerging zones, and income level. MCA showed robust grouping: the first two dimensions captured 49.38% of total variance. Though specific socio-economic and attitudinal factors appear similar, multidimensional profiling uncovers clear structural differences between traditional and emerging Makhana regions. These findings emphasize the need for region-tailored extension strategies, input support, and market interventions to foster equitable growth and resilience in Bihar's Makhana sector.

INTRODUCTION

Makhana (*Euryale ferox*), also known as fox nut or gorgon nut, is an aquatic crop of significant nutritional, economic, and cultural importance in eastern India, particularly in Bihar. It is widely consumed as a healthy snack due to high protein and low-fat content and is valued in traditional Ayurvedic medicine for its therapeutic properties. Bihar accounts for nearly 85% of India's Makhana production, with districts such as Darbhanga, Madhubani, Supaul and Saharsa forming the core of the Makhana belt (Sonu & Jha, 2025a; Kumar et al., 2011). The cultivation of Makhana offers livelihood support to thousands of marginal and small-scale farmers,

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many of whom rely on it as a primary or supplementary source of income. Despite its prominence, Makhana cultivation in Bihar is characterised by notable regional disparities in production inequality, economic, processing, agroecological and policy access disparities (Sonu & Jha, 2025c). While certain districts benefit from favourable natural conditions such as abundant ponds and marshy lands, others lag due to water scarcity, poor market access, or inadequate technical guidance. Consequently, variations exist not only in productivity and profitability but also in cultivation practices, adoption of improved inputs, and access to government schemes and services.

Historically, districts like Darbhanga and Madhubani have been the epicentre of traditional Makhana farming. Farmers in these regions often rely on inherited knowledge and indigenous practices passed down through generations. In contrast, regions like Purnea/Katihar are witnessing a shift towards commercial-scale pond-based cultivation, supported by scientific techniques such as pond rejuvenation, line sowing, improved seed varieties, and mechanized processing. These advancements, however, are not uniformly accessible across all regions, leading to an imbalance in economic returns and development opportunities among farmers (Warshini et al., 2025).

To address these growing disparities, it is important to undertake region-specific assessments that capture both the strengths and challenges of Makhana cultivation across different areas. Understanding regional patterns in input use, productivity levels, income, and socio-economic profiles of farmers is essential for designing policies that promote equitable agricultural growth. Moreover, such analysis can inform targeted interventions to improve technology dissemination, enhance value chain integration, and support the development of farmer collectives and cooperatives (Kumar et al., 2020).

This study aims to assess regional disparities in Makhana farming practices in Bihar by comparing two distinct Makhana-producing regions. It also assesses the impact of socio-economic factors, on farm outcomes. By employing both descriptive and inferential statistical techniques, the research seeks to identify significant differences and contributing factors to regional variability.

METHODOLOGY

The present study was conducted to assess regional disparities in Makhana cultivation practices, productivity, and socio-economic factors among farmers in two selected regions of Bihar, one representing a traditional Makhana-growing zone (Darbhanga/ Madhubani designated as Mithilanchal) and the other an emerging cultivation area (Purnea/Katihar designated as Simanchal). A total of 120 Makhana farmers were purposively selected, with 60 respondents from each region, ensuringhighly localised and practised by a specialised group of farmers possessing unique knowledge of aquatic crop management. A comparative cross-sectional research design was adopted, enabling simultaneous analysis of differences between regions during the 2023-24. Data were collected using a pre-tested, structured interview schedule covering variables such as age, education, landholding size, annual income, input usage, yield (kg ha^{-1}), gross income (Rs. ha^{-1}), knowledge and attitude towards improved practices. Interviews were conducted in local dialects to ensure clarity and accuracy. Primary data were coded and entered into Microsoft Excel, then analysed using SPSS v27 for descriptive statistics and R (Facto Mine R package) for advanced multivariate analysis.

Given that many variables did not meet the assumption of normality (tested via Shapiro–Wilk), the Mann-Whitney U test was used to compare medians between regions:

$$U = n_1 n_2 + \frac{n_1 (n_1 + 1)}{2} R_1$$

where n_1 and n_2 are the sample sizes of Region A and Region B, and R_1 is the sum of ranks for Region A. Statistical significance was set at $p<0.05$.

To explore multidimensional relationships, Multiple Correspondence Analysis (MCA) was applied to categorical variables from socio-economic, knowledge, and attitude dimensions. Socio-economic and knowledge/attitude indicators were treated as active variables, while *region* was included as a supplementary variable to enable between-group comparisons without distorting the factorial space (Greenacre & Blasius, 2006; Husson & Josse, 2014). The barycenter for each region was calculated as:

$$G_k = \frac{1}{n_\kappa} \sum_{i \epsilon k} x_i$$

where G_k is the barycenter of group κ, n_k the number of individuals in group κ, and x_i is the coordinate vector of individual i.

Lebart test values were computed to identify variables most associated with regional separation. A permutation test with 999 replications was conducted to assess whether the observed separation between regions in MCA space exceeded that expected by chance (Husson & Josse, 2014). The test statistic was:

$$P = \frac{\{\delta^* \geq \delta_{obs}\}}{B + 1}$$

where δ_{obs} is the observed inter-group distance, δ^* are permuted distances, and B=999.

Bootstrapping (n = 500) was performed to generate 95% confidence ellipses around regional barycenters, enabling visual interpretation of variability and overlap in the MCA factorial map.

RESULTS

The Mann-Whitney U test results the regional variations between Mithlanchal and Simanchal Makhana growers across multiple socio-economic and behavioural parameters (Table 1). The analysis identified a statistically significant difference in income levels ($U = 2208.5$, $p = 0.023$); however, the direction of the effect indicated no substantial practical difference between the two regions. Landholding size also varied significantly ($U = 2223.5$, $p = 0.021$), with growers in Mithlanchal possessing comparatively larger agricultural holdings than their counterparts in Simanchal.

Perception score presented the most pronounced difference between the groups ($U = 1132$, $p < 0.001$), with Simanchal growers exhibiting more favourable perceptions toward Makhana cultivation and associated technological practices. In contrast, other variables including knowledge level ($p = 0.057$), training received ($p = 0.422$),

Table 1. Mann-Whitney U Test of regional differences across different variables of makhana growers

Variable	U Statistic	P Value	Significant	Effect Direction
Income Level	2208.5	0.023471	Yes	No difference
Land Holding	2223.5	0.021114	Yes	Mithlanchal > Simanchal
Knowledge Level	2075	0.057091	No	No difference
Perception Score	1132	4.90E-05	Yes	Simanchal > Mithlanchal
Training Received	1920	0.421637	No	No difference
Attitude level	1890.5	0.537416	No	No difference
Farm Location	2084	0.112355	No	No difference
Age Group	1801.5	0.995111	No	No difference
Education Level	1478.5	0.081637	No	Simanchal > Mithlanchal

attitude level (p = 0.537), farm location (p = 0.112), age group (p = 0.995), and education level (p = 0.082) did not display statistically significant differences between the two regions. Nevertheless, the education data indicated a non-significant trend towards higher educational attainment among growers from Simanchal.

The MCA was carried out to examine multidimensional relationships among the socio-economic, attitudinal, and behavioural attributes of growers in the two regions. Table 2 presented the eigenvalues and variance contributions for the five extracted dimensions. The first dimension yielded the highest eigenvalue (0.298), accounting for 28.59% of the total variance. This axis primarily differentiated growers based on economic indicators, perception levels, and landholding size, making it the most influential factor in distinguishing regional profiles.

Table 2. MCA Eigenvalues and Variance patterns distinguishing the regional groups

Dimension	Eigenvalue	Explained Variance (%)	Cumulative (%)
Dim 1	0.298216	28.59464	28.59464
Dim 2	0.216823	20.79022	49.38486
Dim 3	0.180723	17.32876	66.71362
Dim 4	0.176319	16.90652	83.62013
Dim 5	0.170827	16.37987	100

The second dimension explained 20.79% of the total variance, raising the cumulative contribution of the first two dimensions to 49.38%. This indicated that nearly half of the total variability in the dataset was explained by these two dimensions, making them the most relevant for visual interpretation. The third dimension accounted for 17.33% of the variance and appeared to represent variations related to education level and access to training programmes. The fourth dimension contributed 16.91% of the variance, reflecting diversity in farm location and age group characteristics. The fifth dimension explained 16.38% of the variance, bringing the cumulative explained variance to 100% and confirming that the extracted dimensions fully summarised the variability present in the dataset.

The barycenter values obtained from the MCA revealed clear positional differences between the two regions on the first two dimensions, as shown in Table 3. Mithlanchal growers recorded negative coordinates on both axes (Dim1: –0.108, Dim2: –0.082), indicating that their overall profile was positioned on the opposite side of the factorial space compared to Simanchal growers. In contrast, Simanchal barycenters were positive on both dimensions (Dim1: 0.108, Dim2: 0.082), reflecting a distinct grouping pattern.

Table 3. Regional Barycenters of different region of Makhana growers

Region	Dim1	Dim2	n
Mithlanchal	-0.10846	-0.08171	60
Simanchal	0.108457	0.081711	60

Both regions had an equal sample size (n = 60), ensuring that the observed differences were not a result of unequal representation but instead reflected genuine contrasts in growers' characteristics. This separation along the two primary dimensions reinforced the interpretation that regional factors played a significant role in shaping technology adoption and entrepreneurial behaviour among makhana farmers.

The Multiple Correspondence Analysis (MCA) plot illustrated the spatial differentiation between makhana growers from the Mithlanchal and Simanchal regions based on their multidimensional characteristics (Figure 1). The two primary dimensions (Dim 1 and Dim 2) accounted for 28.59% and 20.79% of the total variance, respectively, together explaining a substantial proportion of the variation in the dataset. The plot displayed two distinct yet partially overlapping clusters.

Growers from Mithlanchal, represented by blue points, were predominantly positioned in the negative quadrant of Dimension 1, with their barycenter (marked as a diamond) located at approximately -0.108 on Dim 1 and -0.082 on Dim 2. In contrast, growers from Simanchal, represented by red points, were generally situated in the positive quadrant of Dimension 1, with their barycenter (diamond) at approximately 0.108 on Dim 1 and 0.082 on Dim 2. This mirrored positioning along Dim 1 indicated a clear directional contrast in the underlying variables influencing each group.

The shaded ellipses represented the 95% confidence intervals for the regional group distributions. While some overlap was observed, suggesting shared characteristics, the centers were separated by an inter-group distance of 0.27 (p = 0.01), confirming statistically significant regional differences. This separation likely reflected variations in socio-economic profiles, access to inputs, adoption of improved cultivation practices, and market linkages between the two regions.

Figure 2 illustrated the distribution of socio-economic, attitudinal, and perceptual variables among Makhana growers across

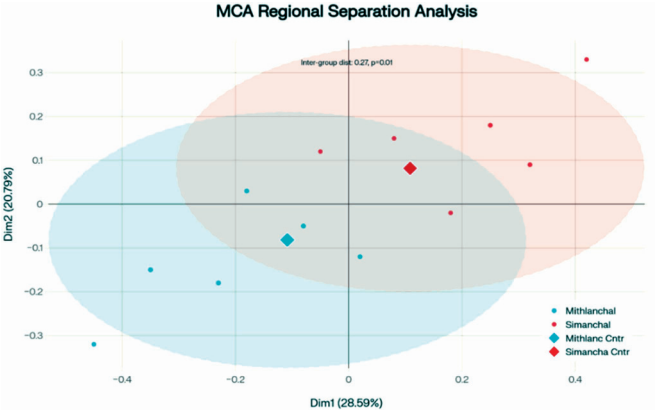

Figure 1. MCA Factorial Map showing regional separation between Mithlanchal and Simanchal

the two principal dimensions. Dimension 1 accounted for 11.98% of the total variance, while Dimension 2 explained an additional 8.84%, jointly capturing a substantial portion of the structural variation in the dataset. In the plot, each black point represented an individual respondent, whereas labelled coordinates denoted categorical variable categories. The positioning of categories along Dimension 1 and Dimension 2 indicated their relative association with respondents' profile. Respondents located on the right-hand side of Dimension 1 were predominantly associated with larger landholdings, higher income brackets (>2.4L), postgraduate education, and high knowledge and attitude levels. This cluster also reflected stronger adoption-related indicators, suggesting that these individuals were socio-economically advantaged and more receptive to innovation. Conversely, the left-hand side of Dimension 1 was characterised by marginal and small landholders, lower income categories (80K), and lower perception scores. These respondents were associated with lower adoption levels and limited resource access, highlighting structural constraints in production capacity.

Along Dimension 2, the upper section contained respondents with very high perception scores and landholding extremes, while the lower section included categories such as medium landholding sizes, medium income levels (80K-1.60L), and mixed perception and knowledge scores. The vertical spread suggested variation in perception and attitude across income and landholding groups, independent of pure economic status. The mirrored positioning of adoption-related variables, such as high knowledge and attitude levels, against low and medium categories along Dimension 1, supported the interpretation of systematic socio-economic and attitudinal contrasts between different farmer groups. Furthermore, the clustering patterns implied that landholding size, income, and education had a stronger alignment with Dimension 1, whereas perception and knowledge distribution contributed more to separation along Dimension 2.

DISCUSSION

The present study examined regional differences in socio-economic, attitudinal, and behavioural variables among makhana growers in Mithilanchal and Simanchal, Bihar, and findings offer insights into the structural and perceptual variations that underpin technology adoption and entrepreneurial orientation in the makhana value chain.

The application of the Mann-Whitney U test proved effective in identifying clear regional differences in Makhana cultivation between traditional and emerging production zones. This choice of test aligns well with the nature of agricultural data, which often deviates from normality assumptions, making non-parametric methods more appropriate (Macfarland & Yates, 2016). The results revealed that farmers in Mithlanchal generally possess larger

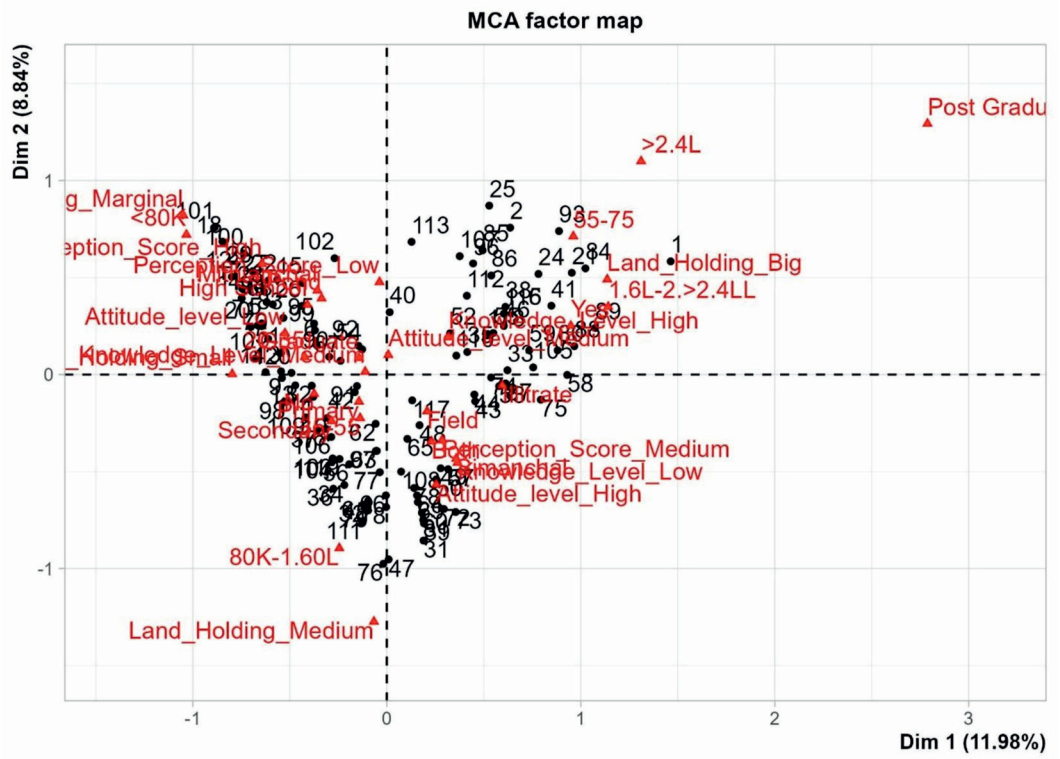

Figure 2. MCA Factor Map showing different variables of Mithanchal and Simanchal region

landholdings compared to those in Simanchal (U = 2223.5, p = 0.021). This disparity can be attributed to long-standing historical land tenure patterns and the presence of well-established irrigation infrastructure in traditional growing areas (Singh et al., 2015). Such structural advantages have allowed Mithlanchal farmers to cultivate Makhana on a larger scale, reinforcing their dominant position in production.

Interestingly, while Simanchal farmers tend to operate on smaller plots, they recorded higher perception scores regarding Makhana cultivation and innovation adoption (Sonu & Jha, 2025a,b or c). This openness to new practices suggests that perception and willingness to adapt may be just as important if not more so than physical resources in driving agricultural transformation. Similar observations have been reported in other contexts, where farmer attitudes and readiness to embrace innovation often outweigh objective factors like land size in determining success (Datta et al., 2022; Vallury et al., 2024).

The Multiple Correspondence Analysis (MCA) provided further insight into these regional differences. The first two dimensions of the MCA accounted for 49.38% of the total variance, with a statistically significant separation between the two regions (inter-group distance = 0.27, p = 0.01). Such a high proportion of variance explained by only two dimensions indicates strong underlying structural contrasts (Hoffman & Leeuw, 1992; Roux & Rouanet, 2021). The positioning of the regional barycenters along Dimension 1, Mithlanchal at –0.108 and Simanchal at 0.108 reflects systematic socio-economic and technological adoption differences. This mirrored arrangement reinforces the argument for region-specific intervention strategies rather than a uniform policy approach.

A notable finding is the absence of significant differences in knowledge levels, training participation, and attitudes toward Makhana cultivation across the two regions (Sonu & Jha, 2025b). This suggests that while institutional support systems such as training programs and advisory services are available in both areas, their utilization and impact differ. This uneven uptake could be linked to the way local cooperatives operate or farmers perceived security and trust in institutional support, both of which strongly influence their willingness to adopt transformative agricultural practices (Masi et al., 2022).

One factor that stands out as a clear differentiator is market access. The study highlights that infrastructure connectivity, such as transportation networks and proximity to marketplaces plays a decisive role in shaping income potential and the adoption of innovative practices. Farmers with better access to markets are more likely to invest in quality improvements, adopt post-harvest innovations, and integrate into value chains. Conversely, inadequate connectivity can limit opportunities even for farmers with high awareness and willingness to adopt.

CONCLUSION

Larger landholdings in Mithlanchal reflect structural advantages, yet Simanchal's stronger perception scores highlight a readiness to adopt innovative practices despite resource constraints. While knowledge and training levels are comparable, the interplay between resource endowment and perception emerge as a central determinant of regional profiles. Strengthening market linkages, promoting farmer collectives, and facilitating targeted training could foster equitable development across regions. Addressing both structural and perceptual gaps is essential for sustainable growth in Bihar's makhana sector, enabling farmers to capitalize on market opportunities and strengthen the resilience of this high-value crop's value chain. The findings also provide valuable insights into the spatial heterogeneity of Makhana cultivation, enabling policymakers, researchers, and extension agencies to design region-specific interventions that promote inclusive and sustainable growth of this vital sector. Bridging regional disparities will not only enhance productivity and profitability but also strengthen the resilience, equity, and long-term competitiveness of Makhana farming in Bihar.

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

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Attitude of Agricultural Beneficiaries towards NGOs in North Coastal Andhra Pradesh

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HIGHLIGHTS

- Respondents below 50 years of age and those with basic education expressed significantly more favourable attitudes towards Non-Government Organisations.
- Regression and Random Forest models identified scientific orientation as the most influential factor shaping positive attitude towards NGOs.
- Family support and social participation were also found to be most important in shaping a positive attitude towards the NGOs.

ARTICLE INFO

Keywords: Attitude, Housing conditions, Non-Governmental Organisations (NGOs), Scientific orientation.

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ABSTRACT

Non-government organisations play a vital role in meeting societal needs. The study, conducted in 2025, explores the influence of socio-economic factors on attitudes of beneficiaries towards NGOs engaged in agricultural development and poverty alleviation. The purpose of this study was to evaluate beneficiaries' attitudes toward NGOs in the districts of Vizianagaram and Srikakulam in Andhra Pradesh's North Coastal regions. A purposive sampling design was used for the selection of districts. Two NGOs from each district were selected based on their performance. 15% of the beneficiaries from each NGO were randomly selected from each district, resulting in a total of 90 farmers. So, in total, 180 farmers were selected from both districts. The analysis of variance (ANOVA) revealed that attitude scores significantly differed by education, age, income and land holding size ($p<0.01$). The multiple regression analysis revealed that scientific orientation, health security and housing conditions emerged as significant predictors. Respondents with basic education and those below 50 years of age showed more significant attitudes than illiterate, graduate and older individuals. Random forest analysis revealed that scientific orientation, health security, family support and social participation were key contributors.

INTRODCUTION

Non-governmental organisations play a vital role in meeting the requirements of societies, providing crucial services, and supporting causes that enhance societies (Kim et al., 2017). These are independent, non-profit organisations that play a vital role in addressing social, economic, and environmental challenges. NGOs have increasingly contributed to rural development efforts since being formally recognized in the United Nations Charter in 1945 (Lewis et al., 2020). In the agricultural sector NGO contributes significantly by providing a substantial contribution by conducting training programmes, prompting the dissemination of advanced technologies, and the encouragement of adoption of sustainable farming practices (Utuk, 2014). In addition to their role in

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environmental preservation (Sahoo et al., 2021), NGOS are instrumental in enhancing rural livelihood through skill development and entrepreneurship, and social welfare (health, education, and women's empowerment). NGOs have been actively involved in increasing farmer's resilience, enhancing soil health, and crop productivity in regions such as North Coastal Andhra Pradesh (Lewis, 2023). Various programmes are in place specifically oriented towards the socio-economic empowerment of women by the voluntary organizations, and there is a need to do more (Slathia et al., 2014).

However, just as important to the success of these interventions as the quality of the services is how respondents view and interact with them (Mondal & Basu, 2014). While skepticism or apathy may reduce the significance of these achievements, a positive attitude among beneficiaries tends to enhance the adoption and long-term sustainability of innovations (Gotz, 2019). The attitude and perceptions of beneficiaries of rural populations mainly in rural setting are pivotal to the success of and sustainability of NGO led-initiatives (Savari & Khaleghi, 2023). Extension Advisory services play very important role in enhancing rural livelihoods (Ranjan et al., 2025). The training imparted are in thrust areas and the farmers have always shown high degree of training need (Nain & Chandel, 2010). Farmers and rural communities are more likely to accept the technology and practices offered by NGOs (Kobba et al., 2020). The development of community-based infrastructure and provision of employment are identified as key factors that facilitate the rural agriculture productivity (Tripathi et al., 2025). Positive beneficiary attitude contributes to long-term impacts, higher adoption rates, and increased community participation (Odyuo et al., 2017). Even stronger programs may fail due to lack of trust or low participation (De, 2020). Although an extensive presence of NGOs for rural development initiatives, only 45–50% of farmers report sustained benefits from their interventions (Phiri, 2020). This implies that although NGOs are operationally active, there is a wide range in their efficacy, which may be caused by systemic problems like inadequate follow-up procedures, a lack of resources, or insufficient community engagement (Mphahlele, 2023). Moreover, there remains a paucity of focused research examining the relationship between recipients' perceptions and the real effects of NGO-led initiatives (Kriti & Mohapatra, 2025). The lack of targeted evaluation necessitates empirical studies to address this gap to provide evidence-based insights to improve NGO performance and improve outcomes for rural communities (Mansuri & Rao, 2012).

METHODOLOGY

The present study was conducted in Vizianagaram and Srikakulam districts of Andhra Pradesh in 2025 which are well known for their agricultural activities. An ex-post-facto research design was used to examine existing conditions and interrelationships among variables. This design is suitable for researching how NGOs affect the spread of agricultural technology and related aspects. A purposive sampling design was used for selection of districts. Two NGOs from each district were selected based on their performance. 15% of the beneficiaries from each NGO were randomly selected from each district resulting in a total of 90 respondent farmers. So, in total 180 respondent farmers were selected from both the districts. A structured interview schedule comprising both close-ended and open-ended questions were used to gather data. The instrument was designed to collect detailed data on attitudes, organizational capacity, technology adoption, NGO activities, and socioeconomic profiles. To extract valuable insights, a number of statistical approaches were applied to the collected data. To summarize respondents' characteristics, a general overview of their socio-economic and behavioural profiles was provided. Analytical tools like regression analysis were used to examine the impact of numerous independent factors on outcomes such as NGO performance and technology uptake. Principal Component Analysis (PCA) was used to reduce dimensionality and expose hidden patterns amongst correlated variables, resulting in the identification of crucial components like institutional support and psychological orientation. In order to improve prediction accuracy and identify the critical elements affecting successful NGO interventions and agricultural technology adoption, the study used the Random Forest algorithm, a potent machine learning technique. This allowed for the identification of the most pertinent elements that contribute to successful technology distribution and recipient participation. This method strengthened the research findings by offering a sophisticated, data-driven comprehension of intricate relationships within the dataset.

RESULTS

Analysis of variance was used to determine whether there are statistically significant differences in the attitude scores of respondents based on different levels or categories of independent variables (Table 1). All four of the socio-economic variables under investigation viz. education, age, income, and landholding showed statistically significant differences in attitude scores, as revealed by the analysis of variance (ANOVA) ($p < 0.01$). Significant differences were found in attitude scores between educational levels; respondents with only primary or middle school education had the most positive attitudes (Mean ≈51), whereas those who were illiterate (42.43) and even graduates (43.91) reported much lower scores. This may indicate that, basic education combined with more direct community involvement may create greater openness towards NGOs than higher academic qualifications alone. Compared to older beneficiaries (>50 years; Mean = 44.03), respondents in younger (<35 years) and middle-aged (35–50 years) had significantly more positive attitudes (Means = 50.91 and 49.59, respectively). This suggests that younger age groups are aligned with development goals promoted by NGOs. This trend was further reflected in income and landholding: respondents with greater landholdings (>5 acres) displayed the strongest attitudes (Mean = 54.83), while attitude scores increased consistently across income levels, peaking among those earning over Rs. 1.5 lakh (Mean = 55.25). These results show that positive opinions of NGOs are highly correlated with economic stability and asset ownership, most likely as a result of improved access to funding and increased participation in development initiatives. All things considered, the findings highlight how important moderate education, economic empowerment, and demographic involvement are in influencing beneficiaries' attitudes of non-governmental organizations.

Table 1. Analysis of variance of the attitude of respondents with independent variables

Variable	F-Value	Sig.	Levels	Mean Attitude Score	DMRT Group
Education	5.38	<0.01	Illiterate	42.43	c
			Can read	49.12	a,b,c
			Can read and write	51.85	a
			Primary level	50.77	a,b
			Middle school	51.05	a,b
			High school	49.17	a,b,c
			Graduate	43.91	b,c
			Post Graduate	49.00	a,b,c
Age	6.90	<0.01	Young <35	50.91	a
			Middle-aged 35-50	49.59	a
			Old >50	44.03	b
Income (Rs.)	19.12	<0.01	<50,0000	41.14	b
			50,000 to 1,00,000	50.28	a
			1,00,000 to 1,50,000	54.70	a
			> 1,50,000	55.25	a
Land holding	11.58	<0.01	Up to 1 acre	44.00	c
			1 to 2.5 acres	47.92	b,c
			2.5 to 5 acres	52.76	a,b
			5.1 and above	54.83	a

Table 2. Regression Analysis of Independent Variables with Attitude

Unstandardized Coefficients			Standardized Coefficients		
Variables	B	Std. Error	Beta	t	Sig.
Age	-1.006	0.539	-0.067	-1.867	.064
Education	-0.131	0.167	-0.029	-0.785	.433
Landholding	0.482	0.424	0.046	1.136	.258
Family type	0.581	0.576	0.036	1.009	.315
Family support	0.123	0.155	0.074	0.791	.430
Annual income	-0.278	0.603	-0.020	-0.461	.646
Material possession	-0.671	0.227	-0.235	-2.953	.004
Information accessing behaviour	0.003	0.136	0.003	0.025	.980
Scientific orientation	0.721	0.117	0.537	6.141	.009
Extension contact	-0.221	0.201	-0.159	-1.096	.275
Social participation	0.333	0.200	0.185	1.663	.098
Health security	1.965	0.412	0.383	4.775	.003
Housing condition	1.877	0.541	0.145	3.467	.001
Sanitation	0.128	0.696	0.007	0.184	.854
Drinking water	0.515	0.635	0.030	0.811	.419

R^2 value of 0.805

The Table 2 from the regression analysis shows how respondents' attitudes about NGOs relate to a number of independent socioeconomic factors. The high R^2 value of 0.805 means that these factors account for 80.5% of the variation in respondents' attitudes. At the 5% level, four of the 15 factors were determined to be statistically significant. The greatest positive predictor was Scientific Orientation (Beta = 0.537, Sig. = 0.009), indicating that people who are more inclined to think scientifically have a more positive opinion of NGOs. Better living circumstances and access to health services are linked to more receptiveness toward NGO initiatives, as seen by the strong influence of housing condition (Beta = 0.145, Sig. = 0.001) and health security (Beta = 0.383, Sig. = 0.003) on positive sentiments. Since their p-values were higher than the 0.05 cut-off, other factors like age, education, landholding, family support, and extension contact did not substantially affect attitude. Overall, the findings from the regression analysis show that material possession, scientific orientation, housing condition and health security rather than conventional socioeconomic indicators are the main factors influencing attitudinal attitude toward NGOs.

To address the potential redundancy and multicollinearity among the predictor variables, Principal Component Analysis (PCA) was applied. Through Principal Component Analysis (PCA), 4 significant latent components, having eigenvalues >1, were found to account for the majority of the dataset's variance.

From Table 3 it is observed that PC1(first Principal Component) alone explained 46.6% of variance, and the first four components together explained 70.20% of total variation. The

Table 3. Principal Component Analysis (PCA) of the independent variables with attitude

PC	Explained Variance Ratio	Eigenvalues
PC1	0.4664	7.0344
PC2	0.0931	1.4036
PC3	0.0748	1.1277
PC4	0.0679	1.0244
PC5	0.0634	0.9563
PC6	0.0526	0.7928
PC7	0.0474	0.7151
PC8	0.0399	0.6022
PC9	0.0370	0.5584
PC10	0.0237	0.3572
PC11	0.0119	0.1800
PC12	0.0089	0.1338
PC13	0.0065	0.0984
PC14	0.0039	0.0592
PC15	0.0027	0.0404

heatmap illustrates the direction and magnitude of variable loadings, where darker red indicates a stronger positive association. The components capture underlying latent structures that influence respondents' attitudes toward NGOs.

PC1: Information accessing behaviour, extension contact, social participation, scientific orientation, family support, and health security all exhibit significant positive loadings. It documents the beneficiaries' assimilation into institutional and social networks, which directly improves their involvement in and exposure to NGO activities.

PC2: This component, which represents the socioeconomic standing and living standards of recipients, is significantly impacted by education, land holding, and housing conditions.

PC3: Age, sanitation facility, and drinking water all have a significant impact on this dimension. It shows how demographic maturity and basic amenities influence both the quality of life and access to benefits from development projects.

PC4: Age, annual income, and housing condition are important factors in this case. This element illustrates how age-related experience and financial stability lead to increased control over decisions made at the local level.

From the Table 4, the most significant predictor among the factors examined was Scientific Orientation (score = 0.183126), suggesting that people with a stronger scientific background are more sympathetic to non-governmental organizations. Health Security came in second (score = 0.170355), underscoring how important access to healthcare is in influencing how people view NGOs. Social participation (score = 0.112761) and family support (scoring = 0.159832) were also significant, indicating that family support and social networks increase people's involvement in NGO operations. The significance of information flow and advisory services was shown in the moderate contributions of variables like Extension Contact (0.088471) and Information Accessing Behaviour (0.086928) to the model. Remarkably, Material Possession scored 0.082331, which is consistent with regression results but indicates a more complex function in affecting views. Housing Condition (0.029233) was somewhat relevant but had a smaller impact. At the lowest end of the spectrum, factors with scores < 0.02 included

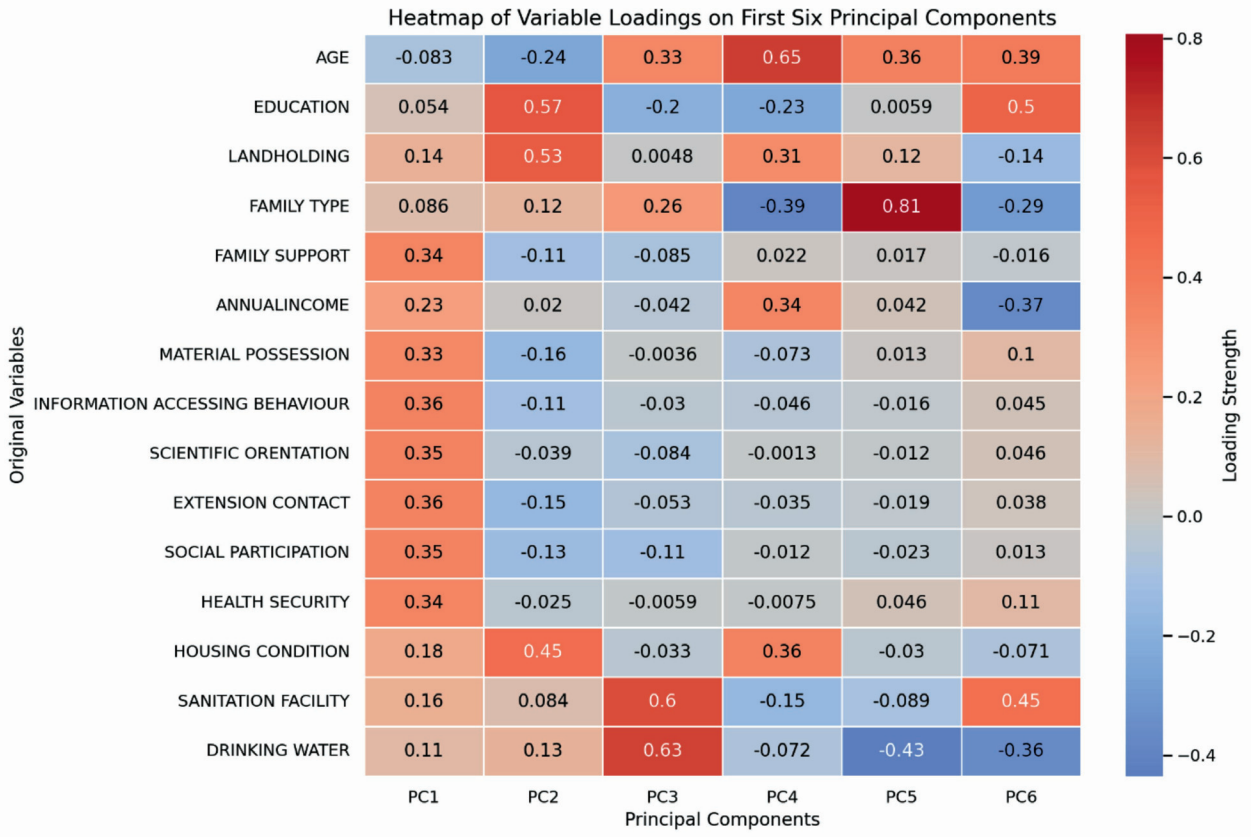

Figure 1. Heatmap illustrating the direction and magnitude of variable loadings

Table 4. Ranking of socio-economic variables based on feature importance (Random Forest Model)

Feature	Score
Scientific orientation	0.183126
Health security	0.170355
Family support	0.159832
Social participation	0.112761
Extension contact	0.088471
Information accessing behaviour	0.086928
Material possession	0.082331
Housing condition	0.029233
Education	0.017862
Annual income	0.015425
Sanitation facility	0.014148
Landholding	0.011738
Family type	0.011232
Drinking water	0.008476
Age	0.008080

education, annual income, landholding, family type, drinking water, sanitation facility, and age. According to these findings, views toward NGOs may be more strongly influenced by cognitive orientation, health access, and family or community integration than by traditional socio-economic level measures, notwithstanding their importance & demonstrates strong predictive accuracy, explaining 85% of the variation in the data with an R^2 of 0.85. The correctness of the model is confirmed by the error metrics, Mean Square Error (9.26) and Root Mean Square error (3.04), which indicate comparatively low prediction errors.

DISCUSSION

The study demonstrates that beneficiaries' opinions about NGOs are heavily influenced by their scientific orientation, social and family support systems. It was discovered that respondents who were younger, more educated, and more scientifically minded had a notably favourable opinion of NGOs, indicating more participation, trust, and openness to NGO-led projects (Gupta, 2014). These individuals showed higher levels of participation and openness towards NGO led programmes and activities. According to the regression analysis, 80.5% of the attitudinal variance could be explained by the statistically significant predictors of positive attitudes, which included housing conditions, health security, and scientific orientation. Beneficiaries with proper housing conditions expressed more favourable attitudes as NGOS supporting housing indirectly improved their quality of life. When respondents felt secure about their health due to NGO interventions, they were more appreciative and trusting. Scientific orientation emerged as the strongest predictor reflecting a strong association between openness to new ideas and favourable attitudes towards NGO led interventions. These results were further supported by the Random Forest model, which showed that scientific orientation was the best predictor, followed by social participation, family support, and health security. NGOs should involve family members while planning training, health interventions or awareness programmes. Individuals actively involved in social groups are more likely to receive timely information about NGO activities, training, schemes and support services. This exposure increases their awareness and understanding to make them more receptive towards NGO interventions. Individuals with openness to scientific ideas, innovation and modern practices showed a more positive attitude towards NGO interventions. Scientifically oriented individuals are more likely to comprehend and appreciate the programmes of NGOs resulting in stronger support and engagement. This correlates with the study that NGOs play an important role by introducing public service innovations and acting as a co-creation partner in government service innovations (Gesierich et al., 2025). Education, annual income, landholding, age, and sanitation facility were found to have little influence.

In general, cognitive engagement and fundamental changes in quality of life have a greater influence on views than conventional socioeconomic measures (Morais & Ahmad, 2011). NGOs must recognise that health is gateway to trust and engagement. Programmes focussing on health care can directly improve community participation. Investment in community health, sanitation, nutrition and hygiene will strengthen the NGO's credibility and long-term impact. Health security should be treated as both an entry point and development goal for broader social transformation. The findings showed a paradigm shift in how attitudes towards NGOS are formed. Rather than solely determined by demographic factors; attitudes are strongly shaped by community participation, improved quality of life and psychological readiness. These findings have important implications for NGOs for increasing the community participation and trust. They must prioritise interventions that enhance cognitive and social empowerment of community.

CONCLUSION

The study used statistical and machine learning methods to explore the multifaceted relationship between the socioeconomic traits of the beneficiaries and their attitudes towards NGOs. The regression results show that cognitive and perceptual factors, such as scientific orientation, health security and housing condition, have a greater influence on attitudes than conventional measures like education or income. NGOs should be encouraged to collaborate with Krishi Vigyana Kendras, agricultural universities and research institutes for scientific capacity building initiatives. NGOs should collaborate with health departments to conduct health camps, telemedicine services in rural and underserved areas. They should give importance to health outreach programmes focusing on nutrition education, maternity health and preventive health care. Social participation and family support were also significant factors, indicating that strong family support and social networks enhance beneficiaries' involvement in NGO activities and play a crucial role in shaping their attitudes towards such organisations.

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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Effect of Soybean Digital Farmer Field School on Knowledge Levels of Respondents in Maharashtra

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HIGHLIGHTS

- Digital Farmer Field School participants showed significantly higher knowledge of SOPs for soybean cultivation.
- Digital Farmer Field Schools reduce traditional barriers of age, gender, and land size by promoting experiential and group learning.
- The DFFS effectively reduces traditional socio-economic barriers to knowledge and provides expert guidance that enhances sustainable soybean farming practices.

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ABSTRACT

The study was conducted in 2023-2024 to assess the knowledge level of participant and non-participant farmers regarding Standard Operating Procedures (SOPs) for soybean cultivation in Ahilyanagar district, Maharashtra. An ex-post-facto research design was used, covering 150 soybean growers (75 participants and 75 non-participants) selected from fifteen villages across three talukas through multistage sampling and were assessed on their knowledge level of Standard Operating Procedures (SOPs)for soybean cultivation. Results showed that 76% of participants had high knowledge *versus* 6.67% of non-participants. Significant differences across nine key soybean cultivation aspects were confirmed by Z-tests. Higher knowledge among participants may be attributed to live expert-led sessions and collaborative group learning, fostering practical skills and experience sharing. Regression analysis identified education, scientific orientation, and techno-savviness as key predictors, while traditional socio-economic factors were less influential in participants' knowledge score on SOPs for soybean cultivation. The study highlights DFFS's potential to overcome traditional barriers, empowering farmers through enhancement in their knowledge about SOPs for soybean cultivation, ultimately promoting sustainable soybean cultivation and improved productivity.

INTRODUCTION

Soybean (*Glycine max* L.), widely recognized as the "golden bean," is one of the world's most important oilseed and pulse crops due to its considerable nutritional and economic value (Kadam et al., 2025). In India, and particularly Maharashtra, soybean occupies a central role in the agricultural economy. The crop is cultivated on nearly 3.8 million hectares in the state, providing both a vital source of dietary protein and a significant contributor to farm incomes. Despite extensive cultivation, statewide productivity remains below potential levels. Farmers face persistent challenges such as labour shortages, inadequate irrigation facilities, pest and disease infestations, limited availability of quality seeds, and restricted access to modern agronomic knowledge (Jaybhay et al., 2017). These production constraints highlight the urgent necessity for effective knowledge dissemination strategies to improve soybean cultivation and farmer livelihoods (Tiwari et al., 2023). Traditional agricultural extension systems in India have struggled to deliver

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timely and context-specific information, particularly to smallholder farmers. Within this gap, the Farmer Field School (FFS) model has emerged as a participatory, experiential approach to agricultural learning. Built on hands-on experimentation and group problem-solving, FFS enables farmers to engage directly with experts, enhance decision-making, and adopt improved practices. Empirical evidence indicates that FFS participation improves knowledge levels, accelerates the adoption of recommended practices, and results in increased yields and incomes (Amarathunga et al., 2023). Critically, FFS has also been shown to benefit marginalized groups–such as women farmers, low-literacy populations, and medium landholders–and to strengthen farmers' adaptive capacity to climate change (Jarial et al., 2024; Mdiya et al., 2024).

Nevertheless, the conventional FFS model presents noteworthy limitations. High costs per trained farmer, fiscal unsustainability at scale, and reliance on specialized expertise constrain widespread diffusion (Van et al., 2020). Moreover, its season-long, time-intensive structure poses barriers for farmers unable to attend weekly sessions (Singh et al., 2020; Maghinay & Guro, 2024). These limitations have prompted the search for alternative, technology-enabled approaches.

Digital Farmer Field Schools (DFFS) represent one such innovation. Integrating mobile applications, social media, and tablet-based learning, DFFS enhances accessibility and continuity of extension services (Witteveen et al., 2017). The rapid expansion of digital infrastructure during and after the COVID-19 pandemic has accelerated their adoption. Among the most prominent examples is the Digital *Sheti Shala* launched by the Paani Foundation in Maharashtra. Paani Foundation, founded in 2016 in Maharashtra, India, is a non-profit organization focused on sustainable water management and improving rural livelihoods. Its Satyamev Jayate Farmer Cup program encourages collective farming through *'gats'* (farmer groups) and promotes science-based agricultural and resource management practices. The program uses a competitive format with cash prizes to motivate farmers to adopt sustainable methods, improve productivity, and collaborate on bulk planning, purchasing, and sales, with participants evaluated on knowledge use, group activities, and sustainable techniques Focusing on soybean cultivation from 2021 onwards, the program combined expert-led digital sessions, participatory forums via WhatsApp, and standardized cultivation protocols. Strikingly, it attracted over 46,000 registrations, underscoring a strong farmer demand for digital extension solutions (Paani Foundation, 2022). Preliminary findings suggest substantial improvements in farmers' knowledge, productivity, and cost efficiency.

The initiative draws on Standard Operating Procedures (SOPs) for soybean cultivation curated by subject experts from State Agricultural Universities, thereby aligning scientific research with field-level practices. This bridging role not only democratizes access to technical guidance but also demonstrates the potential of digital formats to enhance sustainability in soybean farming.

METHODOLOGY

The study employed an ex-post-facto research design to investigate the knowledge levels of participant and non-participant farmers of Digital Farmer Field Schools on soybean cultivation. This design was selected because the variables under investigation had already manifested, and the researcher lacked direct control over the independent variables due to their prior occurrence and inherent non-manipulability. The research was conducted in Ahilyanagar district of Maharashtra State, covering three talukas: Ahilyanagar, Parner, and Sangamner. The study area was characterized by diverse soil types ranging from laterite to medium black soils, with an annual rainfall of 345 mm and an average temperature of 24.0°C. The cropping pattern included major Kharif crops such as bajra, groundnut, soybean, and moong, while Rabi crops comprised jowar, wheat, sugarcane, and chickpea. The selection of this district was purposive, as *Paani* Foundation had organised Digital Farmer Field Schools for farmers across 15 villages in these talukas. A multi-stage sampling procedure was implemented for respondent selection. Initially, *Ahilyanagar* district was purposively selected based on the presence of Digital Farmer Field Schools. Subsequently, three talukas were chosen from the district based on the higher number of participants of DFFS, followed by the selection of five villages from each taluka, totalling fifteen villages. From each village, 5 participants and 5 non-participants each are selected based on the DFFS participant farmers data provided by PAANI Foundation. This sampling strategy ensured balanced representation and facilitated comparative analysis between the two groups, resulting in a total sample size of 150 farmers comprising 75 participants and 75 non-participants.

To assess knowledge levels, a structured schedule was developed based on practices disseminated through the Digital Farmer Field School on soybean. The knowledge assessment was done using specifically designed knowledge test instrument. Further, to know the difference between knowledge level of participants and non-participants Digital Farmers Field School 'Z' test was applied. Relationship with socio-personal characteristics was established, and multiple regression was performed to analyse the factors affecting the knowledge level about Standard Operating Procedures (SOPs) for soybean cultivation of respondents.

RESULTS

Knowledge level of participant and non-participant farmers about SOPs for soybean cultivation

Analysis of respondents' knowledge levels on SOPs for soybean cultivation revealed pronounced differences between Digital Farmer Field School participants and non-participants, emphasizing the influence of the intervention (Table 1). Participant farmers demonstrated predominantly high knowledge levels (76.00%), with

Table 1. Distribution of respondents by knowledge level on SOPs for soybean cultivation

Knowledge level	Participant farmers (n=75) %	Non-Participant Farmers (n=75) %	Overall %
Low (below 32.02)	0.00	64.00	32.00
Medium (32.03 to 40.85)	24.00	29.33	26.67
High (above 40.86)	76.00	6.67	34.44
Total	100.00	100.00	100.00

Mean-36.44; S.D -4.42

Table 2. Aspects-wise comparison of the level of knowledge regarding important aspects of SOPs for soybean cultivation.

Aspects	Participant		Non-Participant		Z value
	Mean	S.D.	Mean	S.D.	
Pre-cultivation	3.74	0.46	3.16	0.93	4.90**
Seed	8.37	0.65	6.55	1.77	8.53**
Sowing	4.77	0.45	4.00	0.77	7.49**
Nutrient Management	2.78	0.44	2.36	0.65	4.69**
Water Management	4.99	0.60	3.88	1.09	4.27**
Weed Management	2.73	0.52	1.54	0.77	10.94**
Pest Management	8.12	0.78	5.29	2.39	9.73**
Disease Management	2.40	0.56	1.72	0.74	6.28**
Harvesting, Threshing and Storage	3.69	0.57	3.04	1.43	3.28**
Pooled	41.32	1.47	31.98	4.07	11.67**

**1% level of significance

the remainder exhibiting medium knowledge (24.00%) and none falling in the low category. Non-participant farmers showed an inverse pattern, with the majority clustered in low knowledge (64.00%), followed by medium (29.33%) and high (6.67%) categories. The overall sample distribution indicated 34.44% high knowledge, 26.67% medium knowledge, and 32.00% low knowledge levels.

Aspects-wise comparison of the level of knowledge

Statistical analysis using Z-test revealed significant differences between participant and non-participant farmers across all nine aspects of soybean SOPs as shown in Table 2. The calculated Z-values exceeded tabulated values at the 1% significance level for pre-cultivation, seed, sowing, nutrient management, water management, weed management, pest management, disease management, and harvesting practices. The overall Z-value (11.67) was significantly higher than the tabulated value, confirming substantial knowledge differences. Mean knowledge scores were higher for participants (41.32) compared to non-participants (31.98).

Association between profile characteristics and knowledge level of participant and non-participant farmers

Table 3 and Table 4 present correlation analysis, which showed distinct patterns for both groups. Among participant farmers, education, scientific orientation, and techno-savviness were positively significant at 1% probability level, while landholding, social media viewing behavior, and cosmopoliteness were significant at 5% level. Age, gender, area under soybean cultivation, farming experience, and annual income showed non-significant relationships. For non-participant farmers, scientific orientation was significant at 1% level, while ten variables (age, education, gender, landholding, area under soybean cultivation, farming experience, annual income, social media viewing behavior, techno-savviness, and cosmopoliteness) were significant at 5% level.

Relationship between profile characteristics and knowledge level of participant and non-participant farmers

Multiple regression analyses in Table 3 and Table 4 identify different predictors for each group. For participant farmers, scientific orientation (β=0.376), techno-savviness (β=0.345), and social media viewing behavior (β=0.292) emerged as significant positive predictors, with the model explaining 93.70% of knowledge variation (R^2=0.937). For non-participant farmers, scientific orientation (β=0.267) was significant at 1% level, while education (β=0.242), area under soybean cultivation (β=0.219), techno-savviness (β=0.224), and cosmopoliteness (β=0.168) were significant at 5% level, collectively explaining 37.40% of knowledge variation (R^2=0.374).

Table 3. Relationship between the independent variables of participants and their knowledge level

		Participant (N=75)		
		Correlation with Knowledge Level (r)	Regression Coefficient	t value
X_1	Age	-0.043	-0.052	-0.34
X_2	Education	0.608**	0.072	0.71
X_3	Gender	0.175	0.147	1.39
X_4	Land Holding	0.374*	-0.041	-0.41
X_5	Area Under Soybean Cultivation	0.113	0.087	0.86
X_6	Farming experience	0.099	0.026	0.37
X_7	Annual Income	0.156	0.107	1.12
X_8	Scientific Orientation	0.421**	0.376**	3.01
X_9	Social media viewing behaviour	0.366*	0.292**	2.49
X_{10}	Techno-savviness	0.474**	0.345**	2.87
X_{11}	Cosmopoliteness	0.313*	0.149	1.44
	R^2	0.9370		

**Significant at 0.01 level of probability; *Significant at 0.05 level of probability; Coefficient of determination (R^2) = 0.9370

Table 4. Relationship between the independent variables of non-participants and their knowledge level

		Non-Participant (N=75)		
		Correlation with Knowledge Level (r)	Regression Coefficient	t value
X_1	Age	0.142	0.121	0.57
X_2	Education	0.379*	0.242*	1.42
X_3	Gender	-0.243*	-0.127	-1.00
X_4	Land Holding	0.277*	0.134	0.64
X_5	Area Under Soybean Cultivation	0.250*	0.219*	1.24
X_6	Farming experience	0.209*	0.115	0.41
X_7	Annual Income	0.305*	0.138	0.76
X_8	Scientific Orientation	0.378**	0.267**	1.56
X_9	Social media viewing behaviour	0.264*	0.106	0.39
X_{10}	Techno-savviness	0.236*	0.224*	1.31
X_{11}	Cosmopoliteness	0.276*	0.168*	1.02
	R^2	0.3740		

**Significant at 0.01 level of probability; *Significant at 0.05 level of probability; Coefficient of determination (R^2) = 0.3740

DISCUSSION

The results clearly indicate that participant farmers of DFFS possess considerably higher knowledge of soybean SOPs compared to non-participants. This difference highlights the effectiveness of digital farmer field schools in knowledge enhancement. The structured training, active expert involvement, and collaborative group learning in DFFS sessions provide participants with practical insights and contextual solutions, which contribute to higher knowledge acquisition (Nitin & Indu, 2017; Rajan et al., 2021; Patel et al., 2022; Banerjee et al., 2022; Rakesh et al., 2022; Thangjam & Jha, 2025). The aspect-wise significant differences further reinforce the effectiveness of DFFS. Farmers exposed to DFFS demonstrate superiority across all domains of cultivation, particularly in areas requiring technical expertise such as pest and disease management. This suggests that digital trainingdo not merely provide basic knowledge but significantly enhance farmers' scientific understanding of complex issues (Samadder et al., 2023). The higher mean scores among participants demonstrate that digital learning environment and structured content create substantial knowledge gaps compared to traditional information access methods. The association of profile characteristics with knowledge levels also reveals important insights. Among participants, knowledge was significantly influenced by education, scientific orientation, and techno-savviness rather than traditional variables like landholding size, age, or income. This underlines the role of cognitive and technology-linked factors in successful digital farmer field school. The insignificance of demographic variables suggests that participation in DFFS reduces dependency on socio-economic status, thereby democratizing access to agricultural knowledge. The findings resonate with Samadder et al. (2023), who emphasized the transformational potential of digital platforms in overcoming structural barriers. In contrast, for non-participants, knowledge acquisition continues to be associated with a wider set of socio-economic characteristics, including education, area under soybean, and cosmopoliteness. This shows that, in the absence of structured digital interventions, access to agricultural knowledge is still governed by conventional factors such as land holding and educational background. Their lower R^2 value (37.40%) compared to participants (93.70%) also demonstrates weaker explanatory power of predictors, implying that traditional knowledge pathways remain fragmented and less efficient. The regression results further substantiate these patterns. For participants, the strongest predictors were scientific orientation, techno-savviness, and social media viewing behaviour, reflecting the synergy between digital learning and farmers openness to technology. The convergence of scientific orientation, techno-savviness, and social media viewing behavior among farmers demonstrates that digital training programs achieve maximum effectiveness when participants possess inherent technological readiness, thereby supporting the hypothesis that these traits create a synergistic effect in digital agricultural learning environments (Oli et al., 2025). On the other hand, non-participants rely more heavily on formal education and farm characteristics to acquire knowledge. This significant difference indicates that digital farmer field school platforms help farmers transcend structural inequalities of landholding or annual income by fostering curiosity, scientific outlook, and adaptability. Thus, the discussion highlights that DFFS act as a strong equalizing force in rural knowledge dissemination. While traditional access to knowledge remains confined to socio-economic hierarchies, digital interventions empower farmers based on learning-oriented traits, thereby promoting more inclusive, equitable, and effective knowledge distribution in soybean cultivation practices.

CONCLUSION

A clear difference in the knowledge level of participant and non-participant farmers in all nine aspects of soybean SOPs was observed. These findings show that Digital Farmer Field Schools (DFFS) have great potential to make farming knowledge accessible to all farmers. Unlike traditional methods, DFFS breaks down barriers like age, gender, land size, or income, which often limit who can get farming information. Instead, it focuses on helping farmers learning by doing, with experts guiding them and farmers learning together in groups. This way, farmers become confident in understanding and applying scientific farming techniques on their

own. Ultimately, this helps improve their crop yields and makes farming more sustainable, especially for soybean cultivation.

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

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Global Research on Nutraceutical Crops: Bibliometric Analysis and the Latent Potential of Agricultural Extension

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HIGHLIGHTS

- A sharp increase was observed after 2020, aligning with greater health consciousness during the COVID-19 pandemic.
- Only a few terms related to agricultural extension, such as technology transfer and vertical farming, could be identified.
- At the country level, India stood out as the clear global leader, contributing more than twice and far ahead of China

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ABSTRACT

Nutraceutical crops are gaining importance for their role in improving nutrition, supporting health, and promoting sustainable agriculture. Yet, their impact depends on how effectively this knowledge is transferred to farmers through agricultural extension. This study analysed global research on nutraceuticals and agricultural extension using 3,485 Scopus-indexed publications between 2015 and 2024, with the primary objective of assessing the role of agricultural extension in bringing nutraceuticals to the grassroots level. Bibliometric tools (Biblioshiny and VOSviewer) were used to examine publication growth, authors, contributing countries, keyword patterns, thematic clusters, and collaboration networks. The analysis reveals steady progress over time, accelerating after 2020. India emerged as the clear global leader, followed by the USA and China, with institutional participation from universities such as Charles Sturt University and King Saud University. Research activity covered two main areas: themes related to agriculture and sustainability, such as food security, climate change, and farming practices; and studies on plant-derived compounds, including phytochemicals, antioxidants, and bioactive substances. The most important finding of this study is the near absence of extension-related themes. Although the search strategy included extension terms, they did not emerge as clusters or trends, highlighting a significant research gap.

INTRODUCTION

Nutraceuticals are gaining global attention as a crucial link between food, health, and sustainability. Nutraceuticals are defined as substances derived from food items with potential medicinal benefits (Souyoul et al., 2018). The term was introduced in 1989 by combining "nutrition" and "pharmaceutical," though its use has often been ambiguous (Gul et al., 2016). Beyond meeting nutritional requirements, they are valued for their potential to prevent and manage chronic diseases (Anand & Bharadvaja, 2022). It is frequently conflated with "dietary supplements," yet an important distinction exists. Dietary supplements primarily fulfil nutritional deficiencies, while nutraceuticals aim to prevent or support treatment of diseases (Mukherjee et al., 2017). This convergence of food and medicine has become a cornerstone of nutrition, with benefits ranging from improved immunity to chronic disease management (Telessy, 2019). Commonly studied nutraceuticals include omega-3 fatty acids, turmeric, garlic, and green tea, recognized for their therapeutic potential (Keservani et al., 2017; Vinayagam et al., 2023; Hay et al., 2019; Sarma et al., 2023).

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Consumption of nutraceuticals has risen steadily, particularly after the Covid-19 pandemic. Increased health awareness has generated strong consumer demand (Santini et al., 2023). However, consumer interest alone is insufficient unless availability is ensured across geographies. Engaging farmers is therefore crucial to bring nutraceuticals to the food chain. In the Indian context, this is particularly important given the country's immense agricultural potential, being the second largest producer of rice and wheat and the top producer of pulses globally (Malik et al., 2023). Agricultural extension can play an essential role in ensuring that advances in nutraceutical science are translated into practice by equipping farmers with the knowledge and skills to cultivate and promote nutraceutical crops. Extension services can also provide platforms for organizing and applying knowledge across the agricultural sector, enabling research outcomes to be effectively adapted at the grassroots level (Nain et al., 2024).

Furthermore, recognizing farmer-led innovations is equally vital, as grassroots efforts often provide low-cost solutions for value addition and marketability. Yet such innovations remain under-recognised and lack institutional support, limiting their contribution to agricultural development (Nain et al., 2019). Nutraceutical crops may provide grassroots farmers with opportunities for crop diversification, entry into high-value markets, and potentially better profits than traditional staples (Mbelebele et al., 2024). Agriculture in India is evolving from traditional small-scale farming to approaches that focus on profitability and market opportunities, creating a need to support farmers in exploring innovative crop options. In this context, agricultural extension services play a key role by providing technical guidance, entrepreneurial support, and institutional connections that may help farmers adopt nutraceutical crops as sustainable sources of income (Kademani et al., 2024). The primary objective of this study is to identify and assess the role of agricultural extension, if any, in translating nutraceutical science from research settings to the grassroots level.

METHODOLOGY

This study was designed to conduct a bibliometric analysis of research on nutraceutical crops and agricultural extension. Data were collected from the Scopus database, which provides comprehensive coverage of peer-reviewed journals, books, and conference proceedings across agricultural sciences, life sciences, and allied disciplines. To ensure accuracy, breadth, and relevance, a carefully refined search string was constructed using the "ALL" field tag in Scopus to cover the core concepts: ALL ("Nutraceuticals" OR "Medicinal plants" OR "Phytochemicals" OR "Natural products" OR "Nutri-crops") AND ("Agricultural extension" OR "Extension services" OR "Farmer education" OR "Technology transfer" OR "Advisory services" OR "Agricultural innovation").

The initial execution of this search string retrieved 4,971 documents. A time filter was then applied to restrict the publication period from 2015 to 2024, which reduced the results to 3,746 documents. Documents were further filtered by selecting four specific categories, Article, Review, Conference Paper, and Book Chapter, a step that yielded 3,573 documents. Finally, an English language filter was applied, resulting in a retrieval count of 3,485 documents. This final dataset was retrieved for further analysis, ensuring a sufficiently large and representative dataset for meaningful interpretation.

The dataset was analysed using Bibliometrix (Biblioshiny 4.5.0), which generated descriptive indicators such as annual scientific production, prolific authors, institutional output, country-wise contributions, and keyword dynamics (Aria & Cuccurullo, 2017; Roy et al., 2024). Bibliometrix provided both quantitative and visual insights into publication trends, authorship patterns, institutional collaborations, and thematic evolution, thereby ensuring a multidimensional representation of the field. To complement these results and strengthen interpretation, network-based mapping was performed using VOSviewer (version 1.6.20), which created keyword co-occurrence networks using author keywords and visualized 420 keywords divided into eight clusters of related research topics, thus offering an additional layer of analytical depth (Wong, 2018). The bibliometric measures applied in this study included annual publication growth, leading authors, contributing institutions and countries, keyword frequency and co-occurrence, thematic mapping, and collaboration networks. All analyses were carried out following established bibliometric procedures to ensure reproducibility, transparency, and validity. The combined use of descriptive indicators, science-mapping, and network analyses therefore provides a more nuanced, reliable, and critically informed understanding of research activity, scholarly influence, and thematic development in the field of nutraceuticals and agricultural extension during the study period. During the initial processing phase in Biblioshiny, the software automatically removed 45 documents due to incomplete metadata, resulting in a dataset of 3,440 documents for the bibliometric analysis.

RESULTS

The results of the bibliometric analysis, based on 3,485 Scopus-indexed publications, provide a comprehensive overview of global research activity in the field of nutraceutical crops. Annual scientific production is first shown to illustrate the growth trajectory of publications over the last decade. Country- and institution-wise contributions were then reported to identify regional leadership and international participation. The conceptual structure of research is revealed through keyword co-occurrence patterns, thematic clusters, and the evolution of research themes across time slices, offering insights into the changing priorities of the field. Thematic mapping was further presented to differentiate between well-established, emerging, and niche areas of investigation. The intellectual structure has been demonstrated through core journals that formed the scholarly foundation of this research, while the social structure has been described by mapping collaboration networks among countries.

Descriptive analysis

The annual scientific production showed steady growth over the last decade, increasing from 112 documents in 2015 to a peak of 666 in 2024 (Figure 1). A sharp increase was observed after 2020, aligning with greater health consciousness during the COVID-19 pandemic. This suggests that nutraceuticals are increasingly being recognized as part of the solution to health resilience and sustainable agriculture.

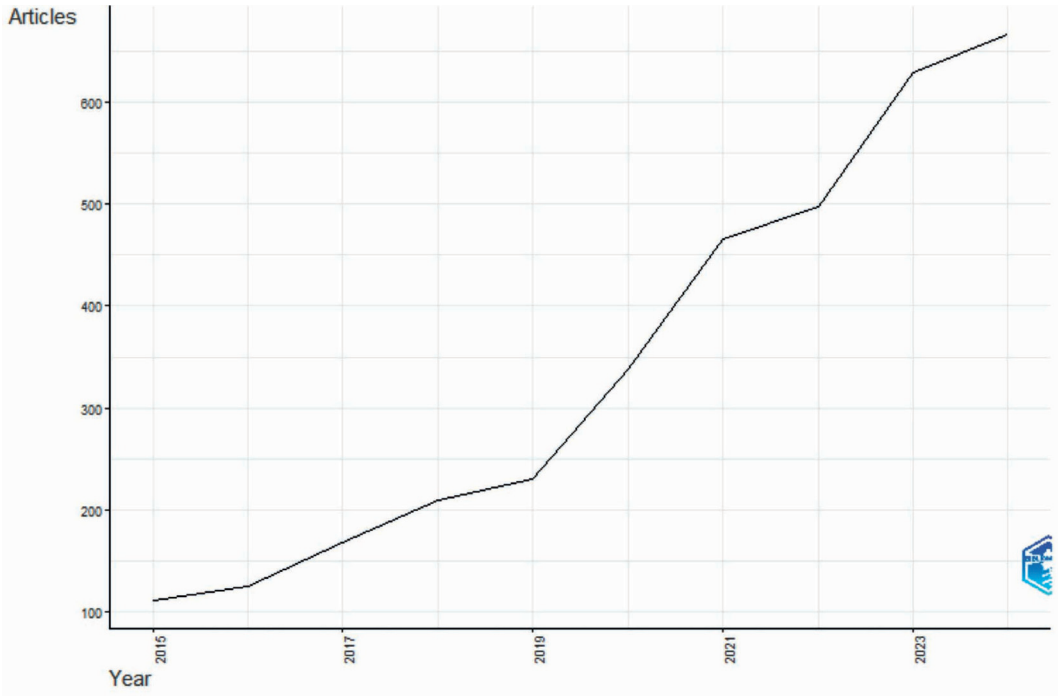


Figure 1. Annual scientific production

When looking at institutions, Charles Sturt University led with 180 publications, followed by King Saud University and the Vietnam Academy of Science and Technology with 60 each (Table 1). Among the most relevant affiliations, Indian institutions also featured, reflecting the country's strong institutional presence and leadership in nutraceutical research.

Conceptual structure of research

The keyword co-occurrence analysis organized 420 author keywords into eight clear clusters (Figure 2). These clusters represent diverse research themes ranging from agroecology and sustainable farming, natural compounds and phytomedicine, allelopathy and stress biology, ethnobotany and indigenous knowledge, anti-inflammatory agents, antioxidant activity, to fermentation and traditional foods. Together, these themes illustrate the dual orientation of the field towards system-level agricultural sustainability and detailed bioactive compound research. Within the keyword co-occurrence analysis, only a few terms related to agricultural extension, such as technology transfer and vertical farming, could be identified. Even within the clusters, these appeared with very limited visibility, suggesting that extension-oriented themes occupy only a marginal position in the overall research landscape.

Table 1. Most relevant affiliations

Affiliation	Articles
Charles Sturt University	180
King Saud University	60
Vietnam Academy of Science and Technology	60
School of Biosciences and Technology	57
Graduate University of Science and Technology	54
Prince of Songkla University	52
Jouf University	47
Maejo University	46
VIT School of Agricultural Innovations and Advanced Learning (VAIAL)	46
Chiang Mai University	45
University of Agriculture	44
Government College University Faisalabad	43
Shoolini University of Biotechnology and Management Sciences	43
Kyungpook National University	42
Tamil Nadu Agricultural University	42

The trend topics analysis (Figure 3) shows how the focus of research had shifted over time. In the early phase (2015–2017), themes such as weed management, organic agriculture, and biorefinery were more prominent, reflecting attention to farming practices and ecological management. By 2018–2020, the emphasis moved towards plant-based mechanisms, with keywords like polyphenols and allelopathy highlighting interest in phytochemical properties and plant interactions. In recent years (2021–2024), research has increasingly focused on antioxidants, food security, and climate change. This progression demonstrated a transition from practice-oriented agricultural themes to compound-focused investigations and, more recently, to health-oriented and sustainability-driven topics. Extension-related keywords were absent from the trend map, which reflects a gap in current research and point to the need for greater attention on how this knowledge could be disseminated effectively to farmers and stakeholders through agricultural extension.

The three-fields plot (Figure 4) shows an overview of the relationships between prolific authors, frequently used keywords, and institutional affiliations in the field of nutraceutical crops and agricultural extension. While the exact linkages between individual authors, keywords, and institutions are less distinct in the visualization, the plot as a whole highlights the diversity of research contributions and the spread of scientific activity across different themes and organizations. Authors such as Hussain M., Radha R., Senapathy M., and Kumar M. appeared among the most productive

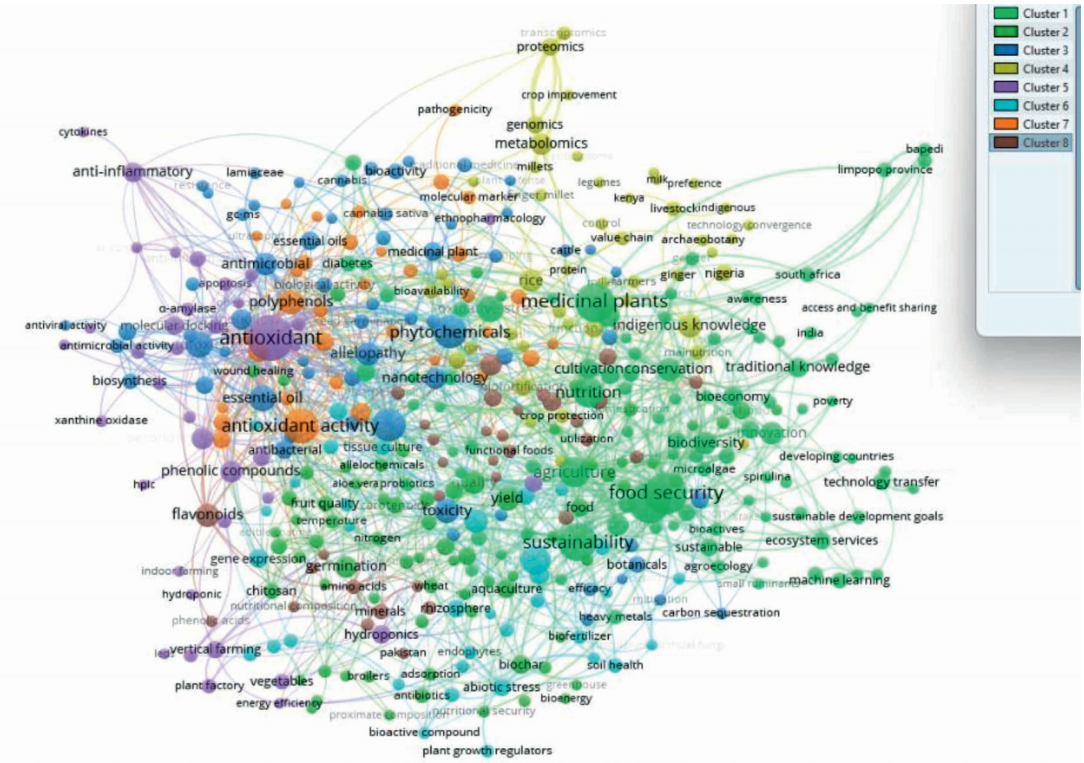


Figure 2. Keyword co-occurrence map

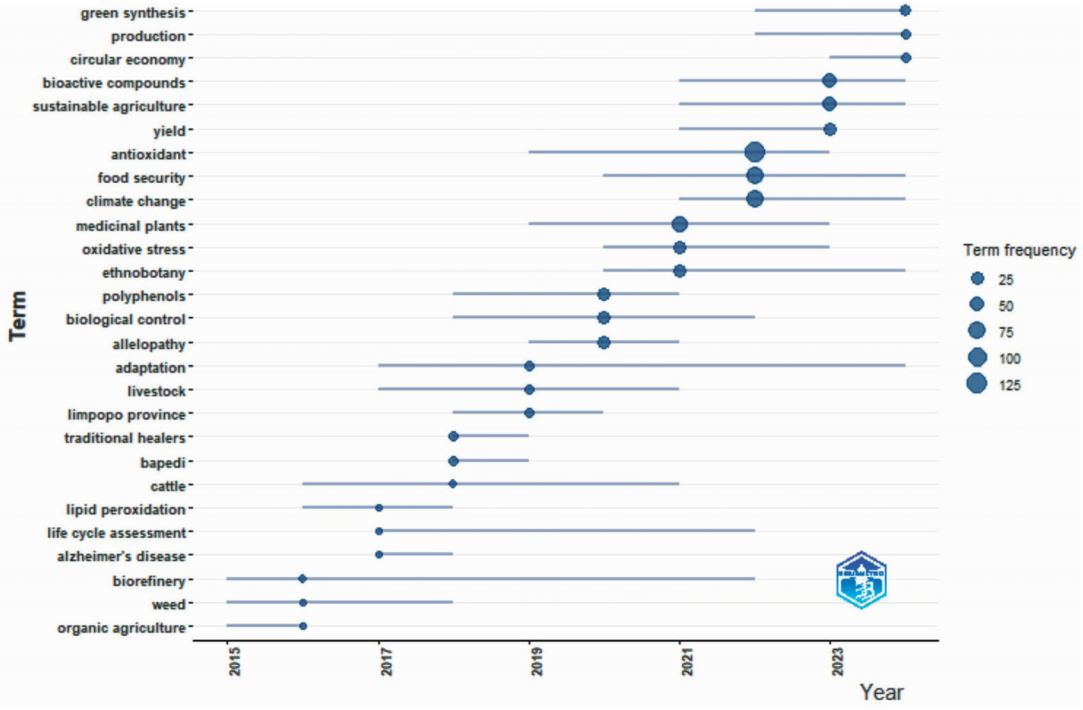


Figure 3. Keyword trend analysis

contributors, with keywords like antioxidant, medicinal plants, and phytochemicals standing out as recurring areas of focus. Prominent institutions included Charles Sturt University, King Saud University, and the Vietnam Academy of Science and Technology feature strongly, reflecting the global distribution of research capacity. Indian researchers and institutions feature strongly in the plot, reflecting the country's leading contribution identified in the country-level analysis. Taken together, the plot highlights the collaborative and cross-disciplinary nature of this field and suggests how clusters of authors, keywords, and institutions collectively shape its growth. It also signals potential opportunities for strengthening networks and expanding the reach of nutraceutical research into extension contexts.

The thematic map (Figure 5) highlighted 10 research clusters across two dimensions: centrality (relevance) and density (development). Motor themes such as sustainable agriculture,

Figure 4. Three-fields plot

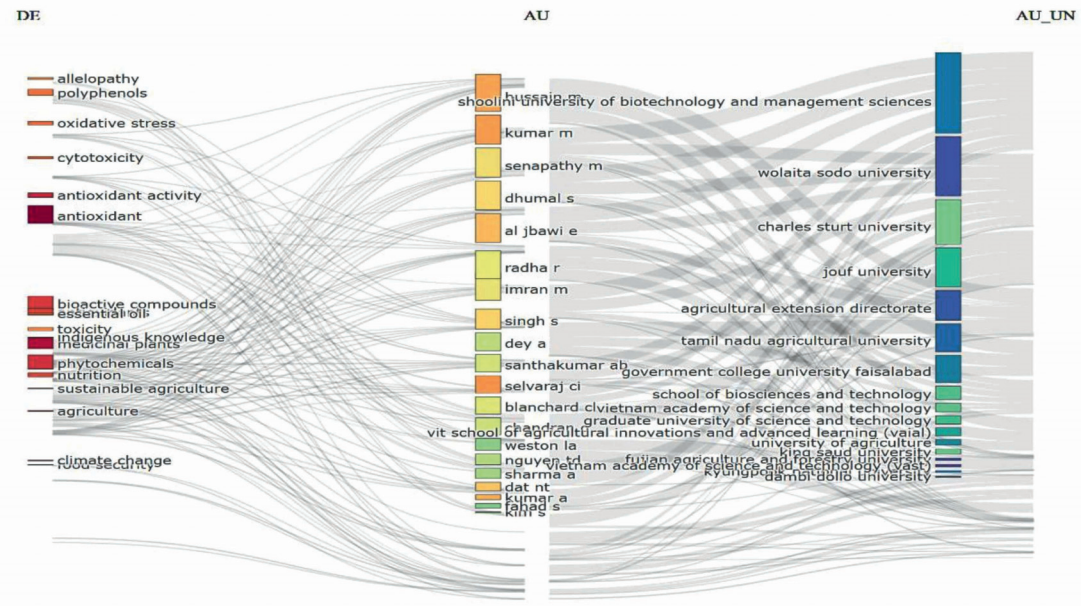
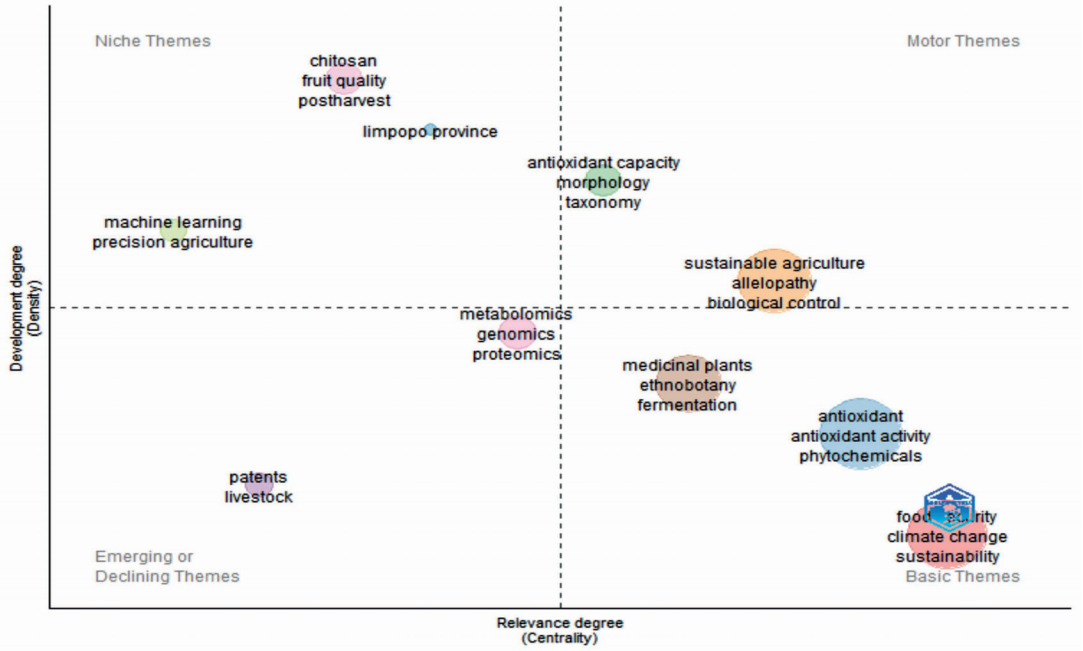


Figure 5. Thematic map



allelopathy, and biological control represented well-established areas driving the field. Niche themes like chitosan, fruit quality, and post-harvest were highly developed but less central. Emerging or declining themes including metabolomics, genomics, and proteomics required further exploration, while basic themes such as food security, climate change, and sustainability remained highly relevant yet demanded more structured research.

Thematic evolution across the three periods (2015-2020, 2021-2023, and 2024) shows how research on nutraceutical crops has gradually moved from narrow biochemical studies to broader and more technologically advanced approaches. In the first phase, most work focused on identifying and describing compounds such as antioxidants and polyphenols, reflecting an early effort to establish their health benefits. The second phase highlighted themes such as climate change, metabolomics, and antioxidant activity, showing that nutraceutical research was expanding to include both environmental concerns and advanced analytical tools. In the most recent period, topics such as food security, genomics, and antioxidants have gained prominence, pointing to renewed attention on sustainability and health outcomes alongside the use of cutting-edge molecular approaches.

Intellectual structure of research

The intellectual base of research on nutraceutical crops and agricultural extension is spread across a diverse range of journals, which reflect the interdisciplinary nature of this field (Figure 7). Important contributions were found in outlets such as *Asian Pacific Journal of Science and Technology, Plants, Sustainability*, and *Agronomy*. Each of these journals highlights a different perspective, from plant sciences and crop management to health, sustainability,

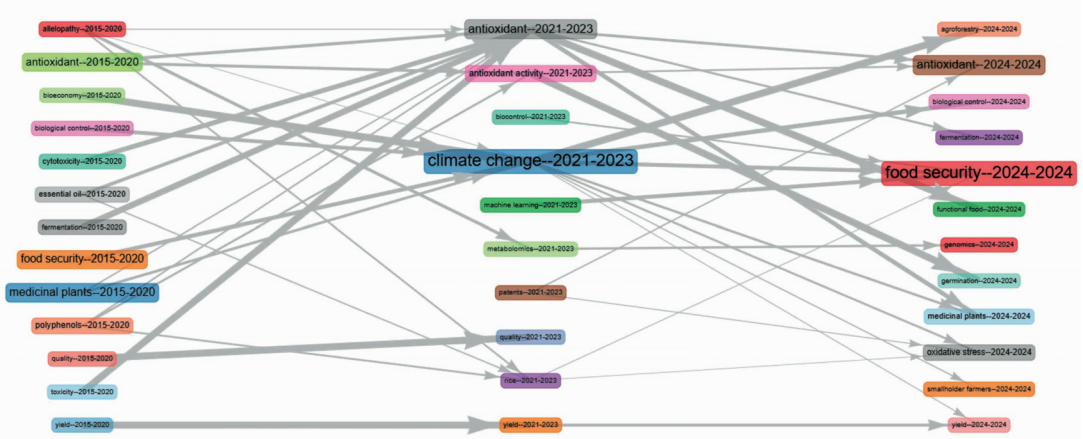


Figure 6. Thematic evolution

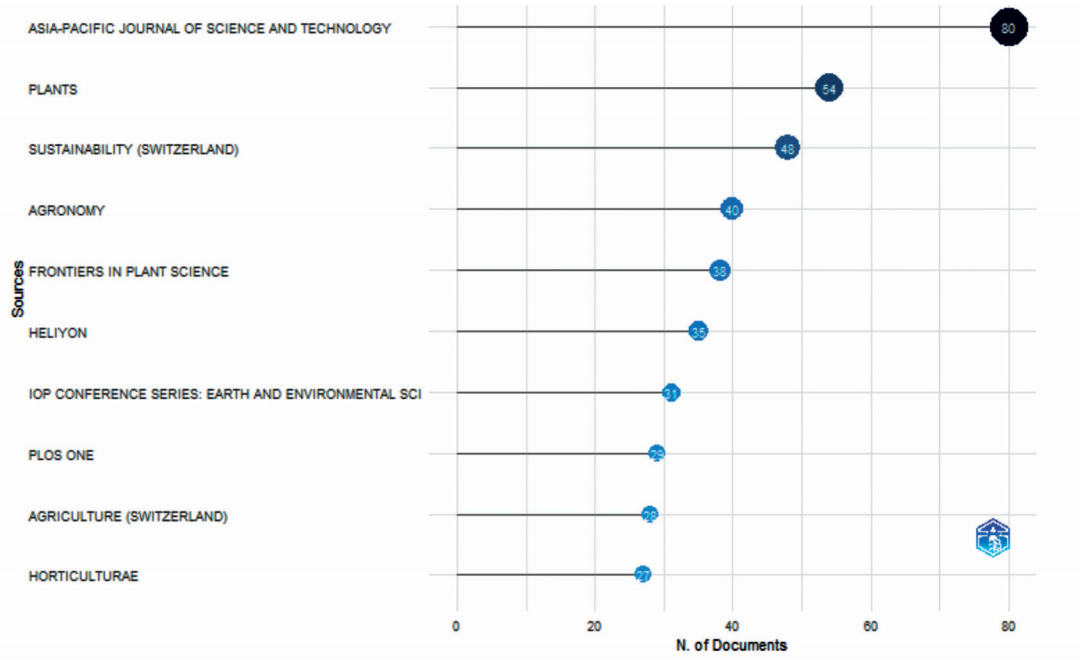


Figure 7. Most relevant sources

and policy. The distribution shows that nutraceutical research is not confined to one discipline but is drawn from agriculture, life sciences, food technology, and environmental studies.

Taken together, the journals form a layered structure. Some remain centred on compounds and health outcomes, others give priority to agricultural practices and productivity, while a growing share situates nutraceuticals within the broader sustainability agenda. This mix shows that the field is dynamic and strategically located at the intersection of agriculture, nutrition, health, and environmental responsibility. At the same time, extension-focused journals were largely absent from this picture. Their absence underlines the earlier finding that farmer education, technology transfer, and grassroots dissemination have not yet become integral to the intellectual foundations of nutraceutical research. Addressing this gap would help ensure that the growing body of knowledge reaches farming communities and contributes more directly to practice.

Social structure of research

The social structure of research on nutraceutical crops is shaped by international collaboration, with India, the United States, and China emerging as the leading hubs (Table 2). At the country level, India stood out as the clear global leader with 2,005 publications, contributing more than twice as much as the USA (920) and far ahead of China (689) (Table 2).

The significant output by India demonstrates a strong commitment to the field of nutraceuticals and establishes India as the most influential source of nutraceutical publications globally. Across Asia, the overall contribution was strong, but progress was uneven. Countries like India, China, and South Korea published heavily, while others such as Malaysia and Bangladesh remained on the margins, indicating that leadership was concentrated in only a few centres. African countries were also less visible in these networks.

DISCUSSION

The bibliometric analysis highlights the steady rise of research on nutraceutical crops and agricultural extension, with a sharp increase after 2020 reflecting health awareness and sustainability concerns. India emerged as the global leader, followed by the USA and China, reflecting its roots in Ayurveda and a growing research

Table 2. Country scientific production

Region	Frequency
India	2005
USA	920
China	689
South Korea	674
Pakistan	597
Thailand	534
Australia	454
South Africa	382
Nigeria	325
Italy	321
Indonesia	277
Saudi Arabia	264
Bangladesh	230
Malaysia	230
Ethiopia	217

base in agricultural and life science universities (Kizhakkeveettil et al., 2024; Kaur & Chakraborty, 2025). It underlines India's central role in shaping nutraceutical research through both cultural heritage and modern innovation (Silpi, 2025). China's research leadership is partly rooted in its long history of traditional medicine, providing a strong foundation for modern nutraceutical studies (Shen et al., 2017). The United States led through its powerful research infrastructure funding, and global influence in agriculture and health sciences (Odeyemi et al., 2024). While Africa and parts of Asia remain underrepresented, regional collaboration can foster inclusivity in nutraceutical research. In Nigeria, the high level of smart phone ownership and willingness to use generative AI tools indicated strong potential for digital transformation in agriculture and advocated digital literacy, infrastructure development, and inclusive access to extension services and AI-based tools (Shitu et al., 2025). Institutions such as Charles Sturt University and King Saud University were among the leading contributors, but several Indian universities also stood out as important affiliations. This highlights that regional priorities and traditional knowledge continue to shape global nutraceutical research, with India's strong presence in the three-fields plot reflecting its central and expanding role in the field (Malve & Bhalerao, 2023).

The conceptual analysis shows two orientations; system-level themes such as agroecology, food security, and sustainability, and compound-level research on phytochemicals, antioxidants, and bioactive metabolites. Over time, research shifted from traditional plant-based studies to advanced, technology-driven approaches like metabolomics and genome editing. India mirrors this progression, moving from studies on medicinal plants to research integrating sustainability and modern analytical tools (Pramanik et al., 2025). The intellectual analysis reveals how earlier publications were more commonly placed in plant science and pharmacology journals, emphasizing the identification of bioactive compounds and their therapeutic potential. Recently, research has shifted towards sustainability and agronomy journals, reflecting a broader focus on food security, climate resilience, and public health (Wichienchot & Ishak, 2017). This trend also aligns with the global shift towards plant-based diets, driven by the environmental and ethical costs of livestock production, including high greenhouse gas emissions, resource use, and biodiversity loss (Chen & Carcea, 2023). Nutraceutical crops are now positioned within this movement, valued for their health benefits and as part of sustainable food systems, including cereals, legumes, fruits, nuts, and emerging sources such as algae and mushrooms.

A striking observation of this study is the near invisibility of agricultural extension in the global nutraceutical research landscape. Although extension-related terms were included in the search, they did not form significant clusters or trends. This absence reflects a structural gap, as systems for translating nutraceutical knowledge to farmers and communities remain underdeveloped. The findings have important implications. Policymakers can use this evidence to develop extension strategies that integrate nutraceutical crops into mainstream agriculture and public health initiatives. Lessons may be drawn from climate-smart agriculture, where extension services promoted productivity, resilience, and sustainability by raising farmer awareness, promoting ICT tools, and facilitating joint learning among farmers, researchers, and extension workers (Raj & Garlapati, 2020). Similar innovative and participatory approaches can be adapted to ensure that nutraceutical crops move beyond laboratory and field trials and are embedded in farmer-oriented programs and community-level initiatives.

Extension workers can help farmers understand the benefits of nutraceutical crops, provide training on cultivation practices, and support value addition and marketing at the local level (Msuya et al., 2017; Singh et al., 2023). Including nutraceuticals in extension programs allows farmers to gain income and improve community nutrition. Farmer-led innovations, often simple, low-cost, and locally adapted, can be scaled through extension networks (Usadadiya & Rathod, 2025).

CONCLUSION

This study mapped global research on nutraceutical crops and agricultural extension between 2015 and 2024, confirming consistent growth and strong contributions from Asia. The analysis revealed dual themes: system-level topics like sustainability and food security, and compound-level studies on bioactive metabolites, reflecting the field's interdisciplinary nature. The absence of extension-related themes is the most pressing gap. For nutraceutical crops to benefit farmers, future research must move beyond lab and field trials to embed extension strategies that ensure effective dissemination, adoption, and value creation. Future priorities include emerging technologies, regional comparisons, and international collaborations to strengthen nutraceuticals' role in public health and sustainable agriculture. Recommendations include taking initiatives to integrate these crops into mainstream agriculture and drawing lessons from participatory climate-smart agriculture approaches. Extension workers should be utilized to provide cultivation training, support local value addition, and actively scale up farmer-led innovations.

DECLARATIONS

Ethics approval and informed consent: Informed consent was not required as the study is a desk research using Bibliometric Analysis.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial

relationships that could be construed as a potential conflict of interest.

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

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Socio-Economic Determinants of Agriculture Households in Punjab: A Principal Component Analysis

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HIGHLIGHTS

- Components like land holding, education, and credit access, explained nearly 70 percent of the variations.
- Crucial livelihood factors identified were Land, livestock, and income.
- Education, credit, and markets were found to be major drivers of Inclusive agricultural development.

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ABSTRACT

The study highlights the socio-economic determinants of agricultural families in Punjab through the main component analysis. A sample of 200 families was surveyed in 2024-25, and ten socio-economic variables were analyzed, including land ownership, income, livestock, education, family size, expansion contact, loan, mechanization, and market access. The suitability of the PCA was confirmed by a clinical test with the Kaiser-Meyer-Olkin value of 0.732 and a significant Bartlett test. The analysis highlights the three major components with more than one Eigenvector value, which cumulatively explain 68.5% of the total variance. The PC1 highlights the relevance of agricultural resources, land, livestock, and income. PC2 emphasizes human and social capital, expansion services, family labour, and education. PC3, institutional and market access, mechanization, obtained loans, and proximity to markets. The multidimensional nature of rural livelihood in Punjab is exposed, where both traditional resources and institutional factors shape domestic results. The study underlines the need for integrated policies emphasizing resource efficiency, human capacity building, and institutional strengthening to ensure inclusive and sustainable agricultural development.

INTRODUCTION

Agriculture, being the backbone of the Indian economy, contributes significantly to food security, rural employment, and livelihood stability (Kaur & Kaur, 2021). Although its stake in the National GDP has been decreasing in the last few years, the region has employment for about half of the country and has remained a major source of income for rural families (Jatav, 2024). In this structure, the Punjab state holds a unique place, ensured national food security through intensive cultivation of cereals like wheat and rice (Chandana et al., 2022). It is facing complex challenges today, including rising costs, instability in agricultural income, excessive exploitation of natural resources, and increasing socio-economic inequalities between farming households (Pal et al. 2017; Meena et al., 2022). The socio-economic parameters of rural farming families play an important role in shaping livelihood outcomes and

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agricultural performance (Kumari et al., 2020; De et al., 2023). Factors such as holdings size, income, and education affect better techniques, use resources, and participation in the market (Nain & Chandel, 2010; Dagar & Upadhyay, 2022; Prakash et al., 2022). For instance, better education is more likely to invest in mechanization and adopt climate-friendly practices (Sarkar et al., 2022). Thus, a systematic understanding of socio-economic determinants of agricultural families is necessary to design targeted policies that can increase inclusion, flexibility, and sustainable development in the primary sector (Kobba et al., 2021; Amitha et al., 2023; Meena et al., 2023).

Previous research has uncovered the socio-economic dimensions of agriculture using descriptive statistics or social-based models. Despite being informative, these approaches often withstand the limitations of multiplicity, as socio-economic variables are highly correlated with each other. PCA enables researchers to condense a large group of corporate variables into a low number of unrelated components, representing the latent dimensions of the socio-economic situation (Gambardella et al., 2021). In India, several studies have used PCA to measure socio-economic development, livelihood security, or vulnerable indices in rural areas. However, limited efforts have been made to systematically implement the PCA to assess the socio-economic determinants of agricultural families in Punjab (Pani & Mishra, 2022). Given the centrality of the state in India's agricultural economy, as well as emerging challenges such as declining agricultural profitability, water crisis, and inter-family inequalities, such analysis is both timely and policy-related. In addition, the component-based approach allows for to identification of extensive dimensions such as agricultural resources, human and social capital, and institutional access, which can guide the creation of integrated development programs (Pandey & Devi, 2023).

In this background, this study applies the Principal Component Analysis on a group of socio-economic variables collected from agricultural families in Punjab, India. Its specific objectives are: testing the socio-economic characteristics of agricultural families, to remove and interpret the major components underlying their socio-economic conditions, and providing insights for policy and program design to increase agricultural stability and farmer welfare (Singariya, 2013). By adopting this approach, this study not only contributes to the empirical literature on rural socio-economics but also presents a methodical structure for analyzing complex, multi-faceted datasets in agriculture.

METHODOLOGY

A multi-step-stalled objective-cum-disciplinary sampling design was adopted for this study in Punjab, India, with a sample of 200. On basis of agricultural intensities, Ludhiana (high) and Mansa (low) districts, along with two blocks named Samrala, Khanna, Budhlada, and Sardulgarh, respectively were selected. Then, respondents from 8 villages, Bhucho, Mangat, Alour, Payal, Bareta, Boha, Jhunir, and Rorki respectively, were surveyed for data.

To ensure credibility, the equipment was pre-tested on 30 respondents outside sample area, and alpha coefficients of Cronbach's. The obtained value $\alpha = 0.79$ indicated a satisfactory internal association of scale items. Each variable X_j was standardized using the following formula:

$$Z_{ij} = \frac{X_{ij} - \mu_j}{\sigma_j}$$

Where Z_{ij} is standardized value of i^{th} observation on j^{th} variable, μ_j is mean of the variable, and σ_j is its standard deviation.

Before applying Principal Component Analysis, the suitability of dataset was examined. The Kaiser-Meyer-Olkin (KMO) sample adequacy measurement and spherical testing of Bartlett were used to check whether the correlation matrix is carriers. KMO value above 0.70 and statistically significant Bartlett's K-Square ($P < 0.05$) confirmed the suitability of the PCA for the data given. Subsequently, PCA was implemented on the standardized correlation matrix. This technique decomposes the total offering into linear combinations of the original variables, where each main component is perpendicular to the other variables and explains the decreasing ratio of the total offering. The extraction of the components was based on the Caesar criteria, that is, components with more than one eigenvalue were retained. Eigen's value (λ) reflects the number of provisions interpreted by each component, which is obtained from the following equation:

$$Rv = \lambda v$$

Where, R is the correlation matrix, v is the eigenvector, and λ is the eigenvalue.

To increase explanation, Varimax orthogonal rotation was applied, rewriting the variance among the residual components, while they remained unrelated. The variables with more than 0.40 factor weights were considered important contributors to the component. Depending on the rotating factor load, the components were designated according to the group of the highest load variables. The component score for each family was calculated using the regression method, which was expressed as follows:

$$Si = W_1 Z_{i1} + W_2 Z_{i2} + \ldots\ldots\ldots + W_k Z_{ik}$$

Where, S_i, i^{th} is a component score for the family, Z_{ij} has standardized variable values, and the W_j component loads. These scores were later used for descriptive interpretation and comparative analysis in various households.

RESULTS

Selection of variables for PCA

In this study, ten socio-economic variables were used to understand the multidimensional nature of rural families (Table 1). These included age, education, family size, land-ownership, livestock, income, loan availability, expansion contact, mechanization, and market access.

The selection was based on the relevance of these variables in the literature and the agricultural context of Punjab. The variables, such as land ownership, livestock, and income, were expected to reveal economic strength. Education, family size, and expansion contacts reflected human and social capital, whereas debt, mechanization, and market access indicated institutional and infrastructure assistance. The market access was expected to have a negative effect, as the long distance of markets usually increases the cost of transactions and reduces profitability.

Table 1. Variables Used for Principal Component Analysis

Variable Code	Variable Description	Unit / Scale	Expected Influence
X1	Age of household head	Years	Neutral
X2	Education level	Years	Positive
X3	Family size	Number	Mixed
X4	Operational landholding	Hectares	Positive
X5	Livestock units	Number	Positive
X6	Annual household income	Rs. ('000)	Positive
X7	Access to institutional credit	Binary (1=Yes, 0=No)	Positive
X8	Extension contact score	Index	Positive
X9	Farm mechanization score	Index	Positive
X10	Market accessibility (distance)	Km	Negative

PCA suitability

Before PCA, the sufficiency of the dataset was tested using the Kaiser-Meyer-Olkin (KMO) measurement and the sphericalness test (Table 2) of the Bartlett. The KMO value was 0.732, which was much above the minimum allowable level of 0.60, indicating that the sample factor was sufficient for analysis.

Table 2. KMO and Bartlett's Test for PCA Suitability

Test	Value
Kaiser-Meyer-Olkin (KMO)	0.732
Bartlett's Test of Sphericity	$\chi^2 = 512.47$, df = 45, $p < 0.001$

Indicates data suitable for PCA

The Bartlett test was highly meaningful ($\chi^2 = 512.47$, $p < 0.001$), which confirmed that the correlation matrix was not an identity matrix and the variables were sufficiently correlated to justify the PCA. These results validated the use of PCA as a suitable technique for data renovation in this study.

Interpretation of variance by components extracted

The PCA extracted three major components with more than 1 standard deviation, which explains 68.5 percent of the total variance (Table 3). The first component explains 34.5 percent of the variance, the second 21.2 percent, and the third 12.8 percent.

This indicates that a large part of the variation in socio-economic characteristics can be condensed into three underlying dimensions. The cumulative variance explained in social science research usually exceeds the 60 percent standard considered satisfactory, indicating a strong explanatory power of the components created. The eigen value of the components ahead of the third was less than 1 and was not considered for interpretation.

Table 3. Total Variance Explained by Extracted Components

Component	Initial Eigenvalues	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings
	Eigenvalue	% of Variance	Cumulative %
1	3.45	34.5	34.5
2	2.12	21.2	55.7
3	1.28	12.8	68.5
4	0.89	8.9	77.4
5	0.70	7.0	84.4
6	0.52	5.2	89.6
7	0.40	4.0	93.6
8	0.34	3.4	97.0
9	0.22	2.2	99.2
10	0.08	0.8	100.0

Retained components with eigenvalue > 1

Factors load and component structure

The rotating component matrix presented in Table 4 clearly adds the variables into three different components. Component 1 had strong loads on land-ownership (0.82), livestock (0.76), and domestic income (0.71). This indicates that families with large land ownership and high livestock ownership report high income, which is a pattern in line with Punjab's agricultural economy. This component was explained as the "Agricultural Resource Aadhaar", which reflects physical and financial resources that define economic capacity. Component 2 had a heavy weight of education (0.83), family size (0.62), and expansion contact (0.74).

Table 4. Rotated Component Matrix (Varimax Rotation)

Variable	Component 1 (Resources)	Component 2 (Human Capital)	Component 3 (Institutional Access)
Landholding size	0.82	0.12	0.05
Livestock units	0.76	0.08	0.22
Household income	0.71	0.20	0.18
Education	0.15	0.83	0.10
Family size	0.09	0.62	0.05
Extension contact	0.10	0.74	0.32
Credit access	0.05	0.18	0.81
Mechanization	0.44	0.36	0.40
Market access	–0.20	0.16	0.66

These variables collectively represent human and social capital. Education strengthens farmers with knowledge and decision-making skills, provides family-sized domestic labor, and facilitates the information flow. Together, these variables reflect human and social resources that increase agricultural management capacity. This component was designated as "human and social capital". Component 3 showed a high load of loan access (0.81), market access (0.66), and mechanization (0.40). These variables represent institutional and infrastructural support, as debt makes investment smooth, reduces the cost of proximity to markets, and increases mechanization productivity. This component was interpreted as "institutional and market access". Thus, the rotating component

Figure 1. Scree Plot

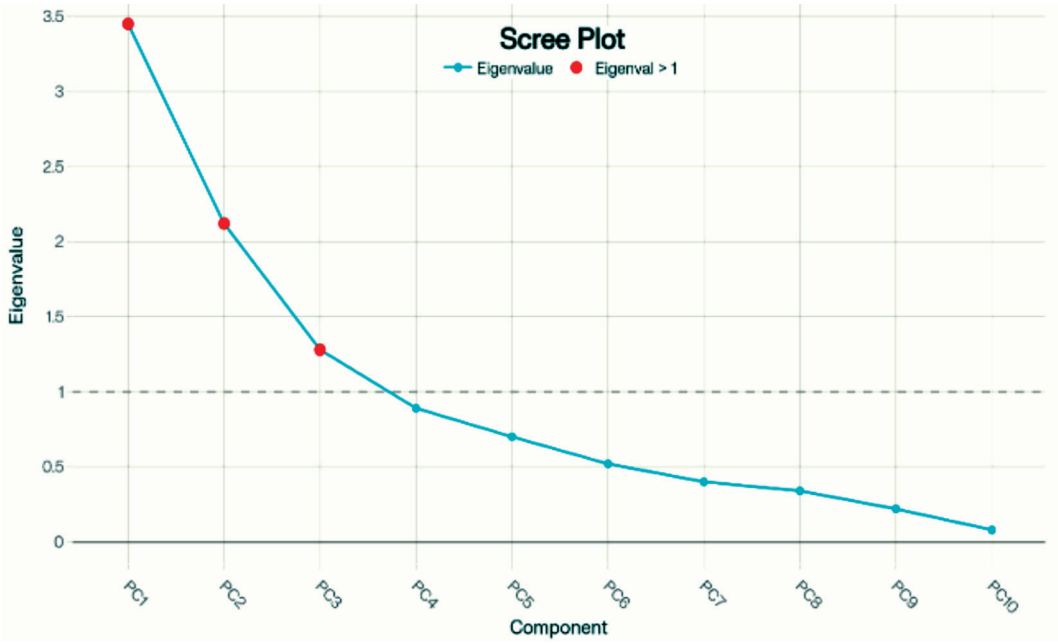
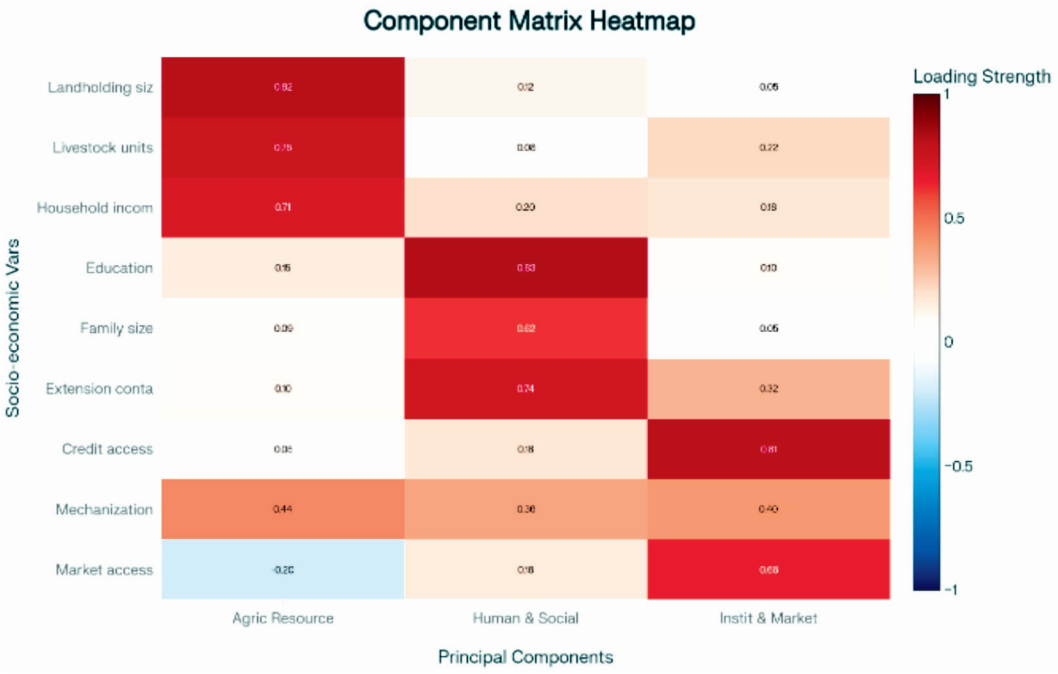


Figure 2. Component Matrix



structure confirms that the socio-economic determinants of the farming families of Punjab can be effectively classified into three underlying dimensions-exasperation, human and social capital, and institutional access.

Interpretation of components

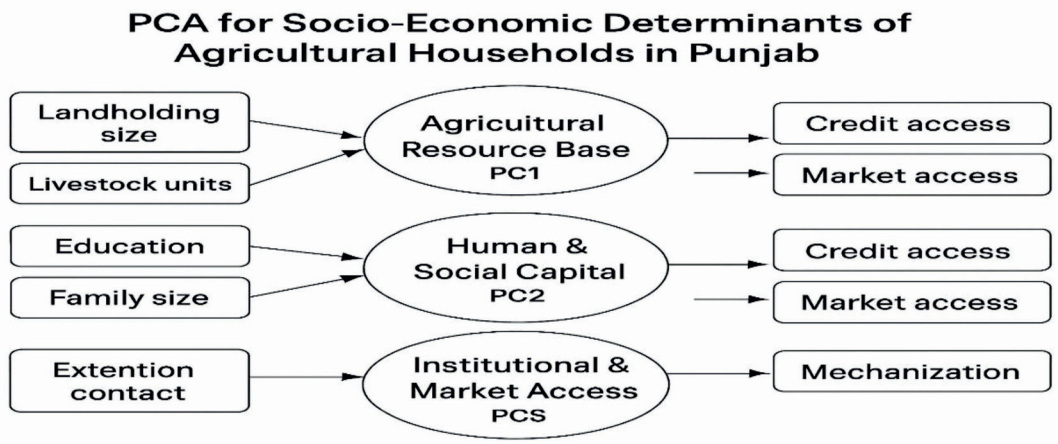
The three components were interpreted as follows in Table 5. Agricultural Resources Aadhaar (PC1), a component, based on land ownership, livestock, and income, highlights the permanent importance of tangible resources in defining domestic prosperity. Agricultural development of Punjab has historically been resource-dominated, which has depended on land, irrigation, and livestock. The results suggest that they remain the primary driver of domestic economic strength. Human and Social Capital (PC 2), with a strong contribution of education, family size, and expansion contact, this component underlines the role of abstract resources.

In the contemporary agricultural scenario, human capital, technology play an important role in adopting efficient agricultural management through literacy and training. Extension contacts act

Table 5. Interpretation of Principal Components

Component	Dominant Variables	Interpretation
PC1	Landholding, livestock, income	Agricultural Resource Base
PC2	Education, family size, extension contact	Human & Social Capital
PC3	Credit access, market access, and mechanization	Institutional & Market Access

Figure 3. Path Diagram



as a bridge between institutions and farmers, which confirms the importance of social networks. Institutional and market access (PC3), reflects an agriculture-friendly environment. Institutional debt helps farmers to overcome cash shortages, while market access ensures profitability by reducing costs and ensuring timely sales of produce. Machination reflects modernization and labor efficiency even more. The group of these variables reflects the growing role of institutional aid systems in maintaining agricultural development.

DISCUSSION

The findings of this study indicate that the socio-economic structure of agricultural families in Punjab can be understood in three broader dimensions: Agricultural Resources Aadhaar, Human and Social Capital, and institutional and market access. Results are in line with multidimensional nature of rural livelihood described in pre -Indian and global studies, although some features are unique to agricultural reference of Punjab (Kumar et al., 2023). Dominance of the resource base component, which includes land ownership, livestock, and income, is not surprising. The most important determinant of land, domestic status, and income in Indian agriculture remains a trend that was exposed in former studies in Punjab and Haryana, where the size of land positively affected productivity and income diversification (Basantaray et al., 2024). Livestock's involvement echoes the evidence of those who noted that dairy farming in Punjab continues to act as a stable factor for agricultural families. These results confirm the argument that despite mechanization and modernization, traditional resources such as land and livestock remain basis of rural prosperity in Punjab (Gulati et al., 2021). Rise of human and social capital as the second major component is in line with studies that highlight the growing role of abstract resources. Education, family size, and expansion contact collectively reflect ability to acquire, process, and implement family knowledge. Punjab studies also emphasize a medium of spreading modern practices on expansion contacts, especially in relation to crop diversification and water-use efficiency. Thus, results of PCA support the notion that continuous agricultural development in Punjab requires not only resources but also strengthening knowledge and social relations. Third component, institutional and market access, reflects increasing importance of the enabled environment. Access to formal loans, proximity to markets, and agricultural mechanization together determined this component. This conclusion, which is, matches research, which showed that institutional debt increases investment and productivity, especially among small farmers. Similarly, studies conducted on market access in India emphasize that the low distance of markets reduces the cost of transaction, improves price receipts, and encourages diversification in high-value crops. Mechanization, although traditionally connected to large farms, is now small farmers through custom hiring centers, which reflects Punjab's developed rural service economy. Collectively, these factors show how institutional and infrastructure relations are giving new looks to agricultural opportunities in the state.

The multifunctional nature of these findings indicates important policy implications. First, there are still resource-based inequalities in Punjab, where small farmers have to face structural obstacles in increasing production. Land consolidation or cooperative agricultural systems can be considered as policy options to improve viability. Second, human and social capital components indicate the need for continuous investment in rural education, vocational training, and expansion services. Strengthening the farmer productive organizations (FPO) can also expand social networks and improve the power of collective bargaining. Third, institutional and market access components highlight the need to expand loan access, improve the infrastructure of the rural market, and ensure that mechanization services are accessible to small and marginal farmers. Targeted intervention in these areas can significantly reduce inequalities and increase overall productivity. On comparing globally, these results are in line with studies conducted in other agricultural economies where the PCA has been implemented. Although the case of Punjab is different in the sense that while resources remain central, institutional and human capital factors are gaining prominence due to the advanced phase of agricultural development of the state. In short, this discussion emphasizes that the agricultural families of Punjab cannot be understood only through land and income indicators. Education, expansion, debt, and the role of the market are equally important in shaping livelihood results (Das et al., 2024).

CONCLUSION

In this study, major component analysis was used to examine socio-economic determinants of agricultural families in Punjab, India. Three major components came out of the results - agricultural

resources base, human and social capital, and institutional and market access - which collectively explain about 70 percent variation between families. Conclusions highlight that while traditional resources such as land and livestock are at the center of rural prosperity, education, expansion services, loans, and the role of market infrastructure are also equally important in shaping domestic results. Especially small farmers face structural deficiencies that require targeted intervention. Therefore, policy efforts should adopt multidimensional approaches, promote land-use efficiency, strengthen education and expansion networks, and improve institutional and infrastructure support. Focusing balanced focus on both tangible and abstract factors can help reduce inequalities in Punjab, increase productivity, and promote inclusive agricultural development.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents for the study.

Competing Interest: The Authors have no competing interests.

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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Effect of Labour Bank-Karshika *Karma Sena* on the Livelihood of Agricultural Labour Households in Kerala

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HIGHLIGHTS

- Labour bank-*Karshika Karma Sena* served as a source of livelihood strategy for poor agricultural labour households by providing work opportunities.
- Participation in Karshika Karma Sena aided in employment generation by providing 24.74 days of additional working days to participants related to non-participants
- Karshika Karma Sena participation enabled the participant's household to increase their annual income by Rs. 65117.

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ABSTRACT

Labour Bank-*Karshika Karma Sena* is an institutional intervention designed to address labour scarcity in the agricultural sector of Kerala. The study was conducted in two districts, viz Palakkad and Thrissur, based on the maximum paddy area and production. The total sample size was 176 agricultural labourers, entailing 80 participants and 96 non-participants pertaining to the year 2024. Agricultural labour work was the major contributor to employment for sample respondents. It was 71.12% and 51.44% for participants and non-participants, respectively. Income from agricultural labour activities formed a sizeable share in overall household income for participants, of which around 70% of the agricultural labour income was obtained from KKS activities. The effect of *Karshiaka Karma Sena* participation on employment and income has been worked out using a regression adjustment model. The results infer that participation in the KKS has enabled the labourers to increase their annually employed days by 24.74 days and to increase their average annual household income by Rs. 65117. Overall, such innovative institutional intervention has opened up avenues for the sustenance of the livelihood security of agricultural labourers in the state.

INTRODUCTION

Agriculture serves as a fundamental source of food, employment, income and livelihood for rural households worldwide, forming the backbone of many rural economies and contributing to social cohesion. But over the years, the contribution of this sector to overall national income and employment has decreased in India. Kerala is one of the Indian states that experienced a significant decline in the agricultural sector's contribution to providing employment. Agricultural labourers face various problems like minimum or inadequate wages, improper employment, inadequate working conditions and indebtedness (Gade et al., 2019). As a labourer is an important factor of production, their migration for earning a better livelihood increases the existing imbalance between demand and supply of labourers (Start & Deshingkar, 2003). The agriculture in Kerala is not an exception to this trend. The shortage

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of agricultural labour makes negative impacts like reduction in crop yield, cropping intensity and changes in the traditional cropping pattern (Prabakar et al., 2011). Cost of cultivation shows that the share of labour cost in total operational cost in paddy is highest in Kerala (69.88%) (Samal et al., 2018). The increase in labour cost in Kerala is attributed to the rural-urban migration, higher wage rate compared to other states and labour scarcity in agriculture (Sharma & Prakash, 2011). Deceleration in area under crops and production of food crops has further exacerbated the lacklustre performance of agriculture in Kerala (Harilal & Eswaran, 2017). Increasing the level of farm mechanization offers an effective solution to the persistent problem of labour scarcity. This highlights the need for stronger participation from both government and non-government organisations to promote mechanised farming practices among rural communities, thereby ensuring sustainable agricultural production (Baruah et al., 2025).

Rural employment schemes not only provide crucial wage opportunities but also enhance agricultural productivity by creating durable and useful assets (Tripathi et al., 2025). To solve the labour scarcity and to protect the rights of agricultural labourers by promising respectable income, social security and dignity, an innovative policy initiative called Labour Bank-*Karshika Karma Sena* (KKS) has been introduced by Kerala. This has brought about a turnaround to the situation in the State. *Karshika Karma Sena* works by forming a group of skilled agricultural labourers at Grama Panchayat level by providing needful training related to package of practices of paddy cultivation and machinery operations. Any additional income of labour generated by this intervention is going to boost the standard of living of labour household. Although *Karshika Karma* Sena has been showing prominence in recent times in the state, empirical studies examining its effect on labourers are limited. In this backdrop it became essential to study the effect of *Karshika Karma Sena* on livelihood of agricultural labour household. The knowledge arising from the research work would pave the way to resolve labour scarcity in agriculture sector for academics, policy makers and other stakeholders engaged in agriculture.

METHODOLOGY

Two districts viz. Palakkad and Thrissur of Kerala were selected based on the maximum area coverage and paddy production. The data on socio-economic characteristics of agricultural labourers, landholding sizes etc, were collected by personal interview method using a pre-tested schedule pertaining to the year 2024. From each selected district two blocks and from each selected block, two grama panchayats where the scheme was implemented were selected randomly. From each grama panchayat, 10 KKS participants and 12 KKS non-participants were selected randomly i.e., Data from a total of 176 agricultural labour were collected and used for the study. It included 80 KKS-participants and 96 KKS-non-participants. Respondents were selected using a simple random sampling method.

To isolate the effect of Labour bank-Karshika Karma Sena on employment and annual income of agricultural labour households, the Regression adjustment technique is used on the dataset. A prerequisite of the application of the regression adjustment method is to make the conditions statistically equal with respect to various observed characteristics that may also influence the outcome. Then fitted a separate outcome equation for the treated and control groups. For KKS participants:

$$Y_i = \alpha + \beta_j X_{ij} + u_i \quad \text{... (1)}$$

For KKS non-participants:

$$Y_i = \delta + \tau_j X_{ij} + e_i \quad \text{... (2)}$$

Where, Y_i =Total number of days employed in a year/total annual household income, X_{ij} is set of possible explanatory variables affecting the Y_i

The explanatory variables influencing the number of days employed include age, education, caste, gender, family size, number of earning members, agricultural labour experience, non-agricultural work experience and landholding size. For household income, the explanatory variables were age, education, caste, gender, family size, number of earning members, agricultural labour experience, employment in agricultural labour work, employment in other activities and landholding size.

α and δ = Constant-term, β_j and τ_j = set of estimated coefficients of explanatory variable, u_i and e_i = Error-term

This model estimates Potential Mean Outcomes (PMO) separately for treated (KKS participants) and control (non-participants) groups. PMO represent the expected value of an outcome, such as total days employed in a year or annual household income if all individuals in the sample were assigned to either the treatment or control group. The impact of KKS participation is measured as the difference between the PMO of participants and non-participants. This difference is expressed as the Average Treatment Effect (ATE). The standard z test was employed to determine if the ATE was statistically different from zero.

RESULTS

Effect of KKS participation on agricultural labourers' employment generation

The agricultural labourers are engaged in different income-generating activities to meet their livelihood requirements. The number of employed days can significantly affect total income and the overall well-being of their households. Participation in the *Karshika Karma Sena* would help to increase the number of days employed by providing regular employment opportunities and focusing on skill development for agricultural machinery operations. The average days of employment for sample agricultural labourers through different activities in a calendar year are presented in Table 1. The results indicated the existence of a significant difference in the total number of days employed between KKS participants and non-participants. For KKS participants, it was 194 days and for KKS non-participants, it was 173 days. A perusal of the number of days employed across different activities revealed a statistically significant difference between participants and non-participants in agricultural labour and non-farm activities. This could be attributed to the role played by KKS in employment generation for agricultural labourers. For KKS participants, the major contribution to the total number of days employed was obtained through agricultural labour activity (71.12%), of which more than 86 per cent came from KKS works. For KKS non-participants, more than half (51.44%) of the

Table 1. Number of days employed in different activities in a year by the agricultural labour

Nature of work		KKS-participants	KKS-non participants	t-value
Agricultural labour	Through KKS	61.85	0	
	Outside KKS	9.27	51.44	
Total agricultural labour		71.12	51.44	31.31*
MGNREGA		21.13	32.36	1.52
Farm activity		2.57	3.46	0.87
Nonfarm activity		5.18	12.74	3.73*
Total		100	100	3.46**

Figures in parentheses indicate percentage of total number of days employed, *Significant at 1%, **Significant at 5%
Source: Field Survey by authors, 2024

total number of days employed in a year derived from agricultural labour activity, followed by MGNREGA (32.36%), non-farm activity (12.76%) and farm activity (3.46%).

Employment is essential for financial stability, subsequent well-being and better standard of living for an individual. This creates a sense of purpose, identity and social integration. For individuals, employment and the income it provides is essential for budgeting and securing financial support. The summary statistics of variables under consideration for evaluating regression adjustment model for employment and household income among KKS participants and non-participants are presented in Table 2. The t-test statistics discern the fact that the differences between the two groups of the *Karshika Karma Sena* were significantly different in terms of that particular variable.

Karshika Karma Sena focuses on enhancing the well-being of agricultural labourers by providing better, regular employment opportunities and skill enhancement. Findings of the regression adjustment technique on the effect of KKS participation on employment generation by calculating PMO and ATE have been presented in Table 3. The results inferred that as the average number of days employed in a year would have been 198.56 days if all the respondents (including KKS non-participants) became KKS participants. This was represented as PMO KKS participants. Likewise, PMO KKS non-participants can be interpreted as the average number of days employed in a year would have been reduced to 173.82 days if all the respondents (including KKS participants) became KKS non-participants. The difference between PMO KKS participants and PMO KKS non-participants was shown as the average treatment effect (ATE). The ATE figure was a positive value, indicating that participation in KKS helped the agricultural labourers to increase their total number of days employed in a year by 24.74 days. Thus, the results revealed the significant role played by KKS in generating a greater number of employment days for the participant workers and thereby better livelihood sustainability.

As income rises, household welfare tends to improve, primarily through increased consumption expenditure. In this context, it becomes important to assess the impact of participation in KKS on household income. The source-wise distribution of income among KKS participants and non-participants has been examined, and the impact of KKS participation on overall household income has been assessed. Average annual household income of KKS participants and non-participants, from various sources like agricultural labour, MGNREGA, farm and non-farm activities, has been presented in Figure 1. Annual household income indicates the income of all earning members in the family in a year. A perusal of the figure showed a notable significant difference between KKS participants' and non-participants' annual household income. The

Table 3. Results of the regression adjustment technique of total number of days employed in a year

Particular	Coefficient	Robust error	Z value
PMO KKS-participants	198.56*	2.52	79.79
PMOKKS nonparticipants	173.82*	1.34	129.30
ATE	24.74*	2.16	11.41

*Significant at 1%;
Source: Author's calculation from field survey,2024

Table 2. Summary statistics of variables used for regression adjustment for employment and income

Variable	Mean values of variables used in Regression adjustment		
	KKS participants	KKS non-participants	t value
Dependent variable			
Total number of days employed in year	194	173	3.46**
Annual household income (Rs./year)	2,40,320	1,98,090	8.31*
Explanatory variable			
Age (years)	38.08	47.70	7.31*
Education (number of years of schooling)	10.46	7.22	7.02*
Caste (0=general 1=OBC 2=SC/ST)	1.38	1.31	-0.77
Gender (1=male, 0=female)	0.33	0.20	2.22
Family size (No)	3.95	3.18	1.09
Number of earning members (No)	1.52	1.60	0.88
Experience as agricultural labour (in years)	12.60	14.40	0.25
Experience of working in non-agricultural activity (in years)	11.00	14.23	0.98
Number of days employed as an agricultural worker	138.00	89.00	31.31*
Number of days employed in other activities	56.00	84.00	23.22**
Land holding size (in cents)	16.60	11.80	-5.2*

*Significant at 1 %, **Significant at 5%, *Source:* Field Survey by authors, 2024

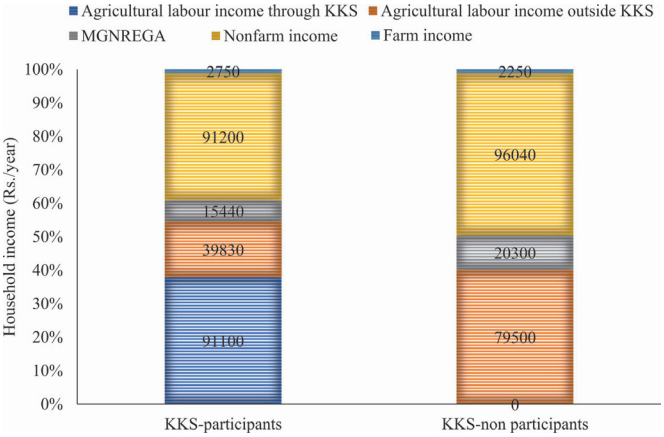

Figure 1. Annual household income of agricultural labour from different sources

average annual income of KKS participants' households was Rs.240320, and that of KKS non-participants was Rs. 198090. Income contribution (%) from different sources for the sample household showed income from agricultural labour work (54.48 %) was the major contributor of KKS-participant's household followed by non-farm work (37.96%), MGNREGA (6.64 %) and farm work (1.14 %). But for KKS non-participants' households, non-farm income (48.48%) was the highest contributor to annual household income, followed by agricultural labour income (40.13%), MGNREGA (10.25%) income and farm income (1.14%). The percentage share of farm income in overall income was very less for both KKS participants and non-participants. This was due to small landholding size of respondents. Findings revealed the existence of a significant difference in agricultural labour income between participants' and non-participants' households. This difference had subsequently contributed to the overall significant difference in annual household income between these two categories. Since agricultural labour income through KKS contributed around 70% of the total agricultural labour income for participants' households, it was clear that *Karshika Karma Sena* had played a significant role in increasing the household income of participants.

Household income plays a crucial role as a key socioeconomic indicator, reflecting a household's financial health and ability to access resources. *Karshika Karma Sena* emphasises enhancing the quality of living for agricultural labourers by assuring a stable income and financial independence. This is possible by way of providing stable work opportunities, better quality work environment and skill upgradation. The results of the regression adjustment technique on effect of KKS participation on the annual household income of agricultural labour was presented in Table 4. Potential mean outcome (PMO) of KKS participants revealed that the mean value of annual household income would have been Rs. 2,36,507.32 if all the respondents (including non-participants) became KKS-participants. Similarly, potential mean outcome (PMO) of KKS non-participants inferred the fact that the mean value of annual household income would have been decreased to Rs. 1,71,390.80 if all the respondents (including participants) became KKS non-participants. The difference between PMO KKS participants and PMO KKS non-participants was shown as the average treatment effect (ATE). Analysis obtained a significantly positive value for ATE, indicating that participation in KKS helped the households to increase the average annual household income by Rs. 65,117.52. Through this intervention, KKS not only enhances the capacity of rural households to earn a stable livelihood but also effectively increases the number of days of employment available to them, thereby improving overall household economic safety.

Table 4. Results of regression adjustment model of annual income of household (Rs/year)

Particular	Coefficient	Robust error	Z value
PMO KKS-participants	236507.32*	22850.95	10.35
PMO KKS non-participants	171390.80*	18291.36	9.37
ATE	65117.52*	7931.30	8.21

*Significant at 1%

Source: Authors' calculation from field survey, 2024

DISCUSSION

The livelihood patterns of agricultural labour households in the study area reveal a dependence on multiple employment sources, including agricultural labour, MGNREGA employment, farm-based activities and non-farm work. Such diversification is a common coping strategy in rural settings, where employment opportunities are often seasonal and educational as well as skill limitations restrict access to stable, high-paying jobs. The present findings are consistent with the results of Ngasainao and Jha (2025), who reported that food and occupational security together explained 70.92% of the variance in the livelihood security of farm women in Kerala. Similar patterns of income diversification were reported by Mary et al. (2015) and Pal et al. (2017). In the current study, agricultural labour work emerged as the predominant source of employment for both KKS participants (71.12%) and non-participants (51.44%). This observation supports the findings of Narasimham and Bhairavamurthy (2014), who highlighted the continued reliance on agriculture as the primary source of employment in rural areas due to limited opportunities in the non-agricultural sector. Regression adjustment analysis further revealed that participation in *Karshika Karma Sena* (KKS) increased the annual number of workdays for agricultural labourers by 24.74 days. This positive effect can be attributed to several factors including relatively higher education levels among KKS participants, improved skills gained through targeted training programmes, effective institutional mechanisms and the provision of more regular employment opportunities through KKS interventions. These results parallel the findings of Malangmeih et al. (2014), who stated an increase in average annual employment from 165.40 days to 222.50 days following the implementation of MGNREGA in Bankura district, West Bengal, demonstrating the critical role of government interventions in enhancing rural employment and overall quality of life. Collectively, these results underscore the vital contribution of government-supported livelihood initiatives in expanding employment opportunities, strengthening labour security and improving rural household resilience.

The findings of the present study demonstrate a significant positive impact of *Karshika Karma Sena* (KKS) participation on household income, with member households reporting an annual

increase of approximately Rs. 65,117. This income enhancement aligns with the results of Praveena et al. (2025), who noted that self-help group (SHG) membership contributes substantially to increased household income, disciplined savings behaviour, investment in productive assets and greater engagement in self-employment activities. The present study further highlights that KKS functions as an important source of supplementary employment for rural households, thereby fostering chance of financial independence among economically disadvantaged populations. The observed outcomes are consistent with evidence reported by Ahemad and Katoch (2022), who described similar improvements under the National Rural Livelihood Mission (NRLM), where the formation and strengthening of SHGs led to enhanced income levels and expanded employment opportunities for rural women. Likewise, Malangmeih et al. (2014) identified that wage employment programmes, such as MGNREGA, play a crucial role in augmenting rural wage income. Further supporting evidence comes from Kumar (2023), who concluded that the Prime Minister's Employment Generation Programme (PMEGP) not only facilitated income generation but also contributed to skill development and empowerment among youth and marginalized groups. Similarly, Kriti et al. (2025) emphasized the effectiveness of NGO-led livelihood initiatives in promoting income generation among rural women in Bihar. Collectively, the findings of this study reinforce the broader understanding that structured livelihood interventions, whether government-led like KKS, NGO-facilitated or community-based, play a pivotal role in improving household income, enhancing employment opportunities, and fostering socio-economic empowerment in rural contexts.

Karshika Karma Sena (KKS), an institutional intervention, was established to address the growing scarcity of agricultural labour in Kerala while simultaneously improving livelihood opportunities for rural agricultural labour households. The findings of the present study demonstrate that KKS has a significant positive impact on employment generation and income enhancement, ultimately contributing to improved household well-being. This effectiveness can be attributed to several enabling factors, including a strong administrative framework, systematic capacity-building initiatives and skill enhancement in areas such as crop cultivation and agricultural machinery operation. Increased motivation and awareness among participants could have further strengthened the programme's outcomes. The role of skill development within KKS mirrors observations in earlier empirical work. Sharma (2021) reported that skill development initiatives undertaken by NGOs significantly empowered rural women, both economically and socially. In the context of KKS, whose functioning revolves around mechanised farm operations, training and capacity-building programmes are indispensable. They help rural labourers overcome practical, technical, and social barriers that often constrain the effective implementation of employment-oriented schemes. The findings also align with the results of Pathak and Kakati (2024), who documented substantial improvements in farmers' skills and knowledge following training interventions under the Assam Agribusiness and Rural Transformation Project (APART). Furthermore, the operational model of KKS underscores the importance of grassroots institutional structures. The programme functions through Gram Panchayats, which regularly disseminate key information regarding KKS formation, labour recruitment processes, and meeting deliberations through the Gram Sabha. This participatory approach ensures transparency and strengthens community engagement. Similar insights were reported by Nain et al. (2015), who emphasized the critical role played by government development bodies in disseminating agricultural information at the local level.

CONCLUSION

The findings of this study demonstrate that the Labour Bank model-*Karshika Karma Sena* (KKS) holds substantial potential as an institutional mechanism to mitigate agricultural labour scarcity in Kerala while simultaneously improving the livelihoods of rural agricultural labour households. By organising skilled labour groups at the Gram Panchayat level and providing targeted training in crop cultivation practices and machinery operation, KKS effectively enhances both employment opportunities and annual household income among its participants.

The success of this intervention emphasises the need for continued investment in strengthening institutional frameworks such as KKS. Enhancing outreach and awareness initiatives is vital to attract more rural youth and build a sustainable, skilled agricultural workforce. Sustained government support in identifying untapped rural employment opportunities is essential for improving livelihood security and overall rural well-being.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents for the study.

Competing Interest: The Authors have no competing interests.

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

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

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Research Article

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Analysing Farmers' Perceptions of Genetically Improved G3 Rohu (*Labeo rohita*) Fish Culture in Mymensingh District, Bangladesh

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HIGHLIGHTS

- The majority of fish farmers (74.3%) had favourable and 25.7% had highly favourable perceptions toward G3 rohu culture.
- Farm size, rohu culture area, organisational participation, and extension media contact positively influenced farmers' perception.
- Household size and social mobility negatively affected perception, highlighting the need for targeted extension support.

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ABSTRACT

Growing G3 rohu (*Labeo rohita*) fish can improve nutritional stability, raise farmer incomes, boost productivity, and promote sustainable aquaculture. The study evaluated fish farmers' perceptions of G3 Rohu culture and identified the socio-economic and contextual factors influencing these perceptions. A pre-tested structured interview was conducted with 105 fish farmers, representing 50% of the total, in the Phulpur sub-district of Mymensingh district, Bangladesh, between February and May 2023. A 5-point Likert scale with 12 statements (six positive and six negative) was used to measure perceptions. Data analysis included both descriptive and inferential statistics. Results revealed that 74.3% of farmers had a favourable perception, while 25.7% reported a highly favourable perception; no respondents indicated unfavourable views. Regression analysis revealed that, among the twelve independent variables, area under fish culture, area under Rohu fish culture, organisational participation, and extension media contact significantly and positively influenced farmers' perception levels of G3 Rohu fish culture. Conversely, household size and social mobility showed negative effects. Furthermore, it is recommended that increasing organisational participation and extension services, while addressing socioeconomic hurdles, can support the widespread adoption of G3 Rohu breeds for long-term aquaculture flourishing in Bangladesh.

INTRODUCTION

In Bangladesh, the fisheries sector is crucial for economic development, contributing 2.53% to the national GDP and 22.26% to agricultural GDP, with a growth rate of 2.81% (BBS, 2024). This sector is vital for the livelihoods of over 20 million people, including 1.4 million women, who rely on it both directly and indirectly. In the fiscal year 2022-2023, fish production reached 4.92 million metric tons, contributing to an increase in per capita fish consumption to 67.8 grams per day (BBS, 2024). Bangladesh has earned global recognition as the second-largest producer of freshwater fish and the fifth-largest producer of closed-water fish farming (FAO, 2024). Among cultured species, Rohu (*Labeo rohita*) stands out as a significant freshwater carp, prized for its nutritional

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value and high consumer demand (Mehar et al., 2022). Nonetheless, traditional strains of Rohu sourced from rivers or commercial systems show considerable drawbacks, such as slow growth rates, vulnerability to diseases, and inefficient feed conversion. These limitations prolong production cycles and elevate farming costs (Mishra et al., 2017). To address these issues, significant attention has been directed towards the genetic improvement of aquaculture species, especially via selective breeding and strain improvement (Momin et al., 2024; Rej et al., 2025). In 2020 and 2021, WorldFish released Genetically Improved G3 Rohu is a major breakthrough in this field (Yeasin et al., 2022). Under local agricultural conditions, this strain, the product of selective breeding efforts, has shown the capacity to grow up to 30% quicker than standard strains (Yeasin et al., 2022). Additionally, it boasts superior feed conversion efficiency, higher survival rates, and enhanced resistance to diseases (Hamilton et al., 2022). These attributes position G3 Rohu as a promising solution for enhancing farm profitability and sustainability while addressing the increasing consumer demand for fish protein.

Despite the documented biological and economic advantages of G3 Rohu, the successful diffusion of this innovation hinges on the acceptance, awareness, and willingness of farmers to adopt it. Previous research in aquaculture has highlighted that farmers' awareness, socio-economic dynamics, and institutional backing significantly influence technology adoption (Mehar et al., 2022; Ataei et al., 2021). Nevertheless, empirical insights regarding the perceptions of Bangladeshi farmers toward G3 Rohu cultivation remain scarce. Understanding these perceptions is crucial, as technology adoption transcends mere technical considerations, encompassing behavioral and socio-economic factors as well.

The aim of this study is to ascertain the socioeconomic and contextual factors that influence fish farmers' perceptions of G3 Rohu culture. The insights derived from this research will provide valuable information for policymakers, researchers, and extension agencies, facilitating the design of effective strategies to promote the wider adoption of genetically improved fish strains. Ultimately, this will contribute to enhanced aquaculture productivity and improved livelihoods for farmers in Bangladesh.

METHODOLOGY

The study was conducted in Phulpur Upazila of Mymensingh district, located in north-eastern Bangladesh, between February and May 2023. This area was purposively selected due to its prominence in aquaculture, particularly the recent expansion of Rohu (*Labeo rohita*) culture, as noted by local fisheries officers, making it an appropriate site for examining farmers' perceptions of Genetically Improved G3 Rohu.

The study population comprised all fish farmers who had experience with, or awareness of G3 Rohu culture. The help from local hatchery holders, the Upazila Fisheries Officer (UFO), and the local extension agent for fisheries (LEAF), a list of 210 growers was compiled. Fifty percent of farmers were randomly selected, following Cochran's guideline for large populations, resulting in a sample of 105 farmers (Cochran, 1977). The questionnaire and perspective statements were designed and improved after three focus group discussions (FGDs) and three key informant interviews (KIIs) with model fish farmers were carried out to uncover contextual factors. Finally, the fish farmers were interviewed in person using a pre-tested structured questionnaire.

Using the developed questionnaire, twelve socioeconomic and personal traits of farmers were measured as independent variables. A 5-point Likert scale with 12 statements, six positive and six negative, was used to evaluate perception. Response options ranged from 'strongly agree' (5) to 'strongly disagree' (1) for positive statements, with reverse scoring applied for negative statements (Podder et al., 2022; Shubham et al., 2022; Smrity et al., 2020). Each respondent's total perception score, obtained by summing scores across all statements, could range from 12 to 60.

On the other hand, the perception score for each statement was calculated by using the perception score (PS), and it was calculated by using the following formula (Smrity et al., 2020):

$$PS = P_{SA}\,x5 + P_{A}\,x4 + P_{NO}\,x3 + P_{DA}\,x2 + P_{SDA}\,x1$$

Where, PSA is the total number of responders who strongly agreed with the statement, PA is the total number of responders who concurred with the argument, PNO is the total number of responders who were undecided about the statement, PDA is the total number of responders who didn't agree with the statement, PSDA is the total number of responders who disagreed strongly with the statement. Comparably, the negative statements received the opposite score.

Finally, linear multiple regression analysis was performed to identify influential factors affecting fish farmers' perception of G3 rohu fish cultivation. A software program called SPSS (Statistical Package for the Social Sciences) was used to code, tabulate, and analyse the findings from the research.

RESULTS

Personal and socio-economic aspects of the fish farmers

Table 1 summarizes the socioeconomic attributes of fish growers. Most farmers (41.0%) are middle-aged (36–55 years), and 40.0% have only primary-level education (1–5 years). A majority (61.9%) live in medium-sized households with 5–7 members.

In terms of farm size, 81.0% operate medium-sized farms (1.01–3.00 ha), and over half (61.0%) have more than 22 years of fish farming experience. Regarding income, 59.0% belong to the medium-income group (Tk. 400,000–1,000,000). Organizational participation is low (87.6%), with 50.5% having received only 1–2 days of training. Nearly half (48.6%) have limited access to credit (up to Tk. 100,000), while 88.6% report medium contact with extension media, and 52.4% show medium social mobility.

Table 2 shows that the perception level of farmers towards G3 Rohu fish culture ranged from unfavourable to highly favourable. Farmers' perceptions of G3 Rohu fish culture ranged from favourable (74.3%) to highly favourable (25.7%), with none reporting an unfavourable opinion. Shanmuka et al. (2022) found that half of the extension (52%) workers had an unbiased perception about using social media to look for agricultural knowledge. Additionally, the results are consistent with the findings presented by Sajeev and Joshy (2024) and Podder et al. (2022).

Table 1. Personal and socio-economic features of the fish farmers

Features of farmers	Categories	Percent	Mean	SD
Age (Actual year)	Middle (36-55)	41.0	46.75	12.65
Level of education (Actual year)	Primary (1-5)	40.0	5.21	3.74
Household size (Number)	Medium (5-7)	61.9	6.05	1.89
Area under fish farming (Hectare)	Medium (1.01-3.0)	81.0	1.65	0.74
Fish farming experience (Year)	High (above 22)	61.0	20.10	8.44
Annual family income ('000' Taka)	Medium (400-1000)	59.0	633.15	282.5
Organizational participation (Scores)	Low (up to 10)	87.6	4.21	3.61
Training exposure in fish farming (Days)	Short duration (1-2)	50.5	1.83	1.54
Credit received ('000' Taka)	Low (up to 100)	48.6	83.81	75.16
Extension media contact (Scores)	Medium (15-28)	88.6	19.91	4.87
Social mobility (Scores)	Medium (11-20)	52.4	6.99	3.23

SD = Standard Deviation

Table 2. Distribution of respondents according to their perception of G3 Rohu fish culture

Categories	Number	Percent	Mean	SD
Unfavorable (12-28)	0	0		
Favorable (29-44)	78	74.3	44.43	3.30
Highly favorable (45-60)	27	25.7		
Total	105	100		

Rank order of the fish farmers' perception of G3 Rohu fish culture

Based on the perception score (PS), Table 3 evaluates fish farmers' perceptions of G3 Rohu culture, reflecting both good and negative views. According to the top-ranked statement, G3 Rohu has lower death rates and requires fewer medicines due to its resistance to common diseases. Farmers report it grows faster than traditional Rohu, reaching marketable size in 6 to 8 months, and adapts well to changes in water conditions. As a result, farmers trust this strain to be strong and profitable.

The bottom three ranked statements reveal key issues regarding G3 Rohu. Farmers note that its cultivation requires advanced techniques, like pond management, which may be challenging for smallholders. Additionally, concerns about the high cost of fingerlings and consumer hesitancy around genetic manipulation pose significant obstacles. Overall, while farmers recognize the biological and economic benefits of G3 Rohu, they remain worried about practical implementation and market acceptance.

Factors influencing farmers' perceptions of G3 Rohu culture

Based on the data in Table 4, the R value was 0.873 and R^2 was 0.763, with an F-value of 24.643 that was statistically significant at the 0.1% level. The multicollinearity analysis, using the Variance Inflation Factor (VIF), showed maximum and minimum VIF values of 7.270 and 1.254, respectively. According to Shrestha (1983), VIFs between 1 and 5 suggest moderate correlation among variables, 5 to 10 indicate non-severe multicollinearity, and values above 10 point to severe

Table 3. Rank order of the fish farmers' perception of G3 Rohu culture

Statements	No. of Respondents					PS	RO
	SA	A	NO	DA	SD		
G3 Rohu exhibits improved resistance to common diseases and infections, leading to lower mortality rates and reduced reliance on medication. (+)	51	54	0	0	0	471	1
G3 Rohu exhibits enhanced adaptability to fluctuating water conditions, such as tolerating lower oxygen levels, wider temperature variations, and even slightly acidic or alkaline water. (+)	45	60	0	0	0	465	2
The genetically improved G3 Rohu grows faster than traditional Rohu, reaching 1 kg in just 6-8 months under optimal conditions instead of 10-12 months, enabling more fish to reach harvest size more quickly. (+)	44	61	0	0	0	464	3
The Genetically Improved G3 Rohu strain exhibits a lower mortality rate than traditional local Rohu varieties	35	70	0	0	0	455	4
G3 Rohu requires less feed to attain the same weight as traditional Rohu, reducing feed costs and enhancing farming profitability. (+)	32	73	0	0	0	452	5
G3 Rohu has better meat texture and taste, making the fish more desirable for consumers and increasing market value. (+)	19	86	0	0	0	439	6
For G3 production, fish farmers must rely on specific hatcheries for quality fingerlings. (-)	10	76	2	17	0	394	7
G3 Rohu fingerlings may be in short supply, especially in remote areas. (-)	6	50	7	42	0	335	8
Fish farmers may face difficulty getting a premium price if buyers do not recognize the strain's value.	1	59	4	41	0	335	9
The higher cost of G3 Rohu fingerlings increases the investment for farming. (-)	0	55	0	50	0	320	10
Consumers are hesitant to embrace G3 Rohu fish because of concerns about genetic modification. (-)	1	25	8	71	0	359	11
G3 Rohu requires more specific or advanced farming practices, such as feeding strategies, monitoring systems, or more sophisticated pond management, compared to traditional Rohu. (-)	0	22	10	73	0	366	12

SA = strongly agree, A = agree, NO = no opinion, DA = disagree, SD = strongly disagree, RO = rank order

Table 4. Summary of multiple linear regression analysis explaining farmers' perceptions of G3 Rohu culture

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	36.555	1.964		18.612	.000		
Age	-0.034	0.064	-0.132	-0.535	0.594	0.343	3.425
Level of Education	0.072	0.069	0.082	1.047	0.298	0.420	2.378
Household size	-1.058	0.160	-0.608	-6.590	0.000	0.303	3.300
Fish farming experience	0.162	0.083	0.413	1.959	0.053	0.158	7.270
Area under fish culture	1.494	0.745	0.336	2.006	0.048	0.192	2.862
Area under rohu fish culture	1.087	1.310	0.671	8.466	0.000	0.411	2.435
Annual family income	-0.005	0.003	-0.363	-1.963	0.053	0.875	1.293
Credit received	0.000	0.003	-0.007	-0.108	0.914	0.569	1.756
Training exposure in fish culture	0.088	0.152	0.041	0.579	0.564	0.514	1.944
Organizational participation	0.267	0.053	0.292	5.034	0.000	0.767	1.304
Social mobility	-0.318	0.107	-0.312	-2.981	0.004	0.236	4.241
Extension media contact	0.373	0.039	0.550	9.679	0.000	0.798	1.254

N = 105, R = 0.873, R^2 = 0.763, Adjusted R^2 = 0.732, F-value = 24.643

multicollinearity. Hence, no severe multicollinearity was identified in the model.

The results of the multiple linear regression analysis showed that the following twelve independent variables, area under fish culture, area under Rohu culture, organizational participation, and extension media contact, had a positive and significant impact on farmers' perceptions of G3 Rohu culture. However, there were negative effects on household size and social mobility.

DISCUSSION

The findings of this study reveal that farmers in Mymensingh generally hold highly favorable perceptions of G3 Rohu culture, with none reporting unfavorable views. This widespread acceptance underscores the recognition of G3 Rohu's biological and economic advantages, including higher disease resistance, faster growth, and adaptability to diverse water conditions. These findings are in line with earlier studies that demonstrated positive farmer attitudes toward innovative agricultural and aquaculture practices (Smrity et al., 2020). The rank order analysis further highlights the primary drivers of positive perceptions. Farmers identified disease resistance and reduced input costs as the most important advantages, consistent with the economic rationale for adopting improved strains. Similarly, faster growth and better adaptability to environmental fluctuations were strongly valued, reflecting the high production risks fish farmers typically face. These advantages build confidence in the strain's profitability and resilience, encouraging adoption.

However, concerns about the higher cost of fingerlings, reliance on specific hatcheries, and the need for advanced management practices suggest barriers to scaling adoption, particularly for smallholders with limited resources. Such reservations are consistent with broader evidence that technological innovations often face challenges of affordability, accessibility, and consumer acceptance (Podder et al., 2022; Shanmuka et al., 2022). The results of the multiple linear regression analysis show that fish farmers' opinions about G3 Rohu farming are greatly influenced by a number of important parameters. Notably, household size has a negative relationship with perception levels, suggesting that larger households face heightened financial and resource constraints. This limitation likely restricts their capacity to invest in or explore new technologies like the G3 Rohu culture (Riley, 2024). Similar conclusions have been drawn by Hoque et al. (2022) and Islam and Sarker (2024), highlighting the significant connection between household size and farmers' attitudes towards aquaculture innovations.

Conversely, the area dedicated to fish culture exhibits a significant positive relationship with perception. Farmers who allocate larger areas for fish farming tend to have more favorable views of G3 Rohu, possibly due to increased resource availability and an openness to adopting innovations that improve productivity (Giller et al., 2021). This finding is supported by Ramos et al. (2015) and Kumar et al. (2018). Additionally, organizational participation positively impacts perception. Farmers involved in cooperatives or community groups typically demonstrate higher awareness and more favorable views of G3 Rohu culture. Such engagement provides access to training and peer learning opportunities (Valleala et al., 2015).

Lastly, extension media contact has a significant and positive correlation with perception levels. Farmers with regular interactions with extension services gain enhanced technical understanding and awareness of the G3 Rohu culture. Extension services are crucial for providing timely information and guidance, thus encouraging improved fish variety adoption (Norton & Alwang, 2020; Jarh et al., 2024). Overall, these findings underscore the importance of household dynamics, resource allocation, community involvement, and extension services in shaping perceptions towards aquaculture practices.

CONCLUSION

A major cultivated species in Bangladesh is the Rohu, and the fishing industry is vital to the economy and food security of the country. However, traditional strains face growth and disease limitations, prompting the introduction of genetically improved G3 Rohu. This study finds that all surveyed fish farmers hold a

favorable perception of G3 Rohu, driven by its faster growth, improved disease resistance, and adaptability to diverse water conditions. As per regression results, household size, fish culture area, organisational membership, mobility in society, and extension media interaction all have a substantial influence on these perceptions. Positive experiences and access to technical knowledge, particularly through extension services and farmer organisations, strengthen adoption potential. These results highlight that targeted training, strengthening farmer networks, and expanding extension outreach can accelerate the uptake of G3 Rohu. Encouraging this superior strain could increase farm profitability, lower production risks, and support the long-term growth of the aquaculture industry in Bangladesh.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents for the study.

Competing interest: The Authors have no competing interests.

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

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

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Research Article

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Big Five Personality Predictors of Career Readiness among Agricultural Graduate Students

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HIGHLIGHTS

- The personality traits of agricultural graduates were assessed using the Big Five Inventory (BFI-44).
- Agreeableness, openness, and conscientiousness acted as significant predictors of career readiness among agricultural graduates.
- Gender plays an insignificant role across *Big Five traits* and is not a key predictor of graduates' career readiness.

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ABSTRACT

Personality traits greatly influence how a graduate selects, adapts, grows and flourishes in their professional career path. The study conducted in 2025 examined the relationship between personality traits and career readiness among 120 final year agricultural graduates of Kerala Agricultural University, corresponding to a ±8% margin of error at a 95% confidence level, using the *Big Five Personality framework*. Results showed higher mean scores in agreeableness (3.68) and openness (3.40), with no significant gender differences ($p > 0.05$). Analysis identified agreeableness ($\beta = 0.354$, $p = 0.001$), openness ($\beta = 0.390$, $p = 0.004$), and conscientiousness ($\beta = 0.300$, $p = 0.021$) as significant predictors of career readiness. Correlational analysis showed positive associations between agreeableness ($r = 0.728$, $p < 0.01$), openness ($r = 0.665$, $p < 0.01$), and conscientiousness ($r = 0.413$, $p < 0.05$) and career readiness. Independent-samples t-tests showed no significant gender differences across the Big Five traits at the 5% level. However, conscientiousness ($d = 0.45$) and neuroticism ($d = –0.54$) showed moderate effect sizes, indicating practical gender-based differences. The study highlights the value of soft skills, industry exposure, and personal and career development programmes in enhancing agricultural graduates' career readiness and competence.

INTRODUCTION

The transition of agricultural university students into professional careers is a pressing yet essential concern in higher education and workforce development. This study emphasised a dual focus—examining personality structures and exploring their relationship with employability outcomes and professional preparedness. In today's rapidly evolving agricultural sector, adaptability, innovation, emotional intelligence, and collaborative skills are increasingly valued alongside technical expertise and domain-specific knowledge. Understanding the personality orientations of students is, therefore, crucial for developing strategies that enhance workforce preparedness and long-term career success. Insights derived from such analyses contribute meaningfully to academic discussions on the interplay between personality and employability. To strengthen graduate readiness, the study offers evidence-based recommendations for curriculum designers, extension professionals, and industry stakeholders (Modak et al., 2018; Amaran et al., 2025).

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Agricultural education in India has undergone steady reforms; nevertheless, a considerable gap persists between classroom learning and the evolving demands of the agricultural sector. Employers increasingly prioritise attributes such as soft skills, creativity, adaptability, and interpersonal competence, which enhance technical expertise and reflect a growing shift toward comprehensive professional development (Harisha et al., 2024). Personality traits, as conceptualised by the Big Five model, are widely recognised as predictors of behaviour, motivation, learning orientation, and performance outcomes (Lee et al., 2023). These personality dimensions shape not only career preferences and orientations but also influence individuals' adaptive capacity, problem-solving ability, and resilience in uncertain and complex professional contexts (Hu et al., 2025). Despite this, empirical studies investigating agricultural graduates' personality profiles in India remain limited, particularly concerning their direct association with career readiness. It is, therefore, vital to address this research gap to better align higher education outcomes with the evolving workforce needs and to equip graduates with the competencies required to navigate the ever-changing professional environment within the tertiary education sector.

Guided by this rationale, the study was directed by three primary research questions: What are the dominant personality traits of agricultural university students as defined by the Big Five model? Are there significant gender-based variations in these traits? How do these personality dimensions influence career readiness and workforce transition? To explore these questions, a null hypothesis was proposed, stating that there are no significant differences in mean personality trait scores between male and female students. The present research thus employed standardised tools such as the Big Five Inventory (BFI-44) and the Career Readiness Index (CRI) to analyse the personality profiles, career orientations, and employability competencies of agricultural graduates within the context of India's evolving agricultural education framework.

METHODOLOGY

A quantitative, cross-sectional research design was used to examine the relationship linking personality traits and career readiness within agricultural university students. It enabled the apprehension of inter-individual variations in personality and their predictive capacity for employability-related competencies within a single time frame. The research was conducted across four constituent colleges of Kerala Agricultural University (KAU): College of Agriculture (CoA), Thiruvananthapuram; CoA, Thrissur; CoA, Kasargod; and CoA, Wayanad. These institutions were purposively selected as they represent agro-ecological and academic contexts, thereby enabling a deep understanding of students' personality orientations within agricultural education in Kerala. The sample comprised 120 students (78 females and 42 males) from the 2021 cohort, representing final-year undergraduates, providing a ±8% margin of error at the 95% confidence level, using proportionate stratified random sampling to ensure representation across all constituent colleges. Eligibility criteria included active current enrolment in the undergraduate agricultural programme and provision of informed consent.

The Big Five Inventory (BFI-44), a validated and widely used psychometric scale, was employed to assess personality traits using 44 items grouped into the five OCEAN dimensions: Openness (10), Conscientiousness (9), Extraversion (8), Agreeableness (9), and Neuroticism (8). The overall internal consistency (Cronbach's alpha) for the five domains ranged from 0.85 to 0.92, indicating excellent reliability of the original scale (Costa & McCrae, 1992). A five-point Likert scale was used to record responses. Additionally, the respondents' Career Readiness Index (CRI) was assessed to measure their employability skills. The CRI was developed based on the NACE (2021) framework for agricultural graduates, covering key areas such as leadership, problem-solving, and teamwork.

A comprehensive, multi-level analytical approach was used to achieve the research objectives and evaluate the proposed hypotheses. Descriptive statistics were calculated to assess the central tendencies and dispersion of personality traits. Inferential statistics were applied to evaluate group differences. Independent-samples t-tests were conducted to examine gender-based variations in personality traits. In addition to significance testing, effect sizes (Cohen's d) were computed to determine the magnitude of observed differences, following Cohen's (1988) thresholds for interpretation: small (≈0.2), moderate (≈0.5), and large (≈0.8). Regression analysis was performed using the CRI as the dependent variable and the Big Five personality traits as independent predictors. Regression outputs included coefficients (β), standard errors, t-values, and p-values. Traits with $p < 0.05$ were considered significant predictors of career readiness. Pearson's correlation analysis was used to assess inter-trait relationships and their connection with the Career Readiness Index at 1% and 5% significance levels, with results visualised through a correlation heatmap for better interpretability.

RESULTS

The analysis of personality traits among agricultural university students offers useful insights into individual differences and their influence on career readiness. The descriptive results of the Big Five traits among undergraduates reveal the relative prominence of each trait and how they vary between male and female students. The analysis also examined how these traits affect employability outcomes. It goes beyond simple description and provides evidence of which traits significantly influence career readiness among agricultural university students.

Descriptive patterns of the big five traits

The descriptive patterns of the Big Five traits explore gender-based differences, and interpret the findings in relation to employability, adaptive behaviour, and professional development in the agricultural sector. The findings from the descriptive analysis of the Big Five personality traits among undergraduate students are presented in Table 1.

The analysis revealed that Agreeableness recorded the highest mean score (3.68), followed by Openness (3.40) and Conscientiousness (3.29). Extraversion exhibited the lowest mean (2.93), indicating relatively introverted tendencies among students, while Neuroticism was moderate (3.00). Gender-based comparisons indicated that female students scored slightly higher on Openness and Conscientiousness, whereas male students recorded higher

Table 1. Descriptive statistics of personality traits with gender comparison

Trait	Total Mean	SD	Girls Mean	Boys Mean	Significance (Girls vs Boys)
Openness	3.40	0.40	3.44	3.31	NS
Conscientiousness	3.29	0.30	3.34	3.20	NS
Extraversion	2.93	0.25	2.91	2.97	NS
Agreeableness	3.68	0.69	3.67	3.70	NS
Neuroticism	3.00	0.35	2.94	3.12	NS

scores on Extraversion and Neuroticism. However, none of these differences were statistically significant ($p > 0.05$), confirming overall similarity between genders. The findings confirm the null hypothesis and align with earlier studies highlighting minimal gender differences in personality traits among higher education cohorts. (Schmitt et al., 2008).

The predictive influence of personality traits on employability outcomes

A multiple regression analysis was conducted to evaluate the predictive impact of the personality traits on employability outcomes, with the Career Readiness Index serving as the dependent variable. This analysis was designed to provide empirical evidence on which specific traits significantly affect career readiness among agricultural university students. Table 2 illustrates the obtained results.

Table 2. Regression results predicting Career Readiness Index

Variable	Coef.	Std. Error	t	P>|t|	S/NS
const	-0.362	0.527	-0.686	0.530	NS
Openness	0.390	0.065	5.978	0.004	S
Conscientiousness	0.300	0.081	3.706	0.021	S
Extraversion	-0.005	0.091	-0.056	0.958	NS
Agreeableness	0.354	0.039	9.129	0.001	S
Neuroticism	0.074	0.104	0.714	0.515	NS

R^2 of 0.61; Adjusted R^2 of 0.58; ($F(5, 54) = 17.23$, $p < 0.001$); S-Significance; NS- Non-significance

The model showed strong explanatory power ($R^2 = 0.61$; Adjusted $R^2 = 0.58$), demonstrating that these five traits together contributed approximately 61% of the variance in career readiness. The regression model was statistically significant ($F(5, 54) = 17.23$, $p < 0.001$), indicating that the predictors collectively have a meaningful effect on career readiness. At the individual trait level, agreeableness ($\beta = 0.354$, $p = 0.001$), openness ($\beta = 0.390$, $p = 0.004$), and conscientiousness ($\beta = 0.300$, $p = 0.021$) emerged as significant positive predictors of career readiness. Conversely, extraversion ($\beta = -0.005$, $p = 0.958$) and neuroticism ($\beta = 0.074$, $p = 0.515$) were non-significant. Agreeableness showed the strongest predictive effect among the significant variables, followed by openness and conscientiousness.

These results of the regression analysis (Figure 1) highlight the dominant role of interpersonal, adaptive, and self-regulatory traits in shaping employability outcomes.

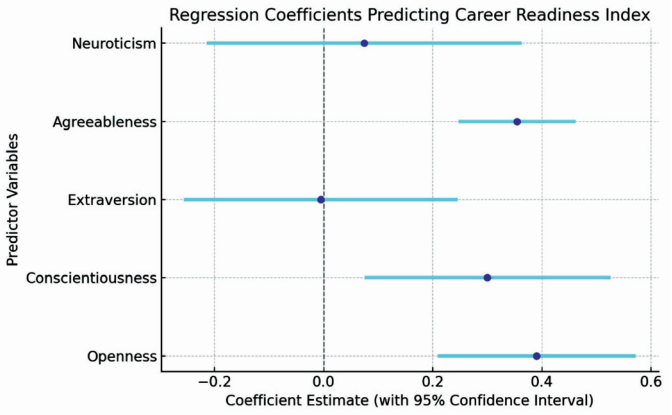

Figure 1. Regression Coefficients Predicting Career Readiness Index

Interrelationships among the big five personality traits and their associations with the career readiness index

To complement the regression analysis, a correlation matrix was constructed to examine the interrelationships among the Big Five traits and their associations with the Career Readiness Index (CRI). This analysis provides a broader perspective on how traits interact with one another and jointly influence employability outcomes, capturing both positive and negative linkages not evident from regression alone. The results are summarized in Table 3 and illustrated in Figure 2.

The analysis displayed several significant associations. At the 1% level, openness ($r = 0.665$), agreeableness ($r = 0.728$), and neuroticism ($r = –0.786$) were strongly correlated with career readiness. At the 5% level, both conscientiousness ($r = 0.413$) and extraversion ($r = 0.413$) exhibited moderate positive correlations with readiness. Inter-trait relationships further highlighted meaningful patterns. A strong and statistically significant positive correlation was found between conscientiousness and extraversion ($r = 0.720$, $p < 0.01$), suggesting that students who are organized and disciplined are also more socially outgoing. Openness and conscientiousness were moderately correlated ($r = 0.495$, $p < 0.05$), indicating a link between curiosity and diligence. In contrast, neuroticism showed negative correlations with both openness ($r = –0.583$, $p < 0.01$) and agreeableness ($r = –0.718$, $p < 0.01$), emphasizing the adverse impact of emotional instability on cooperative and adaptive behaviours.

Gender-based differences in personality traits

To examine potential gender-based differences in personality traits, Independent-samples t-tests were conducted, with results shown in Table 4 and Figure 3. In addition to significance testing, Cohen's d effect sizes were calculated to evaluate the practical magnitude of group differences, based on Cohen's (1988) thresholds.

The findings from Table 4 revealed that none of the observed differences were statistically significant at the 5% level. However, effect size estimates suggested small-to-moderate practical differences in certain traits. Specifically, openness ($d = 0.35$) and conscientiousness ($d = 0.45$) showed moderate effects, despite non-significant *p*-values. Neuroticism ($d = –0.54$) also indicated a moderate effect, with females scoring slightly higher, although this

Table 3. Correlation Matrix of Big Five Traits

Trait	O	C	E	A	N	CRI
Openness (O)	1.0	0.495*	0.254 ^{NS}	0.036 ^{NS}	-0.583**	0.665**
Conscientiousness (C)	0.495*	1.0	0.720**	-0.188 ^{NS}	0.069 ^{NS}	0.413*
Extraversion (E)	0.254 ^{NS}	0.720**	1.0	0.081 ^{NS}	0.044 ^{NS}	0.413*
Agreeableness (A)	0.036 ^{NS}	-0.188 ^{NS}	0.081 ^{NS}	1.0	-0.718**	0.728**
Neuroticism (N)	-0.583**	0.069 ^{NS}	0.044 ^{NS}	-0.718**	1.0	-0.786**
Career Readiness Index (CRI)	0.665**	0.413*	0.413*	0.728**	-0.786**	1.0

Notes: p < 0.01 (highly significant), *p < 0.05 (significant), NS = not significant.O- Openness; C- Conscientiousness; E- Extraversion; A- Agreeableness; N- Neuroticism; CRI- Career Readiness Index

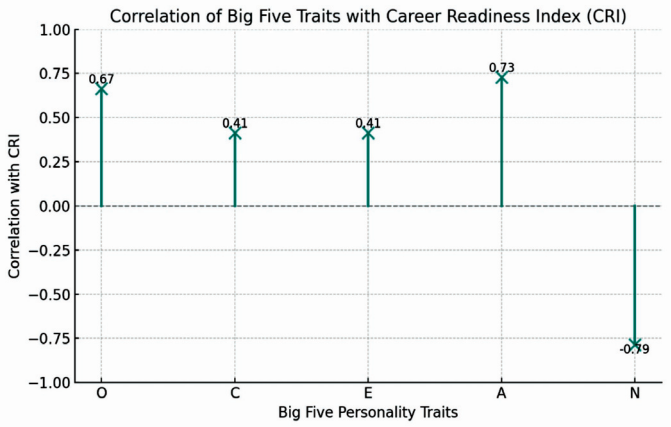

Figure 2. Correlation of Big Five Traits with Career Readiness Index (CRI)

Table 4. Independent samples t-test results (gender comparison) with effect sizes

Trait	t-value	df	p-value	Cohen's *d*	Interpretation
Openness	0.72	17.38	0.481	0.35	Small-to-moderate effect
Conscientiousness	0.88	15.01	0.393	0.45	Moderate effect
Extraversion	-0.456	13.38	0.656	-0.25	Small effect (trivial)
Agreeableness	-0.078	15.92	0.939	-0.04	Negligible effect
Neuroticism	-0.987	13.32	0.341	-0.54	Moderate effect

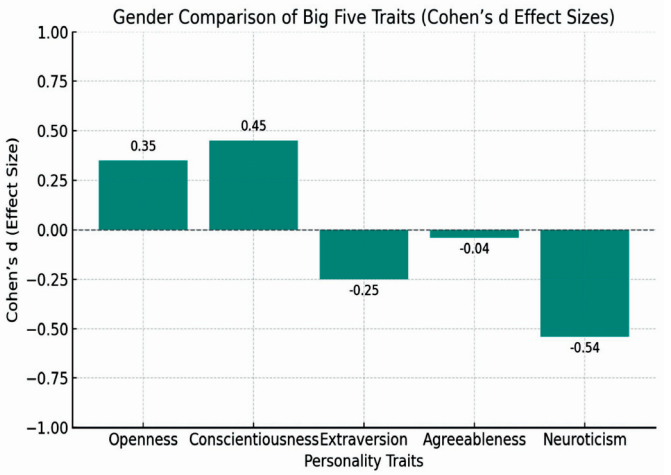

Figure 3. Gender-based differences in personality traits

difference did not reach significance (p = 0.341). In contrast, extraversion (d = –0.25) reflected only a trivial effect, while agreeableness (d = –0.04) was negligible.

DISCUSSION

Descriptive patterns of the Big Five traits offer insights into career readiness. Students exhibited high Agreeableness, promoting teamwork, and moderate Openness, fostering creativity and technology adoption (McCrae & Costa, 2008). Low Extraversion limits communication and leadership, while moderate Neuroticism implies stress vulnerability. Hence, stress management, mentoring, and leadership training are vital to strengthen communication, resilience, and employability in agricultural education.

Agreeableness aligns with studies emphasizing cooperative, pro-social orientations vital for team-based agricultural and extension work (Malik et al., 2020). Openness highlights creativity and adaptability in addressing technological and sustainability challenges (McCrae & Costa, 2008; Mishra et al., 2021). Conscientiousness—diligence and persistence—predicts performance through planning, record-keeping, and resilience (Lounsbury et al., 2004; Qadir, 2014). Extraversion's non-significance suggests sociability is less critical than teamwork, while neuroticism did not hinder readiness. Hence, curricula should integrate team-based, problem-solving, and mentored training with technical education to foster agreeableness, openness, and conscientiousness, strengthening employability and personality development among agricultural graduates. The results of the independent samples t-test reiterate that the regression findings: agreeableness, openness, and conscientiousness positively support career readiness, whereas neuroticism hampers it. Agreeableness emerged as the strongest correlate, emphasizing the importance of pro-social and cooperative orientations in agricultural contexts, where teamwork, negotiation, and stakeholder collaboration are integral (John & Srivastava, 1999; Tziner & Tanami, 2013). Openness positively correlates with career readiness, emphasizing creativity and adaptability essential for agricultural graduates (Shireesha et al., 2023). Conscientiousness supports diligence, goal orientation, and reliability in sustainable management (Barrick & Mount, 1991). Extraversion moderately aids readiness, while neuroticism (r = –0.786, p < 0.01) hinders confidence and resilience. Institutions can enhance readiness through teamwork, technology exposure, mentoring, and stress management, integrating technical and socio-emotional competencies to produce skilled, resilient, and socially equipped agricultural professionals.

Gender-based analysis showed no statistically significant differences, likely due to the small sample size, though moderate

effect sizes suggested practical variations in openness, conscientiousness, and neuroticism. These findings align with prior studies reporting modest gender differences (Feingold, 1994; Weisberg et al., 2011; Shah et al., 2023). Agreeableness and extraversion remained similar across genders, indicating consistent cooperation and sociability (Costa, Terracciano & McCrae, 2001). Slight differences in conscientiousness and openness may influence technology adoption and career readiness, underscoring the need for resilience training in agricultural education. Overall, the results suggest that gender alone is not a decisive factor in predicting personality-linked readiness for agricultural careers. However, capacity-building initiatives that universally enhance openness, conscientiousness, and emotional stability will continue to be critical. This inclusive approach will ensure that both male and female graduates are equally prepared to traverse the complex and ever-evolving demands of the agricultural sector.

CONCLUSION

The study demonstrates that among agricultural undergraduates, agreeableness, openness, and conscientiousness emerge as the most salient predictors of career readiness, whereas extraversion and neuroticism show limited influence. Correlation results further demonstrate the positive association of cooperative and adaptive orientations with employability, alongside the detrimental effect of higher neuroticism. Although gender differences in trait expression were not statistically significant, effect size estimates indicated modest variations, suggesting that interventions should be universally oriented rather than gender specific. Overall, the findings highlight the need for agricultural education programmes to integrate opportunities that cultivate teamwork, flexibility, and conscientious behaviour, while simultaneously inculcating resilience and stress-management orientations. Such measures would enable graduates to translate personality strengths into enhanced employability, ensuring preparedness for the dynamic demands of the agricultural sector.

DECLARATIONS

Ethics approval and informed consent: The study adhered to established ethical principles of social science research. Students were fully briefed on the objectives and scope of the study before participation. Informed consent was obtained, participation was voluntary, and no academic consequences were associated with refusal or withdrawal. All responses were anonymised to protect confidentiality and ensure unbiased analysis.

Conflict of interest: The authors declare that there are no conflicts of interest in conducting this research study.

Authors' contribution: This work was carried out in collaboration between all the authors. The study was conceptualised, interpreted, and the final draft of the manuscript was prepared by Author 1 and Author 5. Author 1 collected the data required for the study and performed the statistical analysis. The draft was edited by Author 2 and Author 5, All authors read and approved the final manuscript.

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Research Article

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Composite Fertilizer Management Index (CMFI) among Major Field Crop Growers of Telangana

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HIGHLIGHTS

- CFMI contains novelty in approach as it consists of planning, purchasing, practising and performance dimensions with 22 underlying indicators, which include FBMPs.
- The comparative analysis was done across six major field crops of Telangana.
- Advanced statistical tools like MGLM and Kruskal wallis test were used in testing hypothesis and identifying determinants of fertilizer management.

ARTICLE INFO

Keywords: Fertiliser use, Manures, Nutrient management, Determinants, Factors, Comparative analysis, FBMPs, GAPs.

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ABSTRACT

The study was conducted during 2023–2025 to develop a composite fertilizer management index (CFMI) for major field crops of Telangana, encompassing planning, purchasing, practicing, and performance dimensions. The research design involved 360 farmers across six major field crops *i.e.* paddy, cotton, maize, red gram, soybean, and Bengal gram. Data on 22 indicators were collected from farmers, normalised and analyzed using Principal Component Analysis (PCA), Kruskal-Wallis test, and Multivariate General Linear Model (GLM). Results revealed that maize farmers ranked highest in overall fertilizer management (CFMI = 0.49), followed by paddy (0.48), red gram (0.46), cotton (0.44), soybean (0.30), and Bengal gram (0.29). Significant difference in fertiliser management across crops (χ^2 = 123.136, $p < 0.01$) was found. Education, farming system, experience in selected crop cultivation, manure and fertilizer availability, social participation, extension contact, scientific orientation, sustainability orientation and economic motivation were key determinants of CFMI (R^2 = 0.643). The findings highlight the need to enhance farmers' knowledge and attitudes toward efficient fertilizer practices, raise awareness of health and environmental impacts, and strengthen input availability and institutional linkages to promote balanced nutrient management and improve soil health, crop productivity, and resource use efficiency.

INTRODUCTION

Fertilizers are important inputs for increasing the production and productivity of crops. Indian soils are deficient in organic carbon, N, P, K, B, Cu, Fe, Mn, S and Zn nutrients, respectively (Khurana & Kumar, 2022). In the consumption of plant nutrients (NPK/ha) in major states of India during 2019, Telangana reported the top (Srinivasarao, 2021). The ratio of N, P, and K fertiliser use indicates noticeable disparities across states, highlighting potential nutrient imbalances across farming systems (Chand & Pandey, 2008). In Telangana, fertilizer use patterns clearly reflect this imbalance, with excessive nitrogen application reported in most

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districts, excessive phosphatic fertilizer use in some districts, and consistent deficiency of potassic fertilizers across all districts. Furthermore, none of the districts recorded 75 to 100% area coverage under the use of farmyard manure (FYM), emphasizing the declining reliance on organic nutrient sources (Bora, 2022). In terms of solid and liquid biofertilizer production during 2020-21, Telangana ranked 13th and 12th among all states and union territories, respectively, with production levels below 5,000 tonnes (Khurana & Kumar, 2022). It has been observed that although chemical fertilizer use among farmers is high, awareness of its impact on soil health remains low (Hussain et al., 2017). These trends highlight an alarming scenario, making it essential to examine these patterns at a micro level. It will help to understand how nutrient imbalances are reflected across different crops and to identify the factors responsible for them. The results of this analysis may provide insights into existing practices of fertilizer planning, purchasing, application, and performance. They can also help explain the reasons behind both efficient and inefficient management. Such insights can guide policymakers in designing targeted interventions, capacity development programs, and infrastructural improvements, including subsidies and soil testing facilities. The Government of India has launched a National Mission on Soil Health Card to promote soil test based, balanced and judicious fertilizer application in the country (PIB, 2021).

There was no early study reported in the area consisting of planning, purchasing, practicing and performance of fertilizers in major field crops. Considering this, a fertilizer management index was developed to enable crop wise comparison, which can also be adapted to other crops with minor modifications. In this context, the study aimed to analyze the fertilizer management by farmers in major field crops of Telangana and to examine the relationship between independent variables and fertilizer management. Accordingly, the following hypotheses are formulated: (i) there is no significant difference in fertilizer management across farmer groups, and (ii) there exists a significant association between independent variables and fertilizer management. The study was confined to one crop per district, limiting the generalization of findings to all major field crop farmers of Telangana. The sample size was restricted to 360 farmers, and the results are therefore context-specific. The findings relied on respondents expressed opinions and recall, which may involve response bias. Additionally, the use of ex-post facto and exploratory research designs entails inherent methodological limitations.

METHODOLOGY

The study was carried out during 2023-2025. The Telangana state was purposively selected. Based on the area under cultivation during previous five years six major field crops *i.e.* paddy, cotton, maize, red gram, soybean and Bengal gram were selected purposively. For each crop, 1 district was selected randomly among the cultivating districts. From each district, 2 mandals were randomly selected. From each mandal, 3 villages were randomly selected. From each village, 10 farmers were selected randomly. Thus, a total of 6 districts, 12 mandals, 36 villages and 360 farmers were selected randomly for the study in a way that each district represents 60 farmers cultivating the respective crop. A total of twenty-five independent variables, two other variables (knowledge and attitude towards Fertilizer Best Management Practices) and one dependent variable (Composite Fertilizer Management Index) were selected for the study.

Development of Composite Fertilizer Management Index

Large number of indicators were identified from studying review of literature and expert consultations and 22 indicators were finalized using relevancy ratings received by 37 experts out of 64 experts (Jairu et al., 2023; Khalkho & Ghosh, 2023; Chandra & Ghadei, 2024) and they were organised under 4 dimensions (Ranjan et al., 2025). The data from farmers was collected on these indicators. The indicators were uniform across crops however, number of indicators and the unit of measurement between the indicators was different. Hence, they were normalized by subtracting the minimum value from the observed value and dividing by range (Kale et al., 2016). Principal Component Analysis (PCA) was employed on normalized data with varimax rotation using Statistical Software for Social Sciences 20 (SPSS 20). The communality values obtained through PCA indicated the proportion of variance explained by all the indicators together. All these values shown communality value of 0.6 (Maiti et al., 2015). The method followed by National University of Educational Planning and Administration (2009) used to assign weights to each indicator for development of Composite Fertilizer Management Index (CFMI). Index validity was measured by content validity, and construct validity using KMO measure of sampling adequacy (0.657) and Bartlett's Test of Sphericity $p <$ .01. The index was calculated by using following formula. The possible range of CFMI was 0 – 1.

$$\text{CFMI} = \frac{\sum_{i=1}^{n} W_i X_i}{\sum_{i=1}^{n} W_i}$$

X_i = is the index value of the concerned indicator
W_i = Weights associated with X_i indicator

Initially, Kruskal Wallis test was performed to test the significant difference in CFMI across the six major field crops. Multiple pairwise comparison using Dunns procedure was performed to test the significant difference in CFMI between each pair of crops. It was done by using SPSS 20. Further, the Pearson correlation coefficient was calculated to assess the correlation between determinants and CFMI of each crop and overall. After finding similarities in results across crops stepwise regression was performed to identify the most significant variables. Then, a Multivariate General Linear Model was used to test the significant variables with CFMI. No significant interaction effect (crop × variable) was found, suggesting that the variables were consistently associated across farmer groups, with no deviation in their relationships among the groups. Further, the univariate general linear model result was calculated to find the effect of independent variables on CFMI.

RESULTS

The PCA results produced nine principal components (PCs) with eigenvalues greater than one, as illustrated in the scree plot (Figure 1). Together, these nine components explained nearly 75%

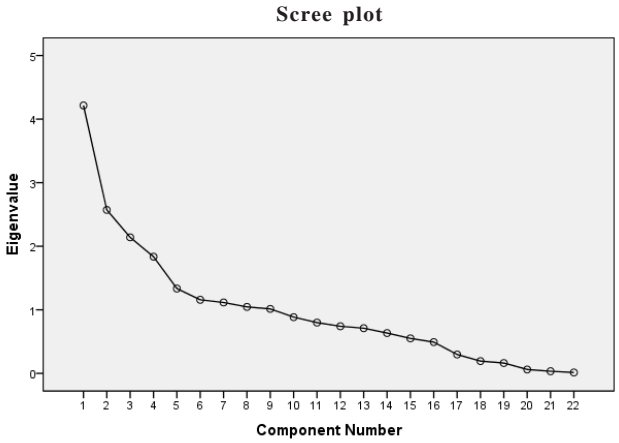

Figure 1. Scree plot of eigenvalue

Table 1. Eigen values and extraction of variability

Principal component	Extraction sums of squared loadings		
	Eigen value	% of Variance	Cumulative %
1	4.214	19.157	19.157
2	2.571	11.687	30.844
3	2.140	9.728	40.571
4	1.835	8.343	48.914
5	1.334	6.065	54.979
6	1.157	5.260	60.240
7	1.115	5.069	65.309
8	1.046	4.754	70.063
9	1.014	4.609	74.672

of the total variation in the standardized data (Table 1). The eigenvalues and factor loadings represented the respective weights assigned to each indicator for developing the index. The computed index values for individual indicators, dimensions, and the overall Composite Fertilizer Management Index for each crop are summarised in Table 2.

Composite Fertilizer Management Index

Maize farmers ranked first (x= 0.49, rank-I), followed by paddy (x= 0.48, rank-II), red gram (x= 0.46, rank-III), cotton (x= 0.44, rank-IV), soybean (x= 0.30, rank-V) and Bengal gram (x= 0.29, rank-VI).

Dimension-wise index values

In case of planning dimension, paddy farmers ranked first (x=0.40, rank-I), followed by maize (x=0.38, rank-II), cotton (x=0.35, rank-III), red gram (x=0.30, rank-IV), soybean (x=0.21, rank-V) and Bengal gram (x=0.20, rank-VI) farmers. In case of purchasing dimension, paddy farmers ranked first (x=0.54, rank-I), followed by maize (x=0.52, rank-II), red gram (x=0.51, rank-III), cotton (x=0.46, rank-IV), Bengal gram (x=0.25, rank-V) and soybean (x=0.25, rank-VI) farmers. In the case of practicing dimension, maize farmers ranked first (x=0.55, rank-I), followed by red gram (x=0.53, rank-II), paddy (x=0.49, rank-III), cotton (x=0.46, rank-IV), Bengal gram (x=0.37, rank-V) and soybean (x=0.35, rank-VI) farmers. In case of performance dimension, cotton farmers ranked first (x=0.55, rank-I), followed by maize (x=0.51, rank-II), red gram (x=0.49, rank-III), Bengal gram (x=0.48, rank-IV), paddy (x=0.48, rank-V) and soybean (x=0.47, rank-VI) farmers.

Indicator-wise index values

In case of planning manures, cotton farmers ranked first (x=0.33, rank-I), followed by maize (x=0.25, rank-II), red gram (x=0.24, rank-III), paddy (x=0.23, rank-IV), soybean (x=0.06, rank-V) and Bengal gram (x=0.06, rank-V). In case of planning fertilizes, red gram farmers ranked first (x=0.70, rank-I), followed by paddy (x=0.67, rank-II), maize (x=0.65, rank-III), cotton (x=0.53, rank-IV), Bengal gram (x=0.40, rank-V) and soybean (x=0.39, rank-VI). In case of planning of nutrient deficiency and adverse condition management, paddy farmers ranked first (x=0.31, rank-I), followed by maize (x=0.23, rank-II), cotton (x=0.23, rank-II), soybean (x=0.17, rank-IV), Bengal gram (x=0.16, rank-V) and red gram (x=0.07, rank-VI). In case of planning of fertilizer transport, paddy farmers ranked first (x=0.58, rank-I), followed by maize (x=0.43, rank-II), cotton (x=0.41, rank-III), soybean (x=0.30, rank-IV), red gram (x=0.26, rank-V) and Bengal gram (x=0.23, rank-VI). In case of planning of fertilizer storage, maize farmers ranked first (x=0.36, rank-I), followed by paddy (x=0.30, rank-II), soybean (x=0.29, rank-III), cotton (x=0.25, rank-IV), Bengal gram (x=0.24, rank-V) and red gram (x=0.24, rank-V). In case of planning of fertilizer handling, paddy farmers ranked first (x=0.24, rank-I), followed by maize (x=0.21, rank-II), cotton (x=0.17, rank-III), Bengal gram (x=0.05, rank-IV), soybean (x=0.04, rank-V) and red gram (x=0.02, rank-VI). In case of planning of fertilizer disposal, maize farmers ranked first (x=0.40, rank-I), followed by cotton (x=0.37, rank-II), paddy (x=0.36, rank-III), soybean (x=0.33, rank-IV), red gram (x=0.30, rank-V) and Bengal gram (x=0.30, rank-V).

In case of purchasing of manures, cotton farmers ranked first (x=0.48, rank-I), followed by red gram (x=0.39, rank-II), maize (x=0.28, rank-III), paddy (x=0.26, rank-IV), Bengal gram (x=0.08, rank-V) and soybean (x=0.08, rank-V). In case of purchasing nitrogenous fertilizers, paddy farmers ranked first (x=0.66, rank-I), followed by maize (x=0.59, rank-II), Bengal gram (x=0.53, rank-III), cotton (x=0.45, rank-IV), soybean (x=0.38, rank-V) and red gram (x=0.20, rank-VI). In case of purchasing of phosphatic fertilizers, maize farmers ranked first (x=0.70, rank-I), followed by red gram (x=0.66, rank-II), paddy (x=0.63, rank-III), soybean (x=0.57, rank-IV), Bengal gram (x=0.53, rank-V) and cotton (x=0.50, rank-VI). In case of purchasing of potassic fertilizers, paddy farmers ranked first (x=0.77, rank-I), followed by red gram (x=0.76, rank-II), maize (x=0.70, rank-III), cotton (x=0.42, rank-IV), Bengal gram (x=0.02, rank-V) and soybean (x=0.00, rank-VI).

In case of practicing manure application, cotton farmers ranked first (x=0.48, rank-I), followed by red gram (x=0.38, rank-II), maize (x=0.29, rank-III), paddy (x=0.28, rank-IV), Bengal gram (x=0.08, rank-V) and soybean (x=0.07, rank-VI). In case of practicing nitrogenous fertilizer application, Bengal gram ranked first (x=0.85, rank-I), followed by maize (x=0.80, rank-II), red gram (x=0.67, rank-III), soybean (x=0.62, rank-IV), cotton (x=0.55, rank-V) and paddy (x=0.37, rank-VI). In case of practicing phosphatic fertilizer application, red gram farmers ranked first (x=1.00, rank-I), followed by soybean (x=0.90, rank-II), Bengal gram (x=0.84, rank-III), cotton (x=0.70, rank-IV), maize (x=0.68, rank-V) and paddy (x=0.51, rank-

Table 2. Indicator-wise index values of Composite Fertilizer Management Index

S.No.	Indicator-wise index values	Paddy Index (Rank)	Cotton Index (Rank)	Maize Index (Rank)	Red gram Index (Rank)	Paddy Index (Rank)	Soybean Index (Rank)	Overall Index (Rank)
Composite fertilizer management index		0.48 (II)	0.44 (IV)	0.49 (I)	0.46 (III)	0.29 (VI)	0.30 (V)	0.41
D1	*Planning*	0.40 (I)	0.35 (III)	0.38 (II)	0.30 (IV)	0.21 (V)	0.20 (VI)	0.31 (IV)
1	Manures	0.23 (IV)	0.33 *(I)*	0.25 (II)	0.24 (III)	0.06 (V)	0.06 (V)	0.20 (XIX)
2	Fertilizers	0.67 (II)	0.53 (IV)	0.65 (III)	0.70 *(I)*	0.39 (VI)	0.40 (V)	0.56 *(IV)*
3	Nutrient deficiency and adverse condition management	0.31 *(I)*	0.23 (II)	0.23 (II)	0.07 (VI)	0.17 (IV)	0.16 (V)	0.19 (XX)
4	Fertilizer transport	0.58 *(I)*	0.41 (III)	0.43 (II)	0.26 (V)	0.30 (IV)	0.23 (VI)	0.37 (XIV)
5	Fertilizer storage	0.30 (II)	0.25 (IV)	0.36 *(I)*	0.24 (V)	0.29 (III)	0.24 (V)	0.28 (XVI)
6	Fertilizer handling	0.24 *(I)*	0.17 (III)	0.21 (II)	0.02 (VI)	0.04 (V)	0.05 (IV)	0.12 (XXII)
7	Fertilizer disposal	0.36 (III)	0.37 (II)	0.40 *(I)*	0.30 (V)	0.33 (IV)	0.30 (V)	0.34 (XV)
D2	*Purchasing*	0.54 (I)	0.46 (IV)	0.52 (II)	0.51 (III)	0.22 (VI)	0.25 (V)	0.42 (III)
8	Manures	0.26 (IV)	0.48 *(I)*	0.28 (III)	0.39 (II)	0.08 (V)	0.08 (V)	0.26 (XVII)
9	Nitrogenous fertilizers	0.66 *(I)*	0.45 (IV)	0.59 (II)	0.20 (VI)	0.38 (V)	0.53 (III)	0.47 (IX)
10	Phosphatic fertilizers	0.63 (III)	0.50 (VI)	0.70 *(I)*	0.66 (II)	0.57 (IV)	0.53 (V)	0.58 *(III)*
11	Potassic fertilizers	0.77 *(I)*	0.42 (IV)	0.70 (III)	0.76 (II)	0.00 (VI)	0.02 (V)	0.44 (XI)
D3	*Practicing*	0.49 (III)	0.46 (IV)	0.55 (I)	0.53 (II)	0.35 (VI)	0.37 (V)	0.46 (II)
12	Manure application	0.28 (IV)	0.48 *(I)*	0.29 (III)	0.38 (II)	0.07 (VI)	0.08 (V)	0.26 (XVII)
13	Nitrogenous fertilizer application	0.37 (VI)	0.55 (V)	0.80 (II)	0.67 (III)	0.62 (IV)	0.85 (I)	0.64 *(II)*
14	Phosphatic fertilizer application	0.51 (VI)	0.70 (IV)	0.68 (V)	1.00 *(I)*	0.90 (II)	0.84 (III)	0.77 *(I)*
15	Potassic fertilizer application	0.78 (III)	0.38 (IV)	0.88 (II)	0.94 *(I)*	0.00 (VI)	0.03 (V)	0.50 (VII)
16	Nutrient deficiency and adverse condition management	0.53 *(I)*	0.45 (II)	0.42 (III)	0.28 (VI)	0.32 (V)	0.39 (IV)	0.40 (XIII)
17	Fertilizer transport	0.67 *(I)*	0.50 (III)	0.56 (II)	0.42 (IV)	0.41 (V)	0.40 (VI)	0.49 (VIII)
18	Fertilizer storage	0.45 (III)	0.38 (V)	0.51 *(I)*	0.37 (VI)	0.47 (II)	0.42 (IV)	0.43 (XII)
19	Fertilizer handling	0.58 (II)	0.56 (III)	0.61 *(I)*	0.52 (V)	0.53 (IV)	0.51 (VI)	0.55 *(V)*
20	Fertilizer disposal	0.25 (II)	0.18 (III)	0.26 *(I)*	0.15 (V)	0.14 (VI)	0.16 (IV)	0.19 (XX)
D4	*Performance*	0.48 (V)	0.55 (I)	0.51 (II)	0.49 (III)	0.47 (VI)	0.48 (IV)	0.50 (I)
21	Manures	0.41 (VI)	0.58 *(I)*	0.43 (V)	0.45 (IV)	0.47 (II)	0.47 (II)	0.46 (X)
22	Primary macro nutrient fertilizers	0.55 (II)	0.52 (IV)	0.59 *(I)*	0.54 (III)	0.48 (VI)	0.50 (V)	0.53 (VI)

Index value range 0 – 1.

VI). In case of practicing potassic fertilizer application, red gram ranked first (x=0.94, rank-I), followed by maize (x=0.88, rank-II), paddy (x=0.78, rank-III), cotton (x=0.38, rank-IV), Bengal gram (x=0.03, rank-V) and soybean (x=0.00, rank-VI). In case of practicing nutrient deficiency and adverse condition management, paddy farmers ranked first (x=0.53, rank-I), followed by cotton (x=0.45, rank-II), maize (x=0.42, rank-III), Bengal gram (x=0.39, rank-IV), soybean (x=0.32, rank-V) and red gram (x=0.28, rank-VI). In case of practicing fertilizer transport, paddy farmers ranked first (x=0.67, rank-I), followed by maize (x=0.56, rank-II), cotton (x=0.50, rank-III), red gram (x=0.42, rank-IV), soybean (x=0.41, rank-V) and Bengal gram (x=0.40, rank-VI). In case of practicing fertilizer storage, maize farmers ranked first (x=0.51, rank-I), followed by soybean (x=0.47, rank-II), paddy (x=0.45, rank-III), Bengal gram (x=0.42, rank-IV), cotton (x=0.38, rank-V) and red gram (x=0.37, rank-VI). In case of practicing fertilizer handling, maize farmers ranked first (x=0.61, rank-I), followed by paddy (x=0.58, rank-II), cotton (x=0.56, rank-III), soybean (x=0.53, rank-IV), red gram (x=0.52, rank-V) and Bengal gram (x=0.51, rank-VI). In case of practicing of fertilizer disposal, maize farmers ranked first (x=0.26, rank-I), followed by paddy (x=0.25, rank-II), cotton (x=0.18, rank-III), Bengal gram (x=0.16, rank-IV), red gram (x=0.15, rank-V) and soybean (x=0.14, rank-VI).

In case of performance of manures, cotton farmers ranked first (x=0.58, rank-I), followed by soybean (x=0.47, rank-II), Bengal gram (x=0.47, rank-II), red gram (x=0.45, rank-IV), maize (x=0.43, rank-V), and paddy (x=0.41, rank-VI). In case of the performance of primary macronutrient fertilizers, maize farmers ranked first (x=0.59, rank-I), followed by paddy (x=0.55, rank-II), red gram (x=0.54, rank-III), cotton (x=0.52, rank-IV), Bengal gram (x=0.50, rank-V) and soybean (x=0.48, rank-VI).

The results presented in Table 3. the Kruskal-Wallis test, revealed a significant difference in composite fertilizer management levels among farmer groups at the 0.01 level of probability ($\div^2$ = 123.136, df = 5). Further, multiple pair-wise comparisons using Dunn's procedure confirmed a statistically significant difference between soybean ($p < 0.01$) and Bengal gram ($p < 0.01$) farmers compared to maize, paddy, red gram and cotton farmers.

Table 3. Pairwise comparison of farmer groups on CFMI based on mean rank as per Kruskal-Wallis test

Farmer groups	Mean rank	P	C	M	R
Paddy	230.60				
Cotton	202.07				
Maize	242.10				
Red gram	215.58				
Soybean	91.10	**	**	**	**
Bengal gram	101.55	**	**	**	**

* Significance at 0.05 level of probability, ** Significance at 0.01 level of probability

χ^2 (5) = 123.136, $p < 0.01$, P – Paddy, C – Cotton, M – Maize, R - Red gram

Relationship between independent variables and fertilizer management

The results of the Multivariate General Linear Model (GLM) analysis from Table 4. were examined to understand the collective influence of several independent variables on three key dependent variables: knowledge, attitude, and fertilizer management. Wilks' Lambda values, significance levels (p-values), and Partial Eta Squared statistics were used to assess the multivariate significance and effect sizes of predictors. The analysis revealed that all included predictors significantly influenced the dependent variables ($p < .05$), suggesting that these factors together explain substantial variance in farmers' knowledge, attitudes, and fertilizer management.

Among these, education (Wilks' Lambda = 0.855, p = 0.000, η^2 = 0.145), social participation (Wilks' Lambda = 0.900, p = 0.000, η^2 = 0.100), scientific orientation (Wilks' Lambda = 0.927, p = 0.000, η^2 = 0.073), farming system (Wilks' Lambda = 0.929, p = 0.000, η^2 = 0.071) , manure and fertilizer availability (Wilks' Lambda = 0.934, p = 0.000, η^2 = 0.066), experience in selected crop cultivation (Wilks' Lambda = 0.932, p = 0.000, η^2 = 0.068), extension contact (Wilks' Lambda = 0.942, p = 0.000, η^2 = 0.058), economic motivation (Wilks' Lambda = 0.950, p = 0.001, η^2 = 0.050), capital availability (Wilks' Lambda = 0.959, p = 0.003, η^2 = 0.041), sustainability orientation (Wilks' Lambda = 0.966, p = 0.008, η^2 = 0.034), institutional access (Wilks' Lambda = 0.958, p = 0.002, η^2 = 0.042), access to information on fertilizers (Wilks' Lambda = 0.966, p = 0.009, η^2 = 0.034) and farmer groups (Wilks'

Table 4. Multivariate General Linear Model analysis of variables with fertilizer management

Effect	Wilks' Lambda	F	Sig.	Partial Eta Squared
Education	0.855	19.173	0.000	0.145
Experience in selected crop cultivation	0.932	8.262	0.000	0.068
Social participation	0.900	12.644	0.000	0.100
Extension contact	0.942	6.999	0.000	0.058
Source of information on fertilizers	0.966	3.936	0.009	0.034
Scientific orientation	0.927	8.972	0.000	0.073
Economic motivation	0.950	5.973	0.001	0.050
Sustainability orientation	0.966	3.967	0.008	0.034
Institutional access	0.958	5.022	0.002	0.042
Capital availability	0.959	4.806	0.003	0.041
Manures and fertilizers availability	0.934	7.994	0.000	0.066
Farming system	0.929	8.599	0.000	0.071
Farmer groups	0.620	11.847	0.000	0.147

Table 5. Between-Subjects Effects (Univariate) of determinants with fertilizer management by farmers

Source	b value	Standard error (SEb)	*t*-value	*F*	Sig.	Partial Eta Squared	VIF values
Corrected model				36.165	0.000	0.643	
Education	0.014	0.003	4.545	20.659	0.000	0.057	1.777
Experience in selected crop cultivation	0.037	0.008	4.478	20.051	0.000	0.055	1.575
Social participation	0.025	0.008	2.989	8.935	0.003	0.025	1.421
Extension contact	0.003	0.001	2.471	6.104	0.014	0.018	1.460
Source of information on fertilizers	0.002	0.001	1.226	1.502	0.221	0.004	1.475
Scientific orientation	0.003	0.001	2.535	6.425	0.012	0.018	1.577
Economic motivation	0.003	0.001	2.296	5.274	0.022	0.015	1.572
Sustainability orientation	0.004	0.002	2.266	5.135	0.024	0.015	1.411
Institutional access	0.000	0.001	.354	.125	0.724	0.000	1.390
Capital availability	0.001	0.001	1.473	2.170	0.142	0.006	1.562
Manures and fertilizers availability	0.002	0.001	3.327	11.070	0.001	0.031	1.420
Farming system	0.052	0.012	4.485	20.117	0.000	0.056	1.196
Farmer Groups				31.899	0.000	0.318	
Paddy	0.126	.018	7.200				
Cotton	0.141	.019	7.576				
Maize	0.131	.018	7.254				
Red gram	0.203	.019	10.765				
Soybean	0.032	.018	1.772				
Bengal gram	0.000	0.000	0.000				

R Squared = 0.643 (Adjusted R Squared = 0.625); Computed using alpha = 0.05; Durbin-Watson =1.724

Lambda = 0.620, p = 0.000, η^2 = 0.147) showed a strong multivariate effect indicating that these variables are significant determinants across all three dependent variables.

The univariate results from multivariate General Linear Model are presented in Table 5. These results indicate how each dependent variable is influenced individually by the predictors, while controlling for other variables in the model. For each outcome *i.e.* knowledge, attitude and fertilizer management. The corrected model was statistically significant, with R-squared values indicating that 64.30% in fertilizer management was explained by the predictors. Among the predictors, education showed a highly significant positive effect on fertilizer management (F = 20.659, p = 0.000) with moderate effect size (partial eta squared 0.057).

Similarly, experience in selected crop cultivation (F = 20.051, p = 0.000), farming system (F = 20.117, p = 0.000), manures and fertilizers availability (F = 11.070, p = 0.001), social participation (F = 8.935, p = 0.003), extension contact (F = 6.104, p = 0.014), scientific orientation (F = 6.425, p = 0.012), economic motivation (F = 5.274, p = 0.022) and sustainability orientation (F = 5.135, p = 0.024) were significantly associated with improvements in fertilizer management. Among categorical predictors, farmer groups demonstrated a strong and significant effect on fertilizer management (F = 31.899, p = 0.000, partial eta squared = .318), indicating substantial variability in fertilizer management among different crop-based farmer categories. Overall, the GLM results underscore the multidimensional influence of educational, social, psychological, and institutional factors on fertilizer management of farmers.

DISCUSSION

The overall planning level varied across crops. Soybean and Bengal gram farmers showed poor planning, mainly due to using manure for other crop simultaneously grown by them and avoiding potassic fertilizers. Unavailability of cattle, insufficient finance, and lack of local manure markets constrained their preparedness. In contrast, red gram, paddy, maize, and cotton farmers planned better owing to advance budgeting, labour planning, and experience-based decisions on fertilizer types and quantities. Group purchasing, early scheduling, and consideration of previous results contributed to their efficiency. However, planning for managing nutrient deficiencies, fertilizer storage, transport, and adverse conditions remained minimal, leading to low index values in these indicators. These results are supported by Li & Shang (2021).

Paddy, maize, and red gram farmers performed better in purchasing practices due to timely procurement of manures and NPK fertilizers at lower costs, often through group purchases (Dwivedi et al., 2021). Cotton farmers ranked lower as many ignored potassic fertilizer purchases. Bengal gram and soybean farmers also scored poorly, reflecting neglect in manure and potassic fertilizer procurement (Dwivedi et al., 2020). Farmers with self-sourced manures incurred lower costs and displayed better planning. Paddy farmers excelled in nitrogenous fertilizer purchasing, while maize and red gram farmers performed better in phosphatic and potassic fertilizers. In contrast, soybean and Bengal gram farmers almost completely avoided potassic fertilizers, resulting in the lowest scores (Akomdo et al., 2023).

Practicing of fertilizer management showed wide variation among crops. Soybean and Bengal gram farmers recorded low index values due to limited manure use (Dessie et al., 2023; Tovihoudji et al., 2023), while maize and cotton farmers applied manure in small but timely quantities. Maize, Bengal gram, and red gram farmers followed the recommended rates and methods for nitrogenous fertilizer (Dwivedi et al., 2020; Akomdo et al., 2023), whereas paddy farmers applied excess quantities at improper times, reflecting gaps in knowledge and fear of crop failure with

recommended doses (Dwivedi et al., 2021). For phosphatic fertilizers, red gram and soybean farmers achieved higher scores by adhering to recommended quantities, timing, and methods. Paddy farmers ranked lower due to excessive application and improper timing (Patil, 2013). In potassic fertilizer use, red gram, maize, and paddy farmers performed better by applying optimal amounts, while soybean, Bengal gram, and cotton farmers avoided potassic fertilizers altogether (Patil, 2013; Dwivedi et al., 2020). Nutrient deficiency and adverse condition management were poorly practiced, as most farmers could not identify deficiencies or adopt mitigation measures (Kumaresh & Praveena, 2012; Sarada & Suneel Kumar, 2013). Only a few paddy, maize, and cotton farmers managed deficiencies effectively. In transport and storage, paddy farmers who purchased fertilizers through cooperatives maintained safer practices, including covered transport and proper storage (Ngoya et al., 2023). However, most farmers neglected FIFO (First Expiry, First Out) and record-keeping systems (Ranabhat et al., 2021). In handling, some farmers partially followed safety measures such as using protective clothing, avoiding eating during application, and cleaning equipment afterward, but overall compliance was low. Disposal practices were also weak as most farmers discarded leftovers and containers carelessly, contributing to lower scores (Sai et al., 2019). These findings align with earlier studies emphasizing inadequate post-purchase fertilizer management among smallholders.

Cotton, maize, and red gram farmers ranked first, second, and third, respectively in performance due to their comparatively balanced fertilizer practices. Cotton farmers' use of manures and adherence to recommended NPK applications contributed to better crop performance. Maize and red gram farmers followed proper nitrogenous and phosphatic fertilizer use but occasionally deviated in potassic fertilizer management. Soybean and Bengal gram farmers, who reused residual nutrients from previous crops and avoided potassic fertilizers, ranked lower. The mismatch between actual practice and perceived performance suggests that farmers judged crop health visually rather than based on scientific nutrient assessment, leading to overestimated performance ratings. These results are in accordance with the findings of the Kumaresh and Praveena (2012) and Dwivedi et al. (2020).

CONCLUSION

Education, farming system, experience in crop cultivation, availability of manures and fertilizers, social participation, extension contact, scientific and sustainability orientation, and economic motivation consistently influence efficient fertilizer management. The Composite Fertilizer Management Index developed in this research serves as a reliable tool for assessing and comparing fertilizer management among crops. The findings confirm that enhancing farmers' knowledge and attitude toward best fertilizer management practices, improving awareness of health and environmental impacts, and strengthening input availability and institutional linkages can improve fertilizer planning, purchasing, and application efficiency. These results underscore the importance of promoting balanced and sustainable nutrient management practices to enhance soil health, crop productivity, and resource use efficiency in the region.

DECLARATIONS

Ethics approval and informed consent: The study adhered to established ethical principles of social science research. Informed consent was sought from the respondents for the study.

Competing Interest: The Authors have no competing interests.

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

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

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Research Article

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Occupational Health Hazards among Women Fish Vendors in Thiruvananthapuram, Kerala

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HIGHLIGHTS

- A significant association was found between the number of dependents and working hours, indicating family responsibilities influence work duration.
- A potential link between occupational engagement and reproductive transitions was established.
- There was a significant link to reproductive status, indicating that hormonal or health changes during menopause may influence daily activity levels.

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ABSTRACT

The informal sector constitutes a significant source of employment for women in India, particularly in coastal regions such as Kerala, where fish vending serves as a primary livelihood, and women frequently encounter substantial occupational health risks stemming from extended working hours and inadequate ergonomic conditions. The study aims to examine the multifaceted occupational health hazards affecting women fish vendors in Thiruvananthapuram district, carried out during 2025, with a particular emphasis on physical, reproductive, and psychosocial health dimensions. Data were collected from a sample of 150 women fish vendors through structured interviews, observational checklists, and a quality of life rating scale. The findings revealed a high incidence of musculoskeletal disorders, fatigue, dermatological conditions, and reproductive health concerns among the women fish vendors. Significant correlations were observed between health status and factors such as education level, household dependency ratio, income, and housing type. The study underscores the critical need for targeted policy interventions, comprehensive health education, infrastructural enhancements, and gender-sensitive occupational safety protocols to safeguard the health and dignity of women engaged in the unorganised sector.

INTRODUCTION

Fisheries constitute a vital component of global food production, contributing significantly to nutrition, livelihoods, and economic growth in coastal regions. In India, and particularly in Kerala, fisheries play a central role in sustaining rural economies and providing employment opportunities across multiple stages of the value chain (FAO, 2022). The state's extensive coastline and rich marine resources have positioned it as one of the leading contributors to national fish production. However, the sustainability of this sector depends not only on ecological management but also on the recognition of the diverse actors engaged in post-harvest and marketing activities. Women occupy a critical position within the fisheries value chain, especially in small-scale and artisanal contexts. Their involvement spans from processing and vending to managing household-level resource allocation, thereby shaping both economic and social outcomes (Biswas, 2011; Gustavsson, 2020). Studies have shown that women's control over income from fisheries-related

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activities often translates into more equitable distribution of resources within households, benefiting children and vulnerable members (Bradshaw et al., 2013). Despite their indispensable contributions, women frequently encounter systemic barriers such as limited access to infrastructure, discriminatory practices in markets, and exclusion from policy frameworks (Rejula et al., 2023). These challenges amplify their economic insecurity and restrict their ability to fully benefit from fisheries development initiatives.

In Kerala, female fish vendors form the backbone of the coastal economy, particularly in districts such as Thiruvananthapuram. Their work involves long hours of physically demanding tasks, including carrying heavy loads, standing or walking for extended periods, and operating in roadside markets exposed to harsh weather and unsanitary conditions. Many lack access to clean drinking water, sanitation facilities, and adequate housing, which directly impacts their health and well-being. Occupational hazards such as musculoskeletal disorders, fatigue, and reproductive health issues are common among these women, yet their risks remain poorly documented (Yadav et al., 2020; Chambon, 2024). Furthermore, low educational attainment and limited awareness of health risks compound their vulnerability, while the absence of occupational health and social protection schemes leaves them without institutional support.

Although Kerala's fisheries sector has been widely studied, research focusing specifically on the occupational health of women fish vendors remains scarce. Existing literature has highlighted women's entrepreneurial potential in value addition and fish processing (Tanuja et al., 2022), but few studies have systematically examined the health hazards they face in daily vending activities. Addressing this gap is crucial, as the perishable nature of fish makes efficient handling and storage essential, and women vendors often lack access to such facilities. This study therefore seeks to identify and categorize occupational health hazards among women fish vendors in Thiruvananthapuram, Kerala, while also examining the influence of socio-demographic factors and assessing their quality of life.

METHODOLOGY

Kerala had a coastline over 590 km, covering nine coastal districts with 222 fishing villages and 187 landing centers. Thiruvananthapuram's coastal stretch is approximately 78 km, representing about 13% of the state's total of 590 km. In 2017-18, Kerala had 5,977 female fish vendors (approximately 35.8%), while Thiruvananthapuram district alone accounted for 1,060 female vendors about 70% of the total fish vendors in the district (Department of Fisheries, Government of Kerala, 2018). The study was conducted in Thiruvananthapuram district, located in Southern Kerala, which was purposively chosen due to its extensive 78 km coastal stretch and the significant concentration of female fish vendors. Out of the six taluks in the district, four taluks with coastal coverage Chirayinkeezhu, Varkala, Thiruvananthapuram, and Neyyattinkara were included to ensure representativeness. From the total of 138 coastal wards, 15 wards were selected to capture the geographic and socio-economic diversity of vending practices. This stratified approach ensured adequate representation of coastal, peri-urban, and urban roadside vending areas, thereby reflecting variations in occupational hazards linked to environmental exposure, infrastructure availability, and market conditions. Based on the data received from the fisheries department, a sample of 150 women was selected. This sample size provided a reasonable balance between statistical precision and logistical feasibility, corresponding to an estimated margin of error of about 7–8 percent at a 95 percent confidence level. The sample size was also justified on practical grounds, as it allowed for in-depth interviews and observations while ensuring coverage across diverse vending contexts within the district. A purposive sampling technique was adopted, with respondents selected based on specific inclusion criteria relevant to the research objectives. Women engaged in roadside fish vending were included, while those vending in sheltered marketplaces or engaged in door-to-door delivery were excluded. A structured interview schedule was designed to collect quantitative data from the selected respondents. The schedule consisted of close-ended questions to ensure uniformity in responses and covered aspects such as socio-demographic profile, working hours, reproductive health, working conditions, and occupational health issues. In addition, an observation checklist was prepared to identify and record visible occupational health hazards faced by the fish vending women. The checklist included items related to physical, chemical, psychosocial, biological, and ergonomic hazards. Data obtained from the checklist were systematically documented as field notes and later used for descriptive analysis. A five point Likert rating scale was developed and used to assess the quality of life of fish vending women, which includes Strongly agree, Strongly disagree, Agree, Disagree, Neutral with scores of 5,4,3,2 and 1 respectively. A total of ten statements were included in the rating scale and were all positive in nature. The sum of the total scores represents the total quality of life score of an individual. Thus the maximum score an individual can score is 50 and the minimum score is 10. Further the scores were categorized into low, medium and high. The scores ranging from 10 to 22 indicate a low level, 23 to 35 represent a medium level, and 36 to 50 indicate a high level of scores. The data were analysed using SPSS Version 27 and Microsoft Excel. The data were classified, tabulated, and interpreted using appropriate statistical methods to address the study objectives. Descriptive statistics were conducted on demographic, socio-economic, and other relevant variables to provide a clear overview of the data. As all variables other than the Quality of life (QoL) scale were categorical, frequency distributions were calculated and visualized using pie charts, column charts, and doughnut charts. Descriptive statistics and reliability analysis was done for the Quality of Life scale. To examine associations between variables, cross-tabulations were used and visualised using multiple bar diagrams. For comparative analysis between groups, the Chi-square test for association was applied. In cases where expected cell counts were less than 5, Fisher's Exact Test was used as an alternative to ensure accuracy and validity of the results. To compare between groups, non-parametric tests were used since the data is not normal. When there were two groups for comparison, Mann Whitney U test were used and for 2 or more groups Kruskal Wallis H test were done following post hoc multiple comparison test were done to find out the which group differs significantly. Statistical significance was determined using p-values, with a threshold of 0.05.

RESULTS

Health Problems of the Respondents

The association between perceived causes of health problems and selected socio-demographic and economic characteristics, such as age, income, education, number of dependents, residence area, and family type, was examined. The physical and occupational health problems were identified in most of the respondents, who suffer from various musculoskeletal problems such as back pain, joint pain, shoulder stiffness and knee discomfort, primarily due to prolonged standing, sitting, walking, and lifting of heavy loads. Many women experienced headaches and dizziness, often associated with long hours of exposure to direct sunlight. Skin infections were also noticed (Table 1). The lack of access to proper sanitation facilities contributed to urinary health issues among several respondents. Improper working postures, such as extended squatting or sitting on low stools, led to joint swelling and pain. Additionally, repeated handling of fish without protective gloves resulted in minor cuts, wounds and infections. A few respondents also reported respiratory issues.

Table 1. Health Problems Currently faced by the Respondents

Variables	Percentage
Type of health problems experienced	
Respiratory issues	0.70
Musculoskeletal problems	36.00
Gastrointestinal issues	0.70
Infections or wounds	2.00
All of the above	59.30
Other	1.30
Perceived causes of health problems	
Work environment	76.7
Lack of access to healthcare	2.00
Financial instability	10.00
Social and family pressure	0.70
Physical strain	10.70
Reason for not using protective equipment	
Not available	16.00
Too expensive	14.70
Lack of awareness	34.00
Not comfortable/practical	35.30

Based on the medical records available from the respondents, a substantial proportion, 59.3% experienced a combination of multiple health problems, particularly musculoskeletal issues 36 percent, and very few reported only a single health issue. The majority 76.7% attributed these health problems to poor working conditions, while others cited physical strain 10% and financial or systemic barriers. Notably, none of the participants reported using any protective gear during work. The main reasons included lack of comfort or practicality 35.3%, lack of awareness 34%, unavailability 16%, and cost constraints 14.7%. This indicates a significant gap in workplace safety practices and access to basic occupational health resources. These findings are in alignment with the study carried out by Tripati et al. (2017), on Occupational health and role of gender, a study in informal sector fisheries of Udupi, India.

The study also examined the reproductive health status of the respondents, as it is closely linked to overall health, productivity and well-being of fish vending women. Their work involves "long hours in uncomfortable and unhygienic conditions, often without access to toilets, clean water and proper shelter". These factors can lead to serious reproductive health problems. This study examines crucial reproductive health indicators, which provide valuable insights into their biological health (Table 2). Most respondents reported that about 70% had attained menarche between 10–12 years of age. Regarding their current reproductive stage, two-thirds 66% were postmenopausal, and 21.3% had reached menopause. Among those, the majority had experienced natural or biological menopause 70.4%, while 28.9% reported surgical menopause. In terms of menstrual characteristics, 59.3% reported

Table 2. Association between working hours and socio-demographic and economic characteristics

Variables		Working hours per day				p-value
		Less than 4 hours n (%)	4- 6 hours n (%)	6-8 hours n (%)	More than 8 hours n (%)	
Age	50 and below	2 (50.0)	5 (13.2)	11 (11.0)	2 (25.0)	0.378
	51-60	1 (25.0)	15 (39.5)	37 (37.0)	2 (25.0)	
	60 above	1 (25.0)	18 (47.4)	52 (52.0)	4 (50.0)	
Education	Illiterate	2 (50.0)	11 (28.9)	45 (45.0)	1 (12.5)	0.033*
	Primary	1 (25.0)	20 (52.6)	49 (49.0)	4 (50.0)	
	Secondary	1 (25.0)	7 (18.4)	6 (6.0)	3 (37.5)	
Residence area	Urban	2 (50.0)	0 (0.0)	11 (11.0)	0 (0.0)	0.003**
	Coastal area	2 (50.0)	38 (100)	89 (89.0)	8 (100)	
Income	Below 5000	3 (75.0)	27 (71.1)	82 (82.0)	6 (75.0)	0.558
	5000-7000	1 (25.0)	11 (28.9)	18 (18.0)	2 (25.0)	
No. of dependents	None	0 (0.0)	3 (7.9)	3 (3.0)	1 (12.5)	0.031*
	1-2	0 (0.0)	6 (15.8)	9 (9.0)	0 (0.0)	
	3-4	3 (75.0)	4 (10.5)	15 (15.0)	3 (37.5)	
	More than 4	1 (25.0)	25 (65.8)	73 (73.0)	4 (50.0)	

*Highly significant at 1%level; ** Significant at 5% level

bleeding lasting 6–7 days, while 19.3 percent experienced longer durations. Irregular menstrual cycles were common 38.7%, followed by 21–28 day cycles in 32% of the respondents. These findings reflect both the reproductive transitions and possible gynaecological health concerns among women fish vendors, emphasising the need for targeted health interventions in this group.

Since the study findings clearly emphasizes about the continuous working hours involved by the respondents, an attempt was made to understand the relationship between hours of working and associated variables.

The association between daily working hours and selected socio-demographic and economic variables was analyzed using Fisher's exact tests. Among the observed variables, education level, residence area, and number of dependents showed statistically significant associations with daily working hours ($p < 0.05$ and < 0.01). On the other hand, age and income did not show significant associations with working hours ($p > 0.05$), though a higher proportion of older individuals (60+) were working 6–8 hours daily. Similarly, participants earning below Rs. 5000 mostly worked 6–8 hours, but the association was not statistically significant. Education, residence area, and number of dependents are hence can be treated as key factors influencing daily working hours. These findings highlight the role of social and economic context in shaping labor patterns. To further contextualize the occupational and socio-economic challenges faced by women fish vendors, studies from other coastal regions of India offer valuable insights. Kumaran et al. (2021) conducted an exploratory study on the socio-economic and livelihood status of coastal fishers in Puducherry, revealing that income diversification was common due to the stagnation in capture fisheries, with many women engaging in non-fisheries occupations to supplement household income. This aligns with the current study's findings on economic vulnerability and limited occupational mobility.

As expected, reproductive status shifts with age (Table 3). Though it is a known fact, reproductive health issues can significantly impact women's economic productivity and livelihoods. Studying the association between these two variables may be vital to policymakers for supporting programmes for women's economic empowerment. Women aged 51–60 are more likely to be menopausal, while those above 60 are predominantly postmenopausal. Perimenopause is concentrated in the early 50s. Women in different reproductive stages tend to work similar hours, with most working 6–8 hours daily. However, the distribution varies slightly, and the association is statistically significant, suggesting reproductive status may influence work capacity or patterns. Hence it can be concluded that age is strongly associated with reproductive status, confirming biological expectations. The working hours also show a significant link to reproductive status, indicating that hormonal or health changes during menopause may influence daily activity levels.

Table 3. Association between Reproductive health and related variables

Variables		χ^2 / F	p-value
Age	50 & above 51-60 60 above	f	0.001*
Working hours per day	4-6 hours 6-8 hours Less than 4 hours More than 8 hours	21.32	0.011*

*Significant at .01%

Quality of Life enjoyed by the Respondents

A five-point Likert rating scale was developed and used to assess the quality of life of fish vending women. The scale was self-structured by the researcher (Table 4). The 5 points include strongly disagree, Disagree, Neutral, Agree, Strongly Agree with scores of 1,2,3,4 and 5 respectively. A total of ten statements were included in the rating scale and were all positive in nature. The sum of the total scores represents the total quality of life score of an individual. Thus, the maximum score an individual can score is 50 and the minimum score is 10. Further, the scores were categorized in to low, medium and high. The scores ranging from 10 to 22 indicates a low level, 23 to 35% a medium level and 36 to 50 indicates a high level of scores. Results showed that the majority of the respondents; 74 percent experienced a low level of Quality of life, followed by 26 percent in the medium category. None of the respondents reported a high Quality of life, indicating significant concerns regarding the overall well-being of the respondents. The low quality of life among the respondents is mainly due to poor working condition, long hours of physical labour, low and unstable income and lack of basic facilities.

The mean total QoL score was 18.5 with a standard deviation of 5.09, indicating moderate variability in the responses (Table 5). The median score was 15, with an interquartile range of 14 to 24, suggesting that 50 percent of the participants scored between these values. Overall the Quality of life of fish vending women is less. The scale comprised 10 items, and the mean item score was 3.71 ± 0.55. The internal consistency of the scale was found to be high, with a Cronbach's alpha of 0.846, indicating good reliability. Respondents working fewer hours per day reported significantly better QoL, with median scores declining steadily as working hours increased ($H=10.3$, $p=0.016$), highlighting QoL is better for women who works less than 4 hours compared to women working for 6-8 hours per day ($p=0.037$). The reason for entering fish vending also had a strong association ($p<0.001$), where women engaged due to tradition had higher QoL scores compared to those who entered due to lack of employment or difficulty in finding other work. Also, those facing multiple occupational challenges such as unhygienic conditions, weather hardships, and physical strain had significantly

Table 4. Quality of life of the Respondents

Descriptive				Scale Reliability		
Mean ± SD	Median (Q_1, Q_3)	Min	Max	N of Items	Mean ± SD	Cronbach's α
18.5 ± 5.09	15 (14, 24)	14	30	10	3.71 ± 0.55	0.846

Table 5. Comparison of QoL Scores with Reproductive Health Variables

Variables	H	p-value	MC (p-value)
Current reproductive status			
Reproductive age	21.5	<0.001	3–4 (0.002)
Perimenopause			1–4 (0.008)
Menopause			
Post menopause			
Days of menstrual bleeding			
Less than 3 days	11.7	0.008	2–3 (0.008)
3-5 days			2–4 (0.031)
6-7 days			
More than 7 days			

lower QoL, especially those reporting all challenges together (H=27.3, p<0.001). This underscores the need for improved occupational environments to support the health and dignity of these workers. Perceived causes of health issues showed a statistically significant impact on QoL (H=33, p<0.001). Women attributing health concerns to work environments had lower QoL scores than those identifying physical strain or financial instability as major contributors. Transport mode also mattered, those carrying fish via vehicles reported lower QoL than those using bicycles or head loads (H=21.5, p<0.001), possibly reflecting ergonomic strain or lack of transportation access.

Fish vending women's reproductive health and quality of life are impacted by their work environment. Poor sanitation, hygiene facilities, prolonged standing, lifting, and physical strain can increase the risk of reproductive tract infections and other health issues. Women in the reproductive age group reported higher median QoL scores (23), compared to those in the perimenopause (14) and postmenopausal (15) stages, with the association being statistically significant (H=21.5, p<0.001). Pairwise comparisons indicated that QoL is lower in women who are in post menopause stage than those who are in reproductive age (p=0.008) and those who are in menopause (p=0.002). Menstrual characteristics also impacted QoL. Participants with typical menstrual duration of 3–5 days reported the highest median QoL (22), while those with shorter (<3 days) or longer durations (6+ days) had lower scores (H=11.7, p=0.008). Post-hoc tests revealed that women with 3–5 days of bleeding had significantly better QoL compared to those with irregular patterns.

DISCUSSION

The present study highlights the occupational health hazards faced by women fish vendors in Thiruvananthapuram, Kerala, with a particular emphasis on demographic vulnerabilities, work-related health issues, and quality of life outcomes. The demographic data reveal that the majority of women fish vendors belong to an older age group, possess low levels of formal education, and bear significant family responsibilities within inter-generational living arrangements. These findings are consistent with earlier studies conducted in South Kerala, where 38% of women fish vendors had no formal schooling and most were aged above 30 years (John & Diwakar, 2014). Similar trends of illiteracy among women in informal sectors have been reported by Aparnaroy et al. (2017), underscoring the persistent educational disadvantage in this occupational group.

The economic instability inherent in marine fisheries, marked by seasonal fluctuations and income instability, exacerbates the vulnerability of fisherwomen. This economic uncertainty, as noted by Rajkumar et al. (2024), reinforces their marginalization within the socio-economic hierarchy. Educational attainment or the lack thereof emerges as a critical determinant in shaping occupational trajectories. Limited education restricts access to alternative employment opportunities, curtails labour mobility, and diminishes awareness of occupational rights and health hazards. The occupational continuity observed among women fish vendors suggests a generational pattern with minimal avenues for occupational transition. Hadaye and Dey (2024) observed that a significant proportion of women in this sector had over 15 years of experience, often without viable alternatives for livelihood.

Health-related findings from the present study further validates the existing literature. Over half (55%) of the respondents reported musculoskeletal pain, with a statistically significant association between pain and the method of carrying fish boxes. A notable proportion (61.1%) had sustained injuries, predominantly incisional wounds. Additionally, 55% of participants experienced skin infections, with itching and redness of the extremities being the most common symptoms (12.4%).

The intersection of age, working hours, and reproductive health also warrants attention. Chen et al. (2023), in a study published in BMC Women's Health, emphasized that age significantly influences reproductive outcomes, including infertility and hormonal transitions. Their findings support the present study's observation that reproductive status is closely linked to age and work-related stressors. Yarger and Brauner-Otto (2024), through a longitudinal analysis, demonstrated that work characteristics such as part-time status and autonomy over working hours significantly affect fertility expectations and reproductive planning. These insights are echoed in Sanjay et al. (2023), who found that menstrual irregularities were associated with extended or inconsistent working hours, suggesting a physiological impact of occupational stress on reproductive health.

A salient contribution of this study lies in establishing the relationship between occupational patterns, health challenges, and quality of life. The findings align with broader evidence indicating that prolonged working hours, poor ergonomic conditions, and inadequate workplace infrastructure adversely affect well-being. Notably, the study highlights that the motivation behind entering the occupation influences one's quality of life. Women who adopted fish vending as a traditional occupation reported a relatively better quality of life, possibly due to greater social acceptance and role familiarity. In contrast, those compelled by unemployment exhibited a lower quality of life, reflecting the psychosocial costs of constrained occupational choices. This observation aligns with the literature on informal employment, where the dichotomy between "choice" and "constraint" significantly influences job satisfaction and psychological well-being. Furthermore, the cumulative impact of multiple occupational stressors physical, environmental, and ergonomic was evident in the diminished quality of life among affected respondents. These findings underscore the need for targeted interventions that

address the multifaceted nature of occupational health hazards faced by women in the fish vending sector.

CONCLUSION

The study provides a clear overview of the socio-economic conditions, occupational challenges, and quality of life (QoL) of women fish vendors. Fish vending, often pursued due to tradition or economic necessity, exposes them to multiple occupational health risks such as physical strain, musculoskeletal problems, and poor reproductive health. These risks are intensified by inadequate infrastructure, lack of permanent shelter, unsafe transportation, and absence of protective gear and health awareness. The study finds significant variation in QoL based on income, education, family structure, working hours, and health status, demonstrating a strong link between socio-demographic and occupational factors. Women with higher income, better education, fewer dependents, and shorter working hours report better QoL, while postmenopausal women and those facing multiple hazards experience poorer outcomes. Overall, the findings highlight the urgent need for gender-sensitive policies, improved workplace infrastructure, health education, and social support systems to improve the well-being of women fish vendors.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents for the study.

Competing Interest: The authors have no competing interests.

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

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

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Research Article

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Assessing the Perceived Training Needs of Farm Women on Modern Crop Technologies in Jhansi District

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HIGHLIGHTS

- Crop storage and cattle production emerged as the most critical training needs, indicating a strong focus on post-harvest management and income diversification.
- The majority of farm women (73.34%) were found to have medium-level training needs, suggesting they possess baseline knowledge but require targeted skill upgradation.
- Psychological traits, especially scientific and risk orientation, were the most powerful predictors of training demand, outweighing many socio-economic variables.

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ABSTRACT

The study assesses the perceived training needs of farm women in modern crop production technologies, situated in the complex agro-economic landscape of Jhansi district. Despite their critical role in agriculture, women farmers often face barriers to accessing technical knowledge, which limits their productivity and empowerment. Using a descriptive survey design with a sample of 120 farm women from Mauranipur block, this research employed a multi-stage sampling technique and a structured interview schedule to collect data during 2022-23. The results reveal that the highest training needs were in crop storage (WS=2.23) and cattle production (WS=2.23), followed by weed control (WS=2.18) and improved crop varieties (WS=2.18). The majority of women (73.34%) fell into the medium training-need category, indicating a widespread demand for skill upgradation. Psychological variables, particularly scientific orientation (r=0.548) and risk orientation (r=0.498), emerged as the strongest predictors of training need, surpassing most socio-economic factors. Education, landholding, and income also showed significant positive correlations. These findings underscore the necessity of designing gender-responsive, needs-based extension programs that not only address technical skill gaps but also foster psychological readiness for innovation, thereby enabling more inclusive and sustainable agricultural development.

INTRODUCTION

Agriculture remains the backbone of India's economy, engaging approximately 50% of the country's workforce, predominantly women (Government of India, 2020). Despite their critical role in crop production, women farmers often face systemic barriers including limited access to knowledge, resources, and technological innovations that hinder their productivity and socio-economic empowerment (Agarwal, 2018). Addressing these gender disparities is essential not only for equitable development but also for achieving global food security and sustainable agricultural intensification (FAO, 2021). The adoption of modern crop technologies such as improved seed varieties, integrated pest management, and precision agriculture has revolutionized

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productivity in various regions (Pingali, 2019). However, the successful dissemination and adoption of these innovations heavily depend on farmers' access to appropriate information and training. For women, who constitute a significant yet often marginalized segment of the farming community, perceived training needs directly influence their capacity to leverage such technologies effectively (Mason et al., 2020). Recognizing and understanding these perceived needs is crucial for designing extension programs that are inclusive and tailored to their specific contexts. The trainers should be trained in skills of instruction andragogy in order to fulfill high expectations and lofty objectives of the training organisations (Nain & Kumar, 2001).

Jhansi district in Uttar Pradesh exemplifies the challenges and opportunities inherent in empowering women farmers through technological enhancement. Located in the Bundelkhand region, Jhansi faces arid climate conditions, water scarcity, and fragmented landholdings factors that complicate crop management but also underscore the importance of innovative, context-specific solutions (District Agriculture Office, Jhansi, 2022).

Despite these challenges, women play a pivotal role in crop cultivation and household food security, yet their access to modern technologies and training remains limited (Sharma & Tripathi, 2021). Existing studies highlight that perceived training needs among women farmers are often shaped by socio-economic factors, cultural norms, and information barriers (Khan et al., 2019). These perceptions influence their willingness to adopt new practices and determine the success of extension interventions. However, there remains a paucity of comprehensive assessments that explicitly explore these perceived needs within the local context of Jhansi, especially in light of rapidly evolving agricultural technologies.

The study aims to fill this gap by systematically evaluating the perceived training needs of farm women in Jhansi regarding modern crop production technologies. By identifying priority areas and underlying factors influencing these perceptions, the research seeks to inform targeted extension strategies that promote inclusivity, resilience, and sustainable productivity. Ultimately, empowering women with the requisite knowledge and skills can catalyse broader socio-economic transformations, fostering a more equitable and resilient agricultural sector that aligns with global sustainability goals (World Bank, 2022).

METHODOLGY

The present study adopted a descriptive survey design to assess perceived training needs and constraints of farm women regarding modern crop production technologies and to elicit suggestions for improving training and subsequent enterprise establishment in the Bundelkhand context. The study was conducted during 2022–23 in the Mauranipur Block of Jhansi district, Uttar Pradesh. Among the eight blocks of the district, Mauranipur was purposively selected owing to the presence of the College of Agriculture serving as a major extension source that regularly conducts trainings for both men and women farmers, ensuring a relevant and accessible respondent pool and an active technology dissemination environment. The sampling frame comprised adult farm women engaged in crop production across selected villages of Mauranipur. A sample of 120 farm women was drawn using a multi-stage approach: villages were identified in consultation with local extension personnel, followed by systematic selection of eligible respondents from village lists. Data were collected through a structured interview schedule administered face-to-face by trained investigators in local language. The instrument captured socio-economic and farm characteristics, exposure to information sources, awareness and adoption of recommended practices, perceived training needs across crop technology domains (seed and varietal management, nutrient, soil health, IPM and plant protection, farm mechanisation, post-harvest, and value addition), constraints to training and adoption, preferred delivery modes, and suggestions.

Perceived training needs were measured on a three-point Likert continuum and summarised using item-wise means and a Weighted Score (WS) computed. The association between categorical respondent characteristics and high-need categories was tested using the Chi-square. To analyse differences in training usage patterns across different socio-economic groups, the Kruskal–Wallis H test (1952) was employed. This non-parametric test is suitable for comparing more than two independent groups when the data are ordinal or not normally distributed.

RESULTS

Assessment of farm women's training needs across major components of crop production revealed distinct patterns of priority. Training needs related to improved agricultural practices were consistently high. Respondents most frequently identified improved crop varieties (WS = 2.18), seed treatment (WS = 2.13), and optimal sowing methods (WS = 2.08) as essential or most essential. Land preparation, seed rate, spacing, and fertilizer application were also rated as important, with weighted scores ranging from 1.68 to 2.06. Training needs in plant protection showed similarly elevated demand. Weed control registered one of the highest scores (WS = 2.18), while disease and insect control were widely rated as essential (WS = 2.06 and 1.92, respectively). Integrated pest- and disease-management practices were also recognized as necessary, each with weighted scores close to 2.00. For agricultural implements, respondents expressed substantial need for training in the use of modern ploughing tools (WS = 2.16), followed by implements related to sowing, irrigation pumps, harvesting, and winnowing (WS ≈ 1.93–1.98). These results indicated a broad interest in mechanisation-related skills. The highest overall training requirement emerged in the area of crop storage (WS = 2.23), signalling persistent challenges in post-harvest handling and loss reduction. Training needs for soil conservation practices were also notable. Crop rotation displayed a relatively high score (WS = 2.16), followed by mulch formation (WS = 2.04) and strip farming (WS = 1.98), suggesting growing recognition of sustainable land-management techniques. Across the dimension of efficient use of conserved water, respondents prioritised selection of suitable crop varieties (WS = 2.15) and adoption of proper crop protection measures (WS = 2.20). Fertiliser management, weed control, and spacing also appeared as recurring training needs within this category. In allied activities, cattle production (WS = 2.23) and poultry farming (WS = 2.16) were the most prominent areas of interest, followed by horticulture and other small enterprises (WS

Table 1. Training needs of farm women in the main and sub-areas of crop production technology

S.No.	Areas of training	Level of training needs Weighted Score	Overall Weighted Score
A	Improved agricultural practices		
1.	Preparation of land	1.68	1.98
2.	Improved varieties of crops	2.18	
3.	Sowing of time	1.90	
4.	Seed treatment	2.13	
5.	Seed rate	2.00	
6.	Method of sowing	2.08	
7.	Plant to plant, line to line distance and depth of seed	1.90	
8.	Quantity of fertiliser and method of application	1.96	
9.	Utilisation method of culture and PSB	2.06	
10.	Method of preparation of bed	2.00	
B	Plant protection measure		
1.	Weed control	2.18	2.03
2.	Disease control	2.06	
3.	Insect control	1.92	
4.	Integrated pest management (IPM)	1.94	
5.	Integrated disease management (IDM)	1.99	
C	Improved agricultural implements		
1.	Modern implement for ploughing	2.16	1.98
2.	Modern implement for sowing	1.97	
3.	Diesel pump for irrigation	1.93	
4.	Hand-drawn implement	1.98	
5.	Modern implementation forharvesting and winnowing	1.98	
6.	Tractor	1.93	
D	Crop storage		
1.	Storage	2.23	2.23
E	Agronomical practices for soil conservation		
1.	Contour farming	1.89	1.98
2.	Ploughing operations	1.93	
3.	Mulch formation	2.04	
4.	Crop rotation	2.16	
5.	Strip farming	1.98	
6.	Cover crops	1.88	
F	Capable use of conserved water		
1.	Selection of the proper crop and its variety	2.15	2.04
2.	Timely sowing and plant to plant proper plant-to-plant distance	1.88	
3.	Use of recommended fertiliser	2.08	
4.	Timely weed control	1.93	
5.	Proper plant protection measures	2.20	
G	Allied activities		
1.	Cattle production	2.23	2.08
2.	Poultry farming	2.16	
3.	Fisheries	1.88	
4.	Horticulture	2.16	
5.	Bee keeping	1.92	
6.	Other enterprise	2.08	

≈ 2.08–2.16). Fisheries received comparatively lower interest (WS = 1.88).

Analysis of the overall training needs of farm women showed a clear concentration in the medium-need category, as shown in Table 2. Most respondents (73.34%) fell within the medium training-need range, indicating that the majority required a moderate level of support to enhance their crop production skills. A smaller proportion exhibited low training needs (16.66%), while only 10.00% reported high training needs (>38). These patterns suggested that although training demand was widespread, the intensity of need was generally moderate across the population.

Table 3 showed that several socio-economic and psychological characteristics were meaningfully related to the training needs of farm women in crop production. Age was positively associated with

Table 2. Overall training needs of farm women on crop production

Categories	Percentage
Low <29	16.66
Medium 29-38	73.34
High >38	10.00
Total	100

Mean=33.775, S.D. 4.43

training need ($r = 0.300$; $\chi^2 = 82.30$; $p < 0.001$), indicating that older respondents tended to report higher training requirements. Education also had a positive relationship ($r = 0.336$; $\chi^2 = 19.77$; $p = 0.003$), suggesting that more educated women expressed greater demand for training. Although the correlation between family size and training need was very weak ($r = 0.062$), the association reached statistical significance ($\chi^2 = 148.60$; $p < 0.001$), implying a detectable – if small – link in the sample. Caste was not related to training need ($r = -0.102$; $\chi^2 = 1.85$; $p = 0.397$). Land holding showed a notable positive relationship with training need ($r = 0.385$; $\chi^2 = 137.00$; $p < 0.001$), and housing pattern was also positively associated ($r = 0.204$; $\chi^2 = 47.45$; $p < 0.001$). Annual income demonstrated a significant positive correlation ($r = 0.248$; $\chi^2 = 168.80$; $p < 0.001$), indicating that women with higher incomes reported greater training needs. Among the psychological measures, scientific orientation had the strongest association with training need ($r = 0.548$; $\chi^2 = 23.80$; $p < 0.001$), followed by risk orientation ($r = 0.498$; $\chi^2 = 61.30$; $p < 0.001$). Economic motivation also correlated positively, though to a lesser extent ($r = 0.192$; $\chi^2 = 37.60$; $p < 0.001$).

Table 4 indicated that the training needs of farm women varied significantly across some of the independent variables. Age did not exhibit any significant variation in training needs among different groups ($K = 23.200$; $p = 0.229$). Similarly, the size of the family and housing pattern showed no significant differences ($K = 19.705$; $p = 0.412$ and $K = 18.658$; $p = 0.479$, respectively). Education, however, showed a significant difference in training needs among its categories ($K = 30.708$; $p = 0.043$), indicating that women with different educational backgrounds expressed varying levels of training requirement. Caste also recorded a statistically significant variation ($K = 35.069$; $p = 0.014$), suggesting social grouping had an influence on training needs. Landholding showed a marginally significant difference ($K = 28.763$; $p = 0.070$), implying that farm size tended to shape training requirements, although the relationship was not strong. Annual income displayed a similar pattern with a near-significant association ($K = 28.347$; $p = 0.149$).

Among the psychological variables, scientific orientation showed a highly significant variation in training needs across groups ($K = 47.845$; $p < 0.001$). Risk orientation also varied strongly and significantly ($K = 48.609$; $p < 0.001$). Economic motivation exhibited a significant difference as well ($K = 40.692$; $p < 0.001$), indicating that women with higher motivation levels tended to express greater need for training in crop production.

Table 4. Kruskal–Wallis H test of independent variables with training needs of farm women on crop production

Variables	K-Statistic	P-value
Age	23.200	0.229
Education	30.708*	0.043
Size of family	19.705	0.412
Caste	35.069*	0.014
Land holding	28.763*	0.070
Housing pattern	18.658	0.479
Annual Income	28.347*	0.149
Scientific orientation	47.845**	<0.001
Risk orientation	48.609**	<0.001
Economic motivation	40.692**	<0.001

DISCUSSION

The assessment of farm women's training needs across key components of crop production revealed clear patterns of priority, with a pronounced emphasis on foundational agronomic practices. Training needs under improved agricultural practices consistently registered moderate to high intensity. Women expressed the strongest requirement for knowledge related to improved crop varieties, seed treatment, and scientific methods of sowing, which recorded some of the highest weighted scores in this category. This pattern suggested that respondents sought skill enhancement in areas directly influencing crop establishment and early growth. Similar observations have been reported in earlier studies, where women farmers identified varietal selection, seed management, and sowing techniques as primary domains requiring technical support (Kher et al., 2004; Bhagat & Nain, 2005; Rani & Rao, 2014). Plant protection emerged as another major area of concern. Weed control exhibited some of the highest training scores, followed by disease and insect management. The elevated demand for training in IPM and IDM reflected an increasing awareness of sustainable plant protection among women farmers. These results aligned with prior research emphasizing women's growing involvement in crop health

Table 3. Relationship between independent variables with training needs of farm women on crop production

Variables (Unit)	Training need of 'r'	Chi-square (χ^2)	P-Value
Age (Years)	0.300**	82.300	<0.001
Education	0.336**	19.767	0.003
Size of family (Numbers)	0.062	148.600	<0.001
Caste	-0.102	1.850	0.397
Land holding (ha)	0.385**	137.00	<0.001
Housing pattern (Kaccha=1; Pacca= 2)	0.204*	47.450	<0.001
Annual Income (Rs.)	0.248*	168.800	<0.001
Scientific orientation (Score)	0.548**	23.80	<0.001
Risk orientation (Score)	0.498**	61.30	<0.001
Economic motivation (Score)	0.192*	37.60	<0.001

management and their need for practical training to reduce crop losses (Dhaka & Chayal, 2010). Training needs related to agricultural implements also indicated substantial gaps, particularly for modern ploughing tools, sowing implements, and irrigation pumps. These findings suggested that while mechanization has expanded in rural areas, women remain less exposed to its technical aspects. Earlier studies also noted similar constraints, wherein access to and familiarity with mechanized tools remained limited for farm women despite mechanization being crucial for labour efficiency (Rani & Rao, 2014). Crop storage recorded the highest overall training score, highlighting persistent challenges in post-harvest handling and loss reduction. Post-harvest losses continue to disproportionately affect smallholders, and women who are often responsible for storage have been shown to require targeted capacity-building interventions (Sharma & Singh, 2016). Soil conservation practices such as crop rotation, mulch formation, and strip farming also received considerable attention, indicating that respondents were increasingly conscious of sustainable farming approaches (Singh et al., 2009). Training needs were also pronounced in the efficient use of conserved water. Women prioritized the selection of suitable crop varieties and appropriate plant protection measures under limited water conditions. Similar findings have been reported in studies where water-saving practices and timely crop management were viewed as essential for climate-resilient production (Mukherjee & Jha, 2024). In allied activities, cattle production and poultry farming were among the top priorities, reflecting their role in income diversification and household nutrition. Other enterprises such as horticulture and beekeeping also showed substantial demand, consistent with previous reports highlighting women's interest in multi-enterprise integration for livelihood stability (Nain & Chandel, 2010; Miller-Klugesherz & Sanderson, 2023). The overall training-need categorisation demonstrated that a majority of farm women fell into the medium training-need group. This indicated that while baseline knowledge existed, significant gaps persisted in technical and managerial aspects of crop production. Similar patterns of moderate but widespread training needs have been noted in earlier extension studies involving women farmers (Kumar et al., 2007; Sharma & Singh, 2016).

Correlation analysis showed that socio-economic variables particularly education, landholding size, housing pattern, and annual income had meaningful positive relationships with training need. Women with higher education levels and larger operational holdings tended to express greater interest in acquiring technical knowledge, consistent with the diffusion and adoption literature (Singh et al., 2009). Income also showed a strong association, supporting earlier findings that financially secure households are more inclined to invest in knowledge acquisition and skill development (Kumar et al., 2020).

Psychological variables emerged as the strongest predictors of training need. Scientific orientation, risk orientation, and economic motivation all showed significant positive associations, a trend echoing previous research linking psychological traits with learning interest and innovation adoption (Sonu & Jha, 2025). The Kruskal–Wallis analysis further revealed significant group differences across education, caste, scientific orientation, risk orientation, and economic motivation, suggesting that socio-psychological differentiation strongly shaped training demand. Similar evidence has been documented in studies exploring determinants of women's participation in agricultural extension programmes (Miller-Klugesherz & Sanderson, 2023).

CONCLUSION

This study reveals that farm women in Jhansi district are not passive recipients of aid, but strategic managers seeking specific skills to enhance their livelihoods. Their demand for training in crop storage, livestock care, and core agronomic practices demonstrates a holistic vision for integrated, sustainable farming. The most powerful finding is that a woman's internal drive her scientific curiosity and willingness to take calculated risks is a stronger predictor of her training needs than many external factors. In light of these findings, it is recommended that agricultural extension agencies design gender-sensitive programs that are tailored to the specific, expressed needs of women. These programs should prioritize drudgery-reducing and income-enhancing technologies, particularly in post-harvest management and mechanisation. To ensure equitable access, training should be delivered through inclusive formats that accommodate the time and financial constraints of women from diverse socioeconomic backgrounds. By recognising and nurturing the inherent psychological readiness of women to innovate, and by addressing the structural barriers they face, India's agricultural extension system can unlock the immense potential of its women farmers, paving the way for a more productive, sustainable, and equitable agricultural future.

DECLARATIONS

Ethical Approval and Consent to Participate: Our study did not require ethical approval, and all the authors agree.

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

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Authors' Contribution: Conceptualisation of research (YP, AKB); Designing of the experiments (YP, AKB); Contribution of experimental materials (YP, AKB); Execution of field survey and data collection (YP, YK); Analysis of data and interpretation (KS); Preparation of manuscript (KS).

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Small-scale Farmers' Willingness to Pay for Extension Services: Evidence from Nigeria

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HIGHLIGHTS

- The majority of the farmers were willing to pay for Extension services
- A huge gap between farmers' willingness and actual practice was observed.
- Contact with extension agents, Gender, and type of farm operation determine willingness to pay.

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Keywords: Willingness to pay, Agricultural extension services, Small-scale farmers, Logistic regression, Ekiti State, Nigeria.

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ABSTRACT

Sustainable financing of agricultural extension services remains a major challenge among small-scale farmers in Nigeria. This study examined small-scale farmers' willingness to pay (WTP) for agricultural extension services in Ikole and Oye Local Government Areas of Ekiti State, Nigeria, using cross-sectional data collected in 2023. Data were obtained through a structured questionnaire and analysed using descriptive statistics and a binary logistic regression model. Willingness to pay for extension services was measured as a binary outcome, with farmers classified as willing or not willing to pay for regular and reliable extension services. The results showed that a substantial proportion of the respondents expressed willingness to pay for extension services. The logistic regression results indicated that education level, farm size, access to extension services, and farming experience significantly influenced farmers' willingness to pay. Age and gender were not statistically significant determinants. The farmers' willingness to pay is closely linked to their capacity to benefit from extension services. Strengthening farmers' awareness of the benefits of extension services and improving service delivery could enhance farmers' willingness to contribute financially. Policy interventions aimed at improving extension service quality at the local level may promote more sustainable extension financing among small-scale farmers.

INTRODUCTION

Agricultural output can be increased in this globalized period by transferring improved technology to end users in an efficient, dependable, and timely manner (Sarnaik et al., 2020). By converting agronomic research into useful, regionally specific guidance for small-scale farmers to increase productivity, resilience, and market involvement, agricultural extension services programs fulfil this responsibility (Bonye et al., 2012; Arowosegbe et al., 2024). In Nigeria, where contribution by agricultural sector is roughly 25% of GDP, and the vast majority of farmers are smallholders, the effectiveness and sustainability of extension delivery have outsized implications for food security and rural livelihoods (International Trade Administration, 2025; FAO, 2025). In Nigeria 36 states, including the Federal Capital Territory (FCT), agricultural extension services provided by the public sector currently are the Agricultural Development Programs (ADPs) (Saliu & Agi, 2009). However, the effectiveness of ADP in achieving the target objective in recent years

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has been questioned. Public budget constraints, variability in program quality, and the push toward pluralistic models (public, private, and NGO providers) have stimulated debate on cost-sharing and fee-for-service modalities. Nigeria's Agriculture Promotion Policy (APP, 2016–2020) and recent national extension policy discussions explicitly envision stronger farmer orientation, improved accountability, and diversified financing streams to make services more responsive and durable (FMARD, 2016). A key empirical lever in this policy conversation is farmers' willingness to pay (WTP) for extension services. It is based on the premise that if farmers perceive clear value in Agricultural extension services (yield gains, cost savings, risk reduction), they may accept partial user fees that, in turn, can enhance service quality and continuity. Ozor et al. (2013) reported substantial willingness to pay for improved extension, while identifying socioeconomic and institutional determinants as salient predictors. The farmers believe that privatisation will result in timely delivery of extension services, help in bringing accountability and increase the professionalism among the extension staff (Kumar & Nain, 2014). However, context matters, such as heterogeneity across states, commodities, and delivery channels, which can shape both willingness and ability to pay, underlining the need for up-to-date, locale-specific evidence. Recent evidence adds nuance. Experimental work from Nigeria shows that when farmers experience high-quality, tailored advisory (e.g., via digital decision tools), their WTP for continued access increases, suggesting that "try-before-you-buy" can overcome information frictions and skepticism about service value (Oyinbo et al., 2025). Broader evaluations also associate strengthened extension with improved farm decisions, expanded cultivated area, and greater economic participation mechanisms consistent with higher perceived returns to advice. Yet affordability constraints and exposure to climate and market shocks may compress effective demand, especially among the poorest small-scale farmers. This underscores the importance of pricing, targeting, and potential subsidies to avoid excluding precisely those who stand to gain. Policy frameworks in Nigeria increasingly emphasise such targeting alongside public–private partnerships (Federal Republic of Nigeria, 2024). Against this backdrop, this study investigates the willingness of small-scale farmers to pay for services rendered by the extension agents in Nigeria, providing contemporary evidence to inform program design and financing. Focusing on smallholders who produce most of Nigeria's food, the study offers practical guidance on where, and for whom, fee-based models are feasible and where public financing or cross-subsidies remain essential.

METHODOLOGY

The study was conducted in Ekiti State, Nigeria, focusing on Ikole and Oye Local Government Areas (LGAs). These LGAs were purposively selected due to their high concentration of small-scale farmers, the presence of public agricultural extension services, and farmers' prior exposure to extension activities, which made them suitable for assessing willingness to pay (WTP) for extension services. A multi-stage sampling technique was employed. In the first stage, Ikole and Oye LGAs were selected purposively. In the second stage, farming communities were randomly selected from each LGA. The final stage involved the random selection of small-scale farmers from the selected communities, resulting in a total sample of respondents used for the analysis.

Primary data were collected in 2023 using a structured questionnaire administered through face-to-face interviews. Information obtained included respondents' socio-economic characteristics, access to extension services, and their willingness to pay for agricultural extension services.

Willingness to pay for extension services was measured using a binary choice approach. Respondents were asked whether they were willing to pay for agricultural extension services if such services were made available on a regular and reliable basis. Responses were coded as 1 for farmers willing to pay and 0 for those not willing to pay. This binary specification justified the use of a logistic regression model to identify factors influencing farmers' willingness to pay.

The logistic regression model estimated the probability that a farmer would be willing to pay for extension services as a function of selected socio-economic and farm-related characteristics, including age, gender, education, farm size, farming experience, and access to extension services. Variables included in the model were selected based on empirical literature and theoretical relevance. One explanatory variable (income) was excluded from the final model due to estimation instability arising from insufficient variation, which resulted in unreliable coefficient estimates.

Descriptive statistics were used to summarize respondents' characteristics, while the logistic regression results were used to determine the significant factors influencing willingness to pay. All analyses were conducted using standard statistical procedures appropriate for cross-sectional survey data.

RESULTS

Willingness to Pay for Agricultural Extension Services

Results in Table 1 indicate that a substantial proportion of the sampled farmers expressed willingness to pay for agricultural extension services if such services were made available on a regular and reliable basis. This suggests that farmers recognize the potential benefits of extension services in improving farm productivity and decision-making. However, a notable proportion of respondents were not willing to pay, highlighting the continued reliance on publicly funded extension services and possible concerns about affordability or service quality. These findings underscore the importance of improving the relevance, reliability, and perceived value of extension services in the study area.

Determinants of Willingness to Pay for Extension Services

The factors influencing farmers' willingness to pay for extension services were analyzed using a binary logistic regression model, and the results are presented in Table 2. Education level had a positive and statistically significant effect on willingness to pay, implying that more educated farmers are more likely to appreciate the benefits of extension services and are therefore willing to contribute financially. Farm size also showed a positive and significant relationship with willingness to pay, suggesting that farmers operating relatively larger farms perceive greater potential returns from improved access to extension services.

Access to extension services was found to significantly influence willingness to pay, indicating that farmers who have prior contact with extension agents are more inclined to pay for such services. Farming experience also had a significant effect, reflecting the role of accumulated knowledge and exposure in shaping farmers' valuation of extension support. In contrast, age and gender were not statistically significant determinants of willingness to pay in the study area.

One explanatory variable (income) was excluded from the final model due to estimation instability arising from insufficient variation, which resulted in unreliable coefficient estimates. The revised model therefore focuses on variables with stable and interpretable effects.

Overall, the results indicate that willingness to pay for extension services among small-scale farmers in the study area is primarily influenced by human capital, farm characteristics, and prior exposure to extension services. These findings align with empirical evidence from similar studies in sub-Saharan Africa, which emphasize the importance of education, farm scale, and service exposure in shaping farmers' demand for extension services.

The results on the availability of public agricultural extension services provide insight into farmers' lived experience and how this influences their willingness to pay for such support. Most farmers reported access to improved seedlings (79%), training on farm recording (73%), information on pesticides (73%) and weather (69%). However, fewer farmers had access to rural infrastructure development (42%), machinery hire linkages (47%), and marketing information (49%). This pattern reflects an extension system strong in technical training but weak in institutional and market linkages. High access to training and input supply corresponds with the production-oriented focus of Nigeria's public extension programs. Exposure to these services tends to increase technology adoption and productivity (Kalogiannidis & Syndoukas, 2024), which can positively affect farmers' perceived value and willingness to pay. Yet, willingness may be tempered by persistent gaps in credit (only 58% availability), infrastructure, and market access. These critical areas determine whether extension translates into tangible income gains (Tambi & Mukum, 2024). When farmers experience fragmented or irregular services, their confidence in paying for future programs decline (Anderson & Feder, 2007). This disparity suggests a need for a more comprehensive approach to extension services that addresses both production and post-harvest aspects of farming, as well as market access and infrastructure support (Anderson and Feder, 2007; Davis, 2008). The result further revealed that 63% of small-scale farmers expressed willingness to pay for agricultural extension services, while 37% were unwilling. This majority willingness suggests that many farmers recognize the value of extension agents' activities and perceive tangible benefits from them. A study in sub-Saharan Africa earlier reported the same trend, indicating that farmers' willingness to pay rises when services are perceived as credible, accessible, and responsive to local needs (Ozor et al., 2013). Farmers who have previously benefited from extension, through access to improved inputs or training are generally more motivated to share the cost of sustaining these services (Kalogiannidis & Syndoukas, 2024). Nonetheless, the 37% unwilling group reveals persistent skepticism about service quality, affordability, and government responsibility.

Table 1. Services by Public Extension Agents accessible to small-scale farmers and farmers' willingness to pay

a) Agricultural Extension Services	Available (%)
Training on farm recording	73.0
Sources of improved seedlings	79.0
Agricultural Credit Facilities	58.0
Information on weather conditions	69.0
Information on best herbicides and pesticides to use	73.0
Rural Infrastructure Development	42.0
Training on maize planting techniques	63.0
Training on best storage practices	62.0
Linkage with farm machinery hiring outlets	47.0
Marketing information	49.0
b) Willingness to Pay	
Willing to pay	63.0
c) Payment of Ext Service in the past	
Paid either in past	21.0

Earlier research shows that smallholders often view extension as a public good that should remain state-funded, especially when past delivery has been inconsistent or poorly targeted (Anderson and Feder, 2007). Limited trust in institutions and irregular field visits can reduce perceived value, discouraging financial participation. Moreover, low farm incomes and credit constraints further dampen farmers' ability to pay even when willingness exists (Moumouni et al., 2009; Tambi & Mukum, 2024).

Furthermore, small-scale farmers were asked if they have ever paid for agricultural extension service in the past. The results in Table 3 revealed that only 21% of small-scale farmers have ever paid for agricultural extension services, while 79% have not. This low history of payment underscores the enduring perception of extension as a public good that should be government-funded rather than user-financed. In much of sub-Saharan Africa, extension programs have traditionally been delivered free of charge through public agencies, creating a culture of dependence and limited cost-sharing (Anderson & Feder, 2007). When service delivery has been inconsistent or poorly monitored, farmers often view payment as unwarranted. The data also reveal a gap between willingness and practice. While 63% of farmers expressed willingness to pay, only 21% had ever done so. This disparity aligns with findings that actual payment behavior depends not merely on intent but on trust in service quality, affordability, and perceived accountability of extension agents (Ozor et al., 2013). Studies across Africa reported similar reluctance, where farmers hesitate to commit financially without tangible evidence of productivity gains or sustained engagement. Also, Economic constraint is another major barrier. Smallholders often operate under severe liquidity limitations, prioritizing immediate production inputs over advisory fees (Tambi & Mukum, 2024). Consequently, unless extension models integrate flexible payment systems, subsidies, or cooperative financing, uptake will remain low. Strengthening transparency, demonstrating measurable farm benefits, and institutionalizing co-funded models through farmer groups may gradually shift attitudes toward consistent cost participation in extension services. To ascertain the factors influencing farmers' WTP for Extension services, a logistic regression was done. The logistic regression results in Table 2

Table 2. Omnibus Tests of Model Coefficients and Model Summary

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	77.500	10	.000
	Block	77.500	10	.000
	Model	77.500	10	.000
Model Summary				
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square	
1	47.873[a]	.539	.755	

provide a robust explanation of the factors that determined willingness of small-scale farmers' to pay for services rendered by the extension agents.

The omnibus test of model coefficients ($\chi^2 = 77.500$, df = 10, $p < .001$) indicates that statistically significance of the overall mode, meaning that the included predictors jointly explain variation in willingness to pay. The model summary further supports this, with a Cox and Snell R^2 of 0.539 and a Nagelkerke R^2 of 0.755, indicating that between 54 and 76 percent of the variation in the dependent variable can be explained by the independent factors. Such explanatory power is considered strong for socio-economic behavior models in agricultural studies (Gujarati & Porter, 2020). Among the predictors (Table 3), extension agent intensity of visit (B = 5.006, $p < .001$, Exp (B) = 149.342) emerged as the most influential determinant of willingness to pay. The result is in conformity with the report of P & K (2022) in their work on Farmers WTP for privatized Agricultural Services in Kerela. The pivotal role of frequent and quality interactions between farmers and extension agents cannot be overemphasized as cogent factor influencing farmers' decision to pay for extension services. Regular and meaningful contact builds trust, improves information flow, and enhances perceived service value (Anderson & Feder, 2007). When farmers experience effective service delivery, they become more willing to contribute financially to sustain such services (Ozor et al., 2013).

Also, Farm size showed a significant positive effect (B = 1.047, p = 0.050, Exp (B) = 2.848), suggesting that compared to their smaller-scale counterparts, larger-scale farmers are almost three times more likely to pay for extension services. Larger farms typically generate higher income, enjoy economies of scale, and can more easily absorb the cost of extension participation (Tambi & Mukum, 2024). Conversely, type of farming operation had a significant negative association (B = -3.895, p = 0.022), indicating that certain enterprise types, such as subsistence or mixed farming are less inclined toward payment, likely due to low commercialization levels and limited cash flow.

Finally, gender was significant (B = 2.287, p = 0.043, Exp (B) = 9.841), suggesting that male farmers are more likely to pay for extension services than female farmers. Similar gender disparities have been documented across Africa, often linked to differences in land ownership, access to credit, and control over household income. Other variables, including age, education, and income, were not statistically significant, implying that behavioral and institutional factors may outweigh demographic ones in determining willingness to pay. Overall, these findings reinforce that enhancing extension agent engagement and targeting gender and enterprise-sensitive strategies are critical to building sustainable, participatory extension systems.

DISCUSSION

The findings of this study provide empirical evidence on small-scale farmers' willingness to pay for agricultural extension services in the study area. The relatively high proportion of farmers willing to pay suggests that extension services are perceived as valuable when they are regular, reliable, and relevant to farmers' production needs. This supports the growing argument that farmers may be willing to contribute financially to extension services when the expected benefits are clear and tangible.

Education level was found to significantly influence willingness to pay, indicating that more educated farmers are better positioned to understand and appreciate the potential benefits of extension services. This finding aligns with previous empirical studies that emphasize the role of human capital in shaping farmers' demand for agricultural information and advisory services. Similarly, farm size had a positive and significant effect on willingness to pay, suggesting that farmers operating relatively larger farms perceive greater economic returns from improved access to extension services.

Access to extension services emerged as a key determinant of willingness to pay, highlighting the importance of prior exposure and interaction with extension agents. Farmers who have benefited from extension services in the past are more likely to value such

Table 3. Determinants of willingness by Small-Scale Farmers to pay for Agricultural Extension Services

	B	S.E.	Wald	df	Sig.	Exp(B)
Age	-.193	.105	3.418	1	.064	.824
Family size	-.152	.274	.307	1	.580	.859
Income	.000	.000	.639	1	.424	1.000
Experience	.172	.145	1.412	1	.235	1.188
Extension agent intensity of visit	5.006	1.240	16.302	1	.000	149.342
Frequency of visit	-.271	.220	1.518	1	.218	.763
Education	.095	.072	1.756	1	.185	1.100
Farm size	1.047	.534	3.839	1	.050	2.848
Type of farm opt	-3.895	1.703	5.232	1	.022	.020
Gender	2.287	1.129	4.099	1	.043	9.841
Constant	4.676	4.275	1.197	1	.274	107.352

services and express readiness to pay for them. Farming experience also significantly influenced willingness to pay, reflecting the role of accumulated knowledge and learning in shaping farmers' perceptions of extension usefulness. In contrast, age and gender were not significant determinants, suggesting that willingness to pay cuts across different demographic groups within the study area.

While the results provide useful insights, they should be interpreted with caution due to the localized nature of the study. The findings are based on data from two Local Government Areas in Ekiti State and may not be generalized beyond similar contexts with comparable socio-economic and institutional characteristics.

CONCLUSION

The results indicate that a substantial proportion of farmers are willing to pay for extension services, with willingness influenced primarily by education level, farm size, farming experience, and access to extension services. Improving the quality, consistency, and relevance of extension services at the local level could enhance farmers' willingness to contribute financially. Policy efforts should focus on strengthening farmers' awareness of the benefits of extension services, expanding farmer–extension agent interactions, and tailoring extension programs to meet the specific needs of small-scale farmers. Introducing flexible and affordable cost-sharing arrangements may further encourage farmers' participation in financing extension services. Given the limited geographical scope of the study, future research should extend the analysis to other regions and incorporate larger samples to improve generalizability. Nonetheless, the study provides useful evidence for policymakers and extension stakeholders seeking to explore more sustainable approaches to financing agricultural extension services in similar rural contexts.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents for the study.

Competing Interest: The Authors have no competing interests.

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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Assessment of Farmers' Knowledge on Nutrition and Nutrition-Sensitive Agriculture

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HIGHLIGHTS

- A standardized knowledge test was developed and validated to assess the knowledge level of respondents regarding nutrition and nutrition-sensitive agriculture (NSA).
- Farmers possess a basic nutrition knowledge; however, enhancing knowledge on innovative NSA technologies and institutional programs remains imperative.
- Regional disparities in knowledge scores emphasise the importance of targeted interventions, particularly in Karnataka, to bridge existing knowledge gaps.

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ABSTRACT

Nutritional knowledge plays a vital role in shaping the dietary behaviour of individuals and communities. This study assessed farmers' knowledge of nutrition and nutrition-sensitive agriculture (NSA) in the southern Indian states of Kerala and Karnataka during 2024-25. A standardized knowledge test comprising 26 statements was developed and administered to a sample of 300 respondents. Statistical analyses, including Welch's t-test, Welch's ANOVA, and the Games-Howell post-hoc test, were used to compare knowledge scores across states and districts. In addition, regression analysis was employed to examine the relationship between farmers' knowledge and socio-economic characteristics. State- and district-level comparisons indicated that farmers from Kerala had higher knowledge levels than those from Karnataka. Regression analysis revealed that factors such as education, gender, age, source of information, number of trainings attended, and family size significantly influenced farmers' knowledge. These disparities underscore the necessity of awareness campaigns and capacity-building programs on nutrition and NSA, particularly through educational institutions, rural organizations, and mass media platforms.

INTRODUCTION

Despite significant progress in agricultural productivity and food security over recent decades, malnutrition continues to pose a persistent public health challenge across many regions of India (United Nations in India, 2023). According to the National Family Health Survey-5 (NFHS-5, 2019-21), 35.50 per cent of children under five are stunted, 19.30 per cent are wasted, and 32.10 per cent are underweight, with wide disparities across states (International Institute for Population Sciences [IIPS] and ICF, 2021). These figures highlight the limitations of conventional food security approaches that prioritize caloric sufficiency over dietary

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diversity and nutritional adequacy. Although overall calorie availability has increased, the quality of diets, particularly in rural communities, remain deficient in essential micronutrients, causing widespread undernutrition, anaemia, and other diet-related health conditions (Ruel et al., 2018; Jose et al., 2020). In this context, NSA has become an essential approach for enhancing health outcomes and tackling malnutrition, especially in regions where agriculture remains the backbone of rural livelihoods. Conventional agricultural practices usually focus on maximising crop yields and economic returns, whereas NSA integrates nutrition goals by promoting farming practices that enhance dietary diversity, food quality, and the nutritional value of local diets (Herforth & Ballard, 2016). These strategies include enhancing access to safe and nutritious food, reducing health risks through sustainable agricultural practices, strengthening nutrition knowledge and norms, increasing household income, and fostering women's empowerment (Ogutu et al., 2020). Farmers, being the primary producers of food, are very important in shaping the dietary behaviour of households and community. Their understanding of dietary diversity, nutritional value of crops & livestock, and benefits of farm diversification directly influence production decisions and household consumption patterns. However, despite their pivotal role, evidence remains limited on how much farmers know about nutrition and how far this knowledge shapes their agricultural practices, especially in the context of NSA (Channal et al., 2024).

Kerala and Karnataka, two southern Indian states, offer contrasting yet instructive cases for exploring farmers' knowledge of nutrition and NSA. Both states perform relatively strong performance in human development and agricultural diversification compared to the national average; however, they differ considerably in health indicators, agricultural policies, and extension systems. Although Kerala is widely recognized for its outstanding social development, as reflected in its high literacy rate of 96.20 per cent (National Statistical Office, 2019), a life expectancy at birth of 75.30 years (National Health Systems Resource Centre, 2021), and a comparatively well-established healthcare infrastructure, the state continues to face challenges related to dietary monotony and micronutrient deficiencies, particularly among tribal and other marginalized communities (Natuvilakkandy & Christabell, 2025). Karnataka, in contrast, demonstrates wide variation in socio-economic conditions and farming systems, where certain regions adopting rapid agricultural innovations while others still struggle with persistent nutrition-related challenges (Rao et al., 2022). Hence, this study investigates the extent of farmers' knowledge regarding nutrition and NSA in Kerala and Karnataka and identify the socio-economic factors shaping their understanding.

METHODOLOGY

The study was conducted during 2024-25 in the southern Indian states of Kerala and Karnataka to assess farmers' knowledge regarding nutrition and NSA. A total of six districts were selected randomly, three from Kerala (Wayanad, Palakkad, and Alappuzha) and three from Karnataka (Dharwad, Kolar, and Mandya). Then, a stratified random sample of 50 farmers was drawn from each district, comprising individuals who were practicing at least two of the four selected NSA technologies, namely kitchen garden, millet cultivation, crop diversification, and value addition. Hence, the total sample size of the study was 300 respondents. A knowledge test consisting of 26 items (knowledge statements) was developed to measure farmers' knowledge. Initially, 36 items were identified based on their relevance to nutrition and NSA, drawing from literature reviews and expert suggestions. These items were then evaluated for appropriateness by subject-matter experts through email consultation, following the procedure outlined by Kumar et al. (2016). After the relevancy test, five items were removed, leaving 31 items, which were further pilot-tested on 48 farmers outside the study area. Respondents were asked to record their answers, with each correct response assigned a score of "1" and each incorrect response a score of "0." The total knowledge score for each item was calculated by summing the individual respondent scores (Kaur et al., 2020). Item analysis was carried out following the standard procedures outlined by Vijayan et al. (2022) and Barua et al. (2023). Out of the 31 items, 26 satisfied the established selection criteria, i.e., a difficulty index between 30 and 80, a discrimination index exceeding 0.30, and a point-biserial correlation coefficient above 0.236. Hence, these 26 items were retained for the final knowledge test (Table 1).

To quantify the percentage knowledge of farmers on each item, a standardized knowledge index (KI) was calculated using the following formula:

$$\text{Knowledge Index (KI)} = \frac{\text{Obtained score}}{\text{Maximum obtainable score}} \times 100$$

The maximum obtainable score for an item was 300. Further, Welch's t-test was applied to compare the mean knowledge scores of farmers in Kerala and Karnataka, while Welch's ANOVA, followed by Games–Howell post-hoc tests, was used for district-wise comparisons. Similar procedures for state- and district-wise comparisons were used by Ranjan et al. (2025). To examine the relationship between farmers' knowledge levels and independent variables, multiple linear regression analysis was conducted using SPSS (version 25). The assumption of linearity was verified, and collinearity statistics, namely Tolerance and the Variance Inflation Factor (VIF), were calculated to assess the extent of multicollinearity (Barua et al., 2023).

RESULTS

The item-wise analysis of farmers' knowledge, presented in Table 2, revealed considerable variation across different concepts. Overall, the percentage of correct responses ranged from 32 per cent to 96 per cent, reflecting differential levels of understanding among respondents. With respect to general nutrition knowledge, most respondents answered correctly on items such as the importance of drinking sufficient water (96%), the variation of nutritional requirements by age, gender, and activity level (90.67%), good hand hygiene practices (94%), and the health risks associated with junk food consumption (92.33%). Similarly, high levels of knowledge were observed regarding the health detriments of skipping meals (91.33%), the inclusion of fruits and vegetables in the daily diet (88%), maintaining ideal body weight (85.33%), and the importance of dietary diversity (84.67%). However, several

Table 1. Item analysis of questionnaire for testing farmers' knowledge about nutrition and NSA (n=48)

S.No.	Knowledge items	Difficulty Index	Discrimination Index	Point-Biserial Correlation (Rpbis)
1.	Dietary diversity indicates access to a variety of foods within a household - T/F	68.75	0.38	0.41**
2.	Balanced diet is essential for good health - T/F	54.17	0.50	0.54**
3.	The consumption of fruit juice is better than consuming raw fruit - T/F	56.25	0.63	0.57**
4.	Skipping meals is good for health - T/F	72.92	0.38	0.44**
5.	A healthy diet depends on drinking enough water - T/F	79.17	0.31	0.45**
6.	Maintaining ideal body weight is essential for good health - T/F	70.83	0.50	0.47**
7.	Sprouting will improve nutrient availability - T/F	64.58	0.44	0.36*
8.	Drinking tap water is good for health - T/F	68.75	0.38	0.32*
9.	Nutritional requirement varies based on factors such as age, gender, and activity level -T/F	75.00	0.56	0.63**
10.	It is healthier to include fruits and vegetables in our daily diet - T/F	62.50	0.44	0.40**
11.	Inclusion of dairy product is necessary in our diets - T/F	66.67	0.38	0.32*
12.	Anaemia is due to deficiency of iron consumption - T/F	64.58	0.44	0.36*
13.	Frequent intake of junk food is good for health - T/F	62.50	0.50	0.43**
14.	Washing hands before consuming food is an important hygiene habit - T/F	70.83	0.38	0.36*
15.	Excess intake of fat may cause obesity - T/F	72.92	0.31	0.47**
16.	What is the major objective of NSA? a) Increased crop yields b) Lower production costs c) Better nutrition outcomes	47.92	0.75	0.58**
17.	Promoting only staple crops is sufficient for achieving better nutrition outcomes – T/F	56.25	0.63	0.57**
18.	Nutri-sensitive Agricultural Resources and Innovations (NARI) and Value Addition and Technology Incubation Centres in Agriculture (VATICA) are two major programs of Indian Council of Agricultural Research (ICAR) to promote NSA - T/F	33.33	0.56	0.51**
19.	Kitchen garden as an NSA technology provide fresh, organic, and nutritious produce for the household consumption - T/F	77.08	0.44	0.48**
20.	Regular participation in nutrition training is important because it: a) Focuses only on technical farming methods b) Updates farmers on NSA production and consumption practices c) Promotes pesticide use	62.50	0.44	0.40**
21.	NSA technologies do not consider environmental sustainability - T/F	68.75	0.38	0.35*
22.	Promoting dietary diversity through the cultivation of various crops and livestock is integral to NSA – T/F	64.58	0.44	0.36*
23.	Which of the NSA practice is most likely improve soil health & increase nutrient content in crops? a) Crop rotation b) Monocropping c) Excessive use of chemical fertilizers	56.25	0.63	0.57**
24.	Millets are nutritional powerhouses, packed with a lot of health benefits – T/F	64.58	0.38	0.37**
25.	Value addition reduce postharvest losses and improve nutritious food availability across different seasons – T/F	52.08	0.50	0.50**
26.	What is the primary benefit of introducing bio-fortified crops?a) Pest resistanceb) Enhanced micronutrient contentc) Higher market value	47.92	0.63	0.62**

** Significant at 1% LOS, *Significant at 5% LOS

misconceptions were evident. For instance, only 68.67 per cent of respondents recognized that consuming fruit juice is not necessarily better than eating whole fruit, and only 66 per cent correctly identified the nutritional benefits of sprouting. Likewise, while 72.67 per cent correctly linked anaemia to iron deficiency, a considerable proportion failed to demonstrate this fundamental nutrition knowledge. Regarding NSA specific knowledge, respondents displayed a generally good understanding of key NSA principles and practices. The majority identified the major objective of NSA as improving nutrition outcomes (82%) and acknowledged the importance of diversified farming systems (84.33%) and kitchen gardens (90.67%) as essential NSA technologies providing fresh, nutritious produce for households. Practices such as crop rotation were correctly identified by 77.33 per cent of respondents as beneficial for soil health and nutrient content, and value addition was recognized by 78.67 per cent for its role in reducing postharvest losses and improving seasonal availability of nutritious foods. Similarly, 78.67 per cent rejected the misconception that NSA technologies do not consider environmental sustainability, demonstrating reasonable awareness of the environmental dimensions of NSA. In contrast, a notable knowledge gap emerged regarding institutional and technical aspects of NSA. Only 32 per cent of

Table 2. Statement-wise knowledge among respondents regarding nutrition and NSA (n=300)

Q.No.	Knowledge items	CR	KI (%)
1.	Dietary diversity indicates access to a variety of foods within a household	True	84.67
2.	Balanced diet is essential for good health	True	62.67
3.	The consumption of fruit juice is better than consuming raw fruit	False	68.67
4.	Skipping meals is good for health	False	91.33
5.	A healthy diet depends on drinking enough water	True	96.00
6.	Maintaining ideal body weight is essential for good health	True	85.33
7.	Sprouting will improve nutrient availability	True	66.00
8.	Drinking tap water is good for health	False	89.33
9.	Nutritional requirement varies based on factors such as age, gender, and activity level	True	90.67
10.	It is healthier to include fruits and vegetables in our daily diet	True	88.00
11.	Inclusion of dairy product is necessary in our diets	True	78.67
12.	Anaemia is due to deficiency of iron consumption	True	72.67
13.	Frequent intake of junk food is good for health	False	92.33
14.	Washing hands before consuming food is an important hygiene habit	True	94.00
15.	Excess intake of fat may cause obesity	True	79.33
16.	What is the major objective of NSA? a) Increased crop yields b) Lower production costs c) Better nutrition outcomes	c	82.00
17.	Promoting only staple crops is sufficient for achieving better nutrition outcomes	False	79.33
18.	Nutri-sensitive Agricultural Resources and Innovations (NARI) and Value Addition and Technology Incubation Centres in Agriculture (VATICA) are two major programs of Indian Council of Agricultural Research (ICAR) to promote NSA	True	32.00
19.	Kitchen garden as an NSA technology provide fresh, organic, & nutritious produce for the household consumption	True	90.67
20.	Regular participation in nutrition training is important because it: a) Focuses only on technical farming methods b) Updates farmers on NSA production and consumption practices c) Promotes pesticide use	b	72.00
21.	NSA technologies do not consider environmental sustainability	False	78.67
22.	Promoting dietary diversity through the cultivation of various crops and livestock is integral to NSA	True	84.33
23.	Which of the NSA practice is most likely improve soil health and increase nutrient content in crops? a) Crop rotation b) Monocropping c) Excessive use of chemical fertilizers	a	77.33
24.	Millets are nutritional powerhouses, packed with a lot of health benefits	True	80.67
25.	Value addition reduce postharvest losses and improve nutritious food availability across different seasons	True	78.67
26.	What is the primary benefit of introducing bio-fortified crops? a) Pest resistance b) Enhanced micronutrient content c) Higher market value	b	51.67

CR = Correct Response, KI = Knowledge Index

respondents were aware of flagship ICAR programs such as Nutri-sensitive Agricultural Resources and Innovations (NARI) and Value Addition and Technology Incubation Centres in Agriculture (VATICA), indicating limited exposure to formal NSA initiatives. Awareness of primary benefits of bio-fortified crops was moderate, with just 51.67 per cent correctly identifying this, suggesting insufficient dissemination of information regarding these advanced NSA innovations. Moreover, only 72 per cent recognized the importance of regular nutrition training for updating NSA production and consumption practices.

A comparison of knowledge scores between respondents from Kerala and Karnataka is summarized in Figure 1. The mean knowledge score was higher in Kerala (20.90) compared to Karnataka (18.99). Statistical analysis using Welch's t-test ($t = 4.96$, $p = 1.24 \times 10^{-6}$) confirmed that the difference in knowledge scores between the two states was significant. The effect size was moderate (Cohen's $d = 0.57$), with a 95 per cent confidence interval ranging from 0.34 to 0.80. While, the district-wise comparison of farmers' knowledge scores, illustrated in Figure 2, revealed that respondents in Alappuzha (20.66) and Wayanad (20.42) districts of Kerala had the highest average knowledge scores, whereas those in Kolar (18.40) and Dharwad (19.10) districts of Karnataka had the lowest. Statistical analysis using Welch's ANOVA indicated a significant variation in knowledge scores across districts ($F = 6.17$, $p = 3.46 \times 10^{-5}$), with a moderate effect size ($\eta^2 = 0.18$). Post-hoc pairwise comparisons using the Games-Howell test further revealed that respondents in Alappuzha had significantly higher knowledge scores compared to those in Kolar (mean difference = 3.22, $p = 1.19 \times 10^{-3}$) and Dharwad (mean difference = 2.16, $p = 0.04$).

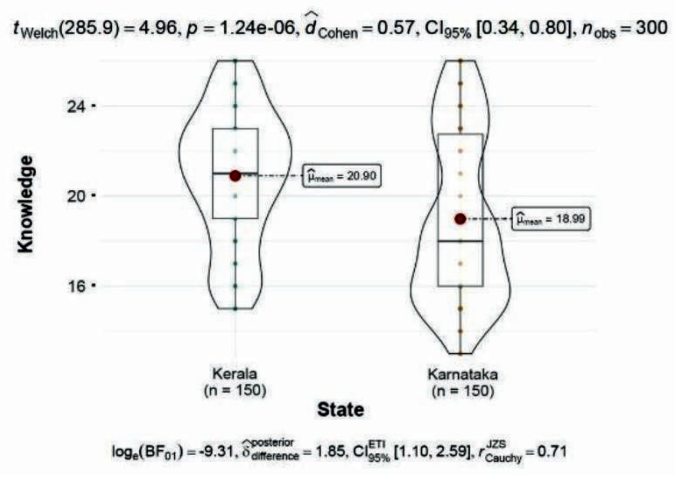

Figure 1. State-wise Comparison of Knowledge Scores: Kerala vs. Karnataka (Violin plot)

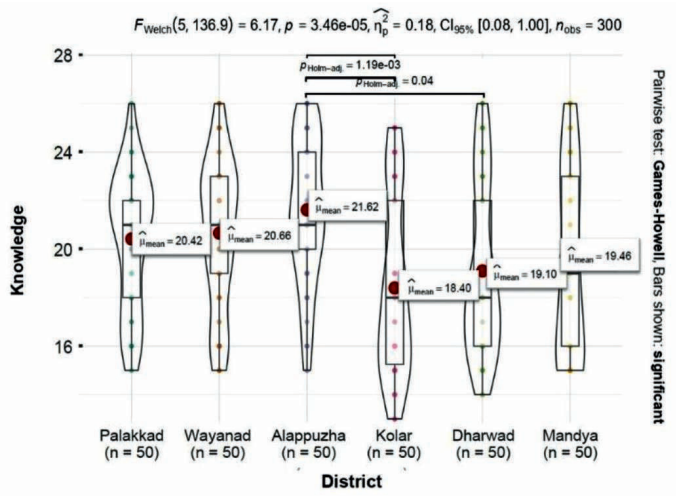

Figure 2. District-wise Comparison of Knowledge Scores (Violin plot)

The results of the regression analysis, presented in Table 3, highlight the key factors influencing farmers' knowledge of nutrition and NSA. Six independent variables viz., age, education, family size, gender, source of information, and number of NSA-related trainings attended were found to explain approximately 74.60 per cent of the variation in the dependent variable, i.e., knowledge level. The same table also presents the collinearity statistics, which were computed to assess the presence of multicollinearity. Generally, a VIF value less than 5 and a tolerance value greater than 0.20 are considered acceptable, indicating a low correlation between a given independent variable and other predictor variables. In this study, all independent variables had VIF values below 5 and tolerance values above 0.20, confirming the absence of significant multicollinearity. Therefore, no variables were excluded from the model on account of multicollinearity.

DISCUSSION

The item-wise analysis of farmers' knowledge about nutrition and NSA revealed that respondents generally demonstrated a strong understanding of fundamental nutrition practices. These included dietary diversity, the importance of safe water consumption, hand hygiene, and the avoidance of junk food. Such findings are in line with earlier studies which highlighted the effectiveness of public health campaigns in improving community-level nutrition literacy (Ruel & Alderman, 2013; FAO, 2017). However, certain misconceptions persisted, particularly regarding the nutritional value of fruit juice compared to raw fruits and the benefits of food sprouting. This reflects previous reports that popular dietary myths frequently misguide food choices (Girard et al., 2012), underscoring the need for more nuanced nutrition education that reinforces correct practices in daily food-related decisions. With respect to NSA, knowledge levels were relatively high in areas such as crop rotation, kitchen gardening, and diversified farming. This suggests a growing recognition of the interlinkages between agriculture, nutrition, and sustainability, which aligns with global evidence demonstrating that household-level agroecological interventions significantly contribute to improved dietary diversity and nutrition outcomes (Fanzo et al., 2020). Nevertheless, the low awareness of institutional NSA programs such as ICAR's NARI and VATICA points to critical gaps in extension outreach and policy communication in India, a challenge similarly highlighted in evaluations of agricultural-nutrition linkages in developing contexts (Gillespie et al., 2013). Limited knowledge about the benefits of bio-fortification also suggests insufficient dissemination of innovations that have been shown to effectively address micronutrient deficiencies in agrarian

Table 3. Determinants of farmers' knowledge about nutrition and NSA (n=300)

Characteristics	Regression coefficient	Standard error	t-value	Collinearity statistics	
				Tolerance	VIF
Age	-0.097**	0.030	-3.195	0.319	3.131
Education	0.489**	0.057	8.632	0.385	2.599
Total annual income	1.797×10^{-7}	0.000	0.005	0.737	1.357
Family type	-0.013	0.381	-0.033	0.428	2.336
Family size	-0.286*	0.114	-2.518	0.372	2.687
Gender	-0.683**	0.245	-2.784	0.825	1.212
Farming experience	0.012	0.029	0.411	0.467	2.142
Social participation	0.000	0.075	-0.004	0.805	1.242
Source of information	0.630**	0.088	7.161	0.585	1.709
No. of trainings attended	0.326**	0.111	2.946	0.789	1.267
Market access	-0.072	0.118	-0.611	0.690	1.448

** Significant at 1% LOS, *Significant at 5% LOS

communities (Bouis & Saltzman, 2017). A state-wise comparison revealed significantly higher knowledge scores among respondents in Kerala compared to those in Karnataka. At the district level, Kerala's districts, particularly Alappuzha (21.62), outperformed their counterparts in Karnataka, including Kolar (18.40) and Dharwad (19.10). These findings support earlier work by Channal et al. (2024), who reported that 62 per cent of rural women in Dharwad had inadequate nutrition knowledge, while only 7.40 per cent demonstrated adequate understanding. The observed regional differences may reflect disparities in educational infrastructure, the effectiveness of local nutrition campaigns, and access to NSA-related extension services. This aligns with previous evidence on substantial geographic variation in nutrition literacy and program exposure across Indian states (Ruel, 2003). Although the effect size was moderate, Kerala's population benefits from factors that encourage acquisition and retention of nutrition knowledge. The results further emphasize the pivotal role of socio-economic variables in shaping farmers' knowledge. Education emerged as a strong determinant, consistent with evidence that links educational attainment to both agricultural and health literacy (Contento & Koch, 2020). Gender differences were also significant: the negative coefficient indicated that female respondents held higher knowledge levels than their male counterparts. Similar trends were also reported by Barua et al. (2023). A negative association with age suggests generational differences in exposure to modern information sources, highlighting the need for tailored outreach targeting older populations. Family size influenced knowledge levels as well, possibly reflecting resource constraints that hinder both knowledge acquisition and practical application, in line with socio-economic theories of household resource distribution (Gillespie et al., 2013).

The overall findings of the study indicate that while farmers possess a solid foundation of basic nutrition awareness, enhancing knowledge on innovative NSA technologies and institutional programs remains imperative. Therefore, targeted strategies such as strengthening extension services, promoting context-appropriate best practices, and enhancing access to educational resources in lagging regions, are essential to bridging existing knowledge gaps. Such efforts would support equitable improvements in nutrition literacy, dietary practices, and long-term public health outcomes (Fanzo et al., 2020). Incorporating participatory extension approaches and integrating nutrition education into existing agricultural advisory services will be essential to improve farmer capacity to adopt NSA strategies (Girard et al., 2012). Moreover, promoting sustained nutrition training can bridge technical knowledge gaps and foster behavioural change (Ruel & Alderman, 2013).

CONCLUSION

The state and district-wise comparisons of knowledge scores indicated regional disparities, while, regression analysis highlighted the significant influence of socio-economic factors such as education, gender, age, source of information, trainings attended, and family size on farmers' knowledge. Overall, the findings reaffirm that while baseline awareness of nutrition and NSA exists, substantial scope remains for improving knowledge levels and ensuring effective translation into practice. Targeted, region-specific, and gender-sensitive interventions are essential to bridge gaps, particularly in Karnataka. Strengthening the dissemination of institutional programs, enhancing extension and educational outreach, and addressing persistent misconceptions will be key to promoting equitable nutrition literacy and sustainable agricultural practices. By doing so, policies and programs can better foster the integration of agriculture and nutrition, ultimately contributing to improved dietary diversity and long-term public health outcomes.

DECLARATIONS

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

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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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Dietary Diversity and Nutritional Status of the *Oraon* Tribal Women: An Anthropometric Measurement Approach

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HIGHLIGHTS

- Despite having wide agrobiodiversity, Oraon tribal women are deprived of dietary diversity and district-wise significant differences in achieving minimum dietary diversity highlighted the variation in dietary intake over a 24-hour recall.
- The emergence of obesity and prevalence of undernutrition were observed, indicating that Oraon women face a double burden of malnutrition.
- A strong positive association was observed between BMI and MUAC, underscoring that MUAC can be employed instead of BMI.

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ABSTRACT

The study was conducted among the *Oraon* tribal women of Chhota Nagpur Plateau, comprising Jharkhand and Chhattisgarh, during 2024-25. Using multi-stage random sampling, 400 respondents were selected. The data concerning dietary diversity was collected using a structured interview schedule. Anthropometric measurement tools, including BMI and MUAC, were employed to measure nutritional status. Only 22 per cent of the respondents met the minimum dietary diversity criteria, and 78 per cent of women had an inadequate nutritional intake, eating less than five defined food groups. A Welch's ANOVA test highlighted significant variation in dietary intake across selected districts. Only 37.75 per cent of the women had normal BMI, whereas 48.75 per cent were affected by chronic energy deficiency, and a transition towards obesity was evident. 73.50 per cent of women were in the undernutrition category, defined by a MUAC cut-off below 22.8 cm. A comparison of nutritional status across selected districts highlighted no significant difference. The Pearson correlation analysis indicated a significant positive relationship between BMI and MUAC. The findings highlighted the efforts to address malnutrition in *Oraon* tribal women and enhance women's nutritional outcomes through kitchen gardening, nutrition-sensitive agriculture, and effective implementation of government nutrition programs.

INTRODUCTION

India continues to be the biggest contributor to worldwide malnutrition rates, accounting for the vast majority of the world's undernourished population. On the other side, the country is seeing a progressive increase in overweight/obesity (Prithishkumar et al., 2024). In India, malnutrition is manifested in a vicious cycle, where childhood malnutrition continues into adulthood and is subsequently passed on to the next generation (Majumder, 2022). According to the NFHS-5 report, 24 per cent of adult women are overweight, 19 per cent of women are underweight, and about 57 per cent of women of reproductive age (WRA) are anaemic in India. The

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proportion of overweight or obese women increased from 21 per cent in 2015-16 to 24 per cent in 2019-21. Dietary diversity assures an appropriate consumption of essential nutrients required for better health. Higher dietary diversity leads to better anthropometric outcomes and overall nutritional well-being. The dietary diversity for women is measured by Minimum Dietary Diversity for Women (MDD-W), which is a global nutrition indicator used to assess whether a woman's diet is likely to meet her micronutrient needs (FAO, 2021).

As per the 2011 census, approximately 104 million tribal people (8.6%) of the country's total population reside in India. They continue to rely primarily on subsistence agriculture for their livelihood and rank among the most marginalised regarding socio-economic development, nutrition, and health. Women have contributed significantly to the socioeconomic advancement of the nation as a whole and the family in particular. Indigenous women play a crucial role in livelihood security by performing triple roles, including child rearing, household and agricultural work, and community development work. They contribute to the local economy through their involvement in subsistence activities. Yet, they are susceptible to numerous forms of malnutrition. Although malnutrition affects all segments of India's indigenous population, indigenous women and children are particularly vulnerable (Shamna et al., 2018; Kapoor et al., 2022).

Balanced food consumption and appropriate nutrient utilisation maintain a normal nutritional status. This indicates that an inadequate pattern of vitamin and mineral intake leads to malnutrition. WRA are particularly at risk for nutritional deficiencies because of the physiological demands of pregnancy and lactation (Kandel et al., 2024). In the tribal population, several factors contribute to the appallingly low nutritional intake. Traditional gender norms can increase women's susceptibility to malnutrition by limiting their access to food, education, and financial resources. Despite food availability, women may eat less or last than other family members due to cultural norms and intra-household food allocation procedures. The consequences of these vulnerabilities are severe (Ariyo et al., 2025). Consuming a varied diet is the greatest way to achieve dietary sufficiency because rich sources of several macro- and micronutrients can be found in different food groups. Indigenous women and children have poor nutritional status, despite considerable agrobiodiversity. Indigenous women achieved an average dietary diversity score of 4.22, which indicates poor intake. Among the women, only roughly one-third (37.3%) achieved a minimum dietary diversity of five or more food groups consumed in a day (Nongrum et al., 2022; Chakona & Shackleton, 2017).

METHODOLOGY

A large proportion of the total population comprises tribal people in Chhattisgarh (30.60%) and Jharkhand (26.20%), which are part of the Chhota Nagpur Plateau; therefore, these states were selected purposively. Additionally, these states have a high concentration of the Oraon tribal population, with 7,48,789 in Chhattisgarh and 17,16,618 in Jharkhand (Census, 2011). For district selection, five Oraon-dominant districts were identified in each state based on 2011 Census data. From these, two districts were randomly selected from each state for the study, namely Jashpur and Surguja in Chhattisgarh, and Ranchi and Gumla in Jharkhand. Two blocks were randomly selected from each of the four districts. Specifically, two blocks were selected from Ranchi district (out of 18 total blocks) and two from Gumla district (out of 12 total blocks) in Jharkhand state; similarly, two blocks were selected from Jashpur district (out of 8 total blocks) and two from Surguja district (out of 7 total blocks) in Chhattisgarh state, totalling eight blocks. Two villages from each block, totalling 16 villages, were selected randomly. From each village, 25 WRA were selected randomly to enhance sample representativeness, thus comprising 400 respondents. The MDD-W, a guideline given by FAO (2021), was used to measure the dietary diversity of women, using the 24-hour dietary recall method. It contains 10 defined food groups, which are 1. Grains, white roots and tubers, and plantains, 2. Pulses (beans, peas, and lentils), 3. Nuts and seeds, 4. Milk and milk products, 5. Meat, poultry, and fish, 6. Eggs, 7. Dark green leafy vegetables, 8. Other vitamin A-rich fruits and vegetables, 9. Other vegetables, 10. Other fruits. This was incorporated into a structured interview schedule to collect data from women on the foods and beverages they consumed the previous day. 'Yes' or 'No' answers were recorded when women from the specified food categories were asked to recollect every food item they had eaten a day earlier. A 'yes' response received a '1' score, while a 'no' response received a '0'. The dietary diversity score was calculated by summing these scores for each Oraon woman, then categorized as either adequate or inadequate dietary diversity. Women with a diversity score of fewer than 5 were considered to have inadequate dietary diversity. In contrast, those with scores from 5 to 10 were considered to have acceptable dietary diversity, following the FAO (2021) guideline.

The following formula was used to determine the proportion of WRA who consumed food or beverages from five or more food groups on the preceding day:

$$\text{Percentage of WRA meet MDD} = \frac{\text{Foods and beverages consumed by WRA from} \geq \text{five food groups during the previous day}}{\text{Total number of WRA surveyed}} \times 100$$

Nutritional status was measured using the most significant and reliable proxy indicators, namely Body Mass Index (BMI), Mid-Upper Arm Circumference (MUAC). The anthropometric measurement tools, including a measuring tape and a weighing scale, were used. BMI, an indicator of body fat based on height and weight, was computed by dividing each woman's weight (kg) by the square of her height (m). The classification of respondents based on BMI followed the criteria given by WHO (2000) for the Asian population. MUAC is a well-established measure of nutritional status. It is a sign of protein-energy deficiency and a reliable and simple tool for assessing nutritional status. MUAC was measured at the midpoint between the acromion of the scapula and the olecranon of the ulna. The respondents were categorized based on the criteria given by Tonder et al. (2019). A Welch's ANOVA test (unequal variance) was employed to analyse the differences in dietary diversity and nutritional status across the selected districts using the statistical software Jamovi (version 2.2.5). To check the association between BMI and MUAC, Pearson correlation analysis was employed using statistical software SPSS (version 26).

RESULTS

Distribution of *Oraon* tribal women based on MDD-W

The prevalence of MDD-W shows that less than half (22%) of WRA who achieved a minimum of five foods from the 10 defined groups indicated higher micronutrient adequacy. The majority (78%) of the respondents consumed fewer than five food groups, indicating poor dietary diversity and a reliance on monotonous diets with limited nutrient variety. This implies that only 22 per cent of women had higher micronutrient intake levels, whereas 78 per cent had insufficient consumption, which indicates micronutrient deficiency. About 19.75 per cent of the respondents reported consuming five to six food groups, reflecting a moderate level of dietary diversity and suggesting some improvement towards balanced food intake. 24-hour dietary recall indicated that the women's diets were dominated by staple foods such as rice, along with pulses including pigeon pea and black gram. Consumption of dark green leafy vegetables was common but limited due to their particular seasonal availability, with most varieties being locally available indigenous species. The diet also included indigenous aquatic foods, particularly snails and fish. Red-fleshed mammal's meat and poultry were occasionally consumed. Fruits consumed during the recall period were largely obtained from forest sources and formed part of the non-timber forest products (NTFPs) traditionally gathered by the community. In contrast, foods such as nuts and seeds, milk and milk products, eggs, processed meat, organ meats, and vitamin A–rich food items were consumed rarely and almost non-existent. Overall, the results highlight that the dietary diversity among the respondents was generally low, indicating micronutrient inadequacy, with a large proportion of the respondents being nutritionally vulnerable and micronutrient-deficient due to limited access to or consumption of diverse food items. Figure 1 illustrates the number of WRA who met the MDD-W across four districts. Ranchi had the largest number of women with MDD-W (31), followed by Jashpur (27). Gumla reported a moderate level (18), while Surguja had the fewest number of women with MDD-W (12).

Welch ANOVA result in Table 1 & Figure 2 indicated variations in both the average score and the distribution of scores across the districts. The study found a significant difference at the 1% level of significance in mean MDD-W scores across districts F_{welch} (3, 218.7) = 4.50, p = 4.36 × 10⁻³), indicating that dietary diversity among women varies notably across the study locations. The effect size (η^2 = 0.06) suggests a small-to-moderate practical significance. Ranchi exhibited the highest mean MDD-W score (4.02), suggesting the best average dietary diversity, while Gumla recorded the lowest mean score (3.65). The violin shapes indicate that scores range widely, from approximately 2 to 7, suggesting significant individual variability in dietary diversity within every district.

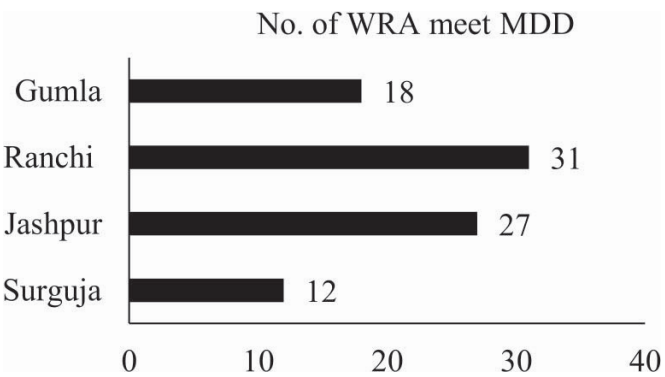

Figure 1. Bar graph representation of MDD-W among the respondents across the districts

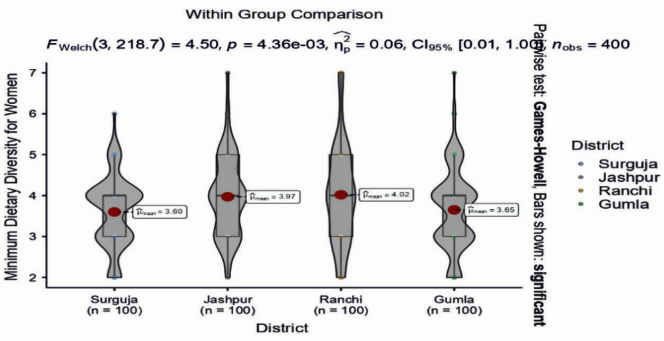

Figure 2. Violin plot depiction of MDD-W among women across selected districts

Table 1. Test Summary of MDD-W comparison across the selected districts

Component	Details of the test
Test Name	Welch's ANOVA
Test Statistics	F (3, 218.7) = 4.50
p-value	4.36×10^{-3} =0.00436 (significant at 1% level of significance)
Effect Size	Partial eta squared (η^2_p) = 0.06

Categorization and distribution of *Oraon* tribal women based on BMI & MUAC

The nutritional status results in Table 2 revealed that nearly half of the respondents (48.75%) were classified as underweight (BMI <18.5), indicating a high prevalence of chronic energy deficiency. Only 37.75 per cent of the women fell within the normal BMI range (18.5–22.9). In contrast, the proportion of women who were overweight or obese was relatively low. Only 8.25 per cent of the respondents were categorized as overweight (BMI 23.0–24.9), while 4.50 per cent were found to be in Obesity Class I (BMI 25.0–29.9). A very small proportion (0.75%) fell under Obesity Class II (BMI ≥30). The findings indicate that undernutrition remains a significant concern among Oraon tribal women, with half suffering from chronic energy deficiency (CED). The predominance of underweight women aligns with broader nutritional patterns observed among tribal communities in India, where socio-economic constraints, limited dietary diversity, and inadequate access to health and nutrition services contribute to persistent undernutrition. The statistical analysis, a Welch's ANOVA, revealed that the overall difference in mean BMI across the districts was not statistically significant (Figure 3).

The Oraon women's nutritional status based on MUAC, as shown in Table 3, revealed a highly skewed distribution toward undernutrition. The majority of respondents, comprising 73.50 per

Table 2. Categorization and Distribution of Respondents Based on the Nutritional Status Indicator Body Mass Index

Category	Asian BMI Classification	Percentage
Underweight	< 18.5	48.75
Normal weight	18.5 – 22.9	37.75
Overweight	23.0 – 24.9	8.25
Obesity class I	25.0 – 29.9	4.50
Obesity class II	≥30.0	0.75
Total		100

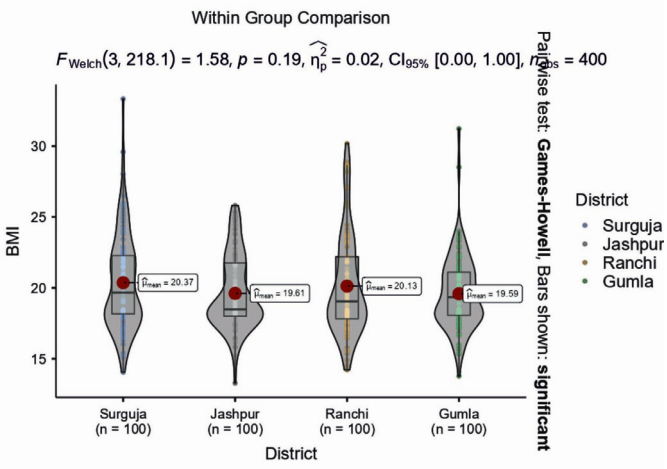

Figure 3. Violin plot depiction of BMI among the women across selected districts

Table 3. Categorization and Distribution of Respondents Based on Mid-Upper Arm Circumference

MUAC cut off* (cm)	MUAC Tertiles Categories	Percentage
Below (<) 22.8	Undernutrition	73.50
22.8-25.4	Normal	21.00
Above (>) 25.5	Obese	5.50
Total		100

cent, were in the undernutrition category, defined by an MUAC below 22.8 cm. In contrast, only 21.00 per cent are classified as normal with an MUAC between 22.8–25.4 cm. Only 5.50 per cent of the respondents were categorized as obese, defined as having an MUAC above 25.5 cm, indicating a transition from traditional diets to processed and calorie-dense foods, contributing to weight gain. It indicates a serious public health concern of widespread undernutrition in this tribe. From Figure 4, it is evident that MUAC values did not show any statistically significant differences across the four selected districts.

Association between BMI and MUAC

Pearson correlation analysis between BMI and MUAC in Oraon tribal women indicated a strong, positive, and statistically significant association (Table 4). This high correlation indicates that MUAC can serve as a reliable proxy for assessing women's nutritional status, although the cut-off values differ. The measure is particularly useful in field conditions where obtaining accurate height and weight data for BMI may not be feasible.

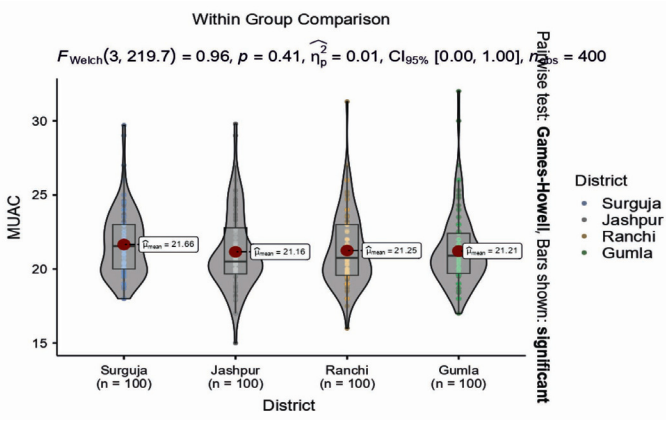

Figure 4. Violin plot depiction of MUAC among the women across selected districts

Table 4. Relationship between BMI and MUAC among Oraon women

Variables		BMI	MUAC
BMI	Pearson Correlation	1	.766**
	Sig. (2-tailed)		0.000
	N	400	400
MUAC	Pearson Correlation	.766**	1
	Sig. (2-tailed)	0.000	
	N	400	400

**Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

The prevalence of specific MDD-W food group consumption was evaluated in the study, and found that only 22 per cent of WRA were meeting nutritional adequacy, indicating that most WRA were unable to maintain diverse food intake. Dietary diversity significantly influences nutritional status, and failing to achieve minimum diversity can lead to malnutrition issues. This finding supports the findings of Ghosh-Jerath et al. (2018) that Oraon tribal women have a significant rate of undernutrition despite having extensive knowledge of the nutrient-dense native foods, and consumption of these foods was low. There was notable variation in dietary diversity among the selected districts. The Oraon tribe's diet was inadequate in all recommended food groups. Cereal consumption was the least deficient, whereas milk and fruit consumption were almost non-existent. The intake of green leafy vegetables was notably inadequate and was largely limited to a few lesser-known, locally available varieties. Among these, *dheki saag,* a type of edible fern cultivated alongside roots and tubers in household kitchen gardens, was commonly consumed. Substantial gaps were observed in the consumption of milk, a diverse range of vegetables (particularly green leafy varieties), and fruits (Mittal & Srivastava, 2006). Khadatkar et al. (2024) also indicated that poor micronutrient intake in relation to work activity leads to poor health. To tackle this issue, Kumbhare et al. (2023) suggested that healthy habits of nutritious food consumption should be promoted to achieve food security and improve nutritional security at the household level by promoting nutri-gardens and nutri-sensitive agricultural practices.

A significant proportion of Oraon tribal women are undernourished, indicating inadequate dietary diversity and a lack of nutritional awareness. This finding also reflects gendered nutritional inequality caused by factors such as intrahousehold food disparity, resource utilization gaps, and lack of agency, which lead to an intergenerational cycle of malnutrition. The findings support those of Ghosh-Jerath et al. (2018), who reported that women face various degrees of CED and underweight, indicating a high prevalence of CED. It has been noted that the Oraon tribe suffers high rates of CED and malnutrition. Monika et al. (2018) also highlighted that tribal women are more vulnerable to malnutrition, and they are a weaker part of society that has struggled in all aspects. Their BMI and nutritional intake are significantly lower than those of the reference women. More work must be done at the local level to uplift the tribal women's condition, whether it is awareness about nutrition, health, education, or male dominance in society. Majumder (2022) also pointed out that the primary reason for undernourishment among tribal women is household food insecurity and low caloric intake. Furthermore, he recommended addressing malnutrition with a lifecycle approach, ongoing behavior change communication, and effective enactment programs to increase food security and purchasing power. Kapoor et al. (2022) found that the prevalence of CED was significantly higher among tribal women than among rural women. Undernutrition was evident as a high proportion of Oraon tribal women with low MUAC 73.50 per cent, was observed in the study area. This supports Bhattacharya et al. (2019), who found a 64.90 per cent prevalence of undernutrition based on MUAC among Oraon tribal women. Women's nutritional status is crucial for identifying deficiencies and deploying effective nutritional interventions. To address the alarming rates of undernutrition, chronic energy malnutrition, and micronutrient deficiency among women, programs must be implemented with greater emphasis and commitment. Targeted interventions should focus on improving awareness of food choices and encouraging the cultivation of nutrient-dense crops, including leafy vegetables and pulses. Furthermore, the consumption of millets alongside staple cereals, as well as indigenous foods, should be encouraged among the tribal community, especially among women. Policies and nutrition programs to overcome the nutritional gap in tribal women by enhancing dietary diversity, orienting extension services toward women, are also essential (Priyanka et al., 2024; Mishra et al., 2025; Sekhri et al., 2025; Khadatkar et al., 2024).

It was found that BMI and MUAC had a strong, positive, and significant relationship. This finding is aligned with Rohini et al. (2025), who found a strong positive correlation between MUAC and BMI in both men and women across the three survey periods using NFHS data. Also, they highlighted that MUAC is commonly employed in nutritional surveillance, particularly in low-resource settings, but BMI remains the standard measure for measuring adult nutritional status. The MUAC is a reliable instrument for identifying malnutrition. Since MUAC and BMI are well correlated, MUAC can be used as a complement or substitute for the same in certain situations. MUAC has various benefits, such as measurement convenience, minimal logistical support, and accuracy. It may also test nutritional status in geographically isolated places (Benítez Brito et al., 2016; Negi et al., 2024; Das et al., 2020; Salih et al., 2023).

CONCLUSION

The study reveals chronic energy malnutrition, micronutrient deficiency, and the emerging trend of obesity among Oraon women. This implies that, due to being socio-economically disadvantaged and facing gendered nutritional inequality, women continue to suffer from an intergenerational cycle of malnutrition. The majority of women consuming less than 5 food groups indicate inadequate dietary diversity. Despite living in a region rich in agrobiodiversity, social norms and heavy workloads prevent these women from accessing and consuming local nutritious foods. The significant relationship between BMI and MUAC supports MUAC as a reliable substitute for measuring nutritional status in adults. Oraon tribal women's nutritional outcome can be considerably improved by enhancing their access to diverse foods through kitchen gardening, nutrition-sensitive agriculture, and effective implementation of government nutrition programs. Integrated interventions to address malnutrition, nutrition education, and empowerment programs should be prioritised to raise awareness and improve dietary practices.

DECLARATION

Ethics approval and informed consent: The respondents were made aware of the purpose, scope, and methodology of the research before the survey was conducted. Verbal informed consent was obtained from the respondents individually.

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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 author declares that during the preparation of this article, the author utilised Grammarly to enhance grammar and improve the text's readability. After using this tool, the authors carefully reviewed, revised, and edited the content as necessary. The authors take full responsibility for the final content of this publication.

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Factors Associated with Perception and Knowledge of Punjab's Farm Youth about Stubble Management

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HIGHLIGHTS

- A statistically significant association between caste and land holding were associated with perception of farm youth towards stubble management.
- Families owning medium and particularly large tracts of land displayed substantially higher involvement in burning, likely due to greater residue volume requiring quick clearance.
- Findings highlight need for targeted awareness and knowledge enhancement programme

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ABSTRACT

The study, conducted in 2025, examined how socio-personal variables were associated with the perception and knowledge of farm youth toward stubble management, and how family and farming-related characteristics were associated with families' involvement in stubble burning. A structured questionnaire was administered to 720 respondents selected through multistage purposive and random sampling from five agro-climatic zones of Punjab. Data were analysed using chi-square and Fisher's exact tests to determine associations between variables. Gender and caste showed significant associations with both perception and knowledge. School type and medium of education showed no significant association with either variable. Family type was significantly associated with knowledge but not with perception. Among family and farming variables, caste and landholding size were significantly associated with the family's involvement in stubble burning, while family size, family educational status, and number of earning members showed no significant relationship. Overall, the results indicated that a combination of socio-personal characteristics and structural agricultural factors shaped stubble management behaviour. The study concluded that enhancing perception and knowledge among rural youth, particularly youth enrolled in Punjabi-medium and government schools, and those belonging to the general caste and large landholding families are essential for fostering long-term behavioural change.

INTRODUCTION

The Indo-Gangetic Plain remains one of the most productive agricultural regions of the world, where the Green Revolution through improved crop varieties and synthesized fertilizers continues to support national food security (Pingali, 2012). India is currently the leading global producer of rice, with an average annual output of 151 million metric tonnes (Anonymous, 2025). Such high levels of production naturally generate vast quantities of crop residue, and the widespread practice of burning this residue

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in open fields has emerged as a major environmental and agricultural challenge (Choudhary et al., 2021). Stubble burning adversely affects air quality, soil health, and human well-being, contributing to the severe smog episodes that disrupt the social, economic, and cultural fabric of northern India each October–November (Chawla & Sandhu, 2020). Although long-term environmental improvement requires community participation and personal responsibility (Mukherjee, 2017), political misalignment across central, state, and local governments often limits effective coordination and enforcement (Khundrakpam & Sarmah, 2023; Kumar et al., 2015).

The present study is theoretically anchored in the framework of Social and Behavior Change (SBC), which recognizes that behavior related to environmental practices are shaped by an interaction of cognitive, emotional, and contextual factors rather than information alone (Lee & Davis, 2019). At the core is formative research: understanding the target audience's beliefs, practices, social norms, barriers, facilitators, and context, so that the interventions are tailored, relevant, and culturally appropriate. Monitoring, feedback, and participatory involvement are essential to ensure that changes are adopted and sustained over time. SBC also functions at multiple levels: individual (knowledge, attitude and skill), interpersonal (family and peers), community (norms, social networks and cultural practices), and structural/institutional (policies, facilities and system). The scale of change is often greater when interventions address not only individuals but also the social and environmental context in which people live. Since stubble burning is not merely an agricultural practice but a socially embedded behavior, the perception and knowledge of the younger generation particularly school students from farming families are critical to understand future behavioral trends in residue management.

In this context, the role of rural youth becomes increasingly critical. With growing technological aptitude and entrepreneurial potential, youth are key agents in shaping future sustainability efforts. Sensitizing them early to issues of climate change and sustainable agriculture is therefore essential. Current national initiatives, including those under the *Rashtriya Krishi Vikas Yojana* (RKVY), actively involve schools, colleges, *Krishi Vigyan Kendras* (KVKs), social organizations, and NGOs in awareness campaigns on stubble management. These efforts engage students through essay writing, debates, painting competitions, technical lectures, and other activities approved by the State Level Executive Committee (SLEC) and ICAR (Department of Agriculture & Farmers Welfare, 2023).

Given this backdrop, examining how socio-personal, family, and farming variables shape youth perception and knowledge related to stubble management and how these factors relate to families' stubble-burning behaviour becomes essential for designing more targeted and effective interventions.

METHODOLOGY

The area for present investigation was conducted in five agro-climatic zones of Punjab state of India. Following the probability proportional to size sampling, eight districts out of twenty three districts spread over five agro-climatic zones (ACZ) were selected. Care was taken not to select adjoining districts of the same agro-climatic zones. From ACZ-I, ACZ-II and ACZ-IV Gurdaspur, Rupnagar and Fazilka districts were selected respectively. From ACZ III, being the largest zone three districts were selected, i.e. Sangrur, Jalandhar and Amritsar. From ACZ V, total two districts were selected i.e. Moga and Sri Muktsar Sahib. Three rural blocks from each selected districts were randomly selected. Thus, a total of 24 blocks were selected. From each block, two senior secondary co-educational schools were randomly selected thus making total of 48 schools. Five students belonging to farming families from each class i.e. class 10^{th}, 11^{th} and 12^{th} were selected from each senior secondary, co-educational school. Total number of 720 students was taken as the sample from selected schools. The study was conducted in the year 2025 and data was collected by using a self-made questionnaire. The questionnaire was pre-tested on 60 non-sampled students from farming families of two senior secondary schools of Sidhwan bet block of Ludhiana district to ascertain the clarity and nature of responses among the respondents before proceeding with the research. The knowledge test and the perception scale yielded a Cronbach's alpha of 0.90 and 0.72, indicating acceptable reliability of the research instrument (Ray et al., 2021). The objectives of study were explicitly explained to respondents in their vernacular language, ensuring that they perceived the questions correctly. Perception was operationalized as the belief or opinion of student regarding stubble burning and its effects for the present study. The responses of students for twenty seven statements were sought on 5-point Likert scale. The knowledge was operationalized as the understanding of effects of stubble burning on health and environment as well as knowledge about stubble management technologies/practices to stop stubble burning. Score 1 was given to each correct answer and 0 for incorrect answer. Accordingly, knowledge score for each respondent was calculated and further categorized as low, medium and high knowledge level. In order to assess the association between the selected dependent and the independent variables, the data was subjected to chi square test and Fisher's exact test. Fisher's exact test was used when the cell had expected frequency less than five. A p-value less than 0.05 were considered statistically significant.

RESULTS

The data presented in Table 1 reveals the association between socio-personal variables and the perception of respondents regarding stubble management. Among male respondents 1.50 per cent had a negative perception, 62.70 per cent had neutral, and 35.80 per cent had a positive perception about stubble management. In contrast, among females no respondents reported negative perception, 46.90 per cent had neutral perception. A little more than half of the female respondents (53.10%) reported positive perception. This shows a clear divergence, with females demonstrating stronger positive perception compared to males. Further, Fisher's exact test (24.393; $p = 0.000$) confirmed that there was statistically significant association between gender and perception of respondents at 5 per cent level of significance.

Among private school respondents 2.60 per cent had negative, 64.10 per cent neutral, and 33.30 per cent had positive perception towards stubble management. In government schools, 0.2 per cent respondents showed negative, 53.00 per cent neutral, and 46.90 per cent positive perception towards stubble management. A

Table 1. Association of socio-personal variables and perception of respondents regarding stubble management

Variables		Perception			Total	Fisher's exact test	p-value
		Negative	Neutral	Positive			
Gender	Male	6	259	148	413	24.393*	.000
	Female	0	144	163	307		
Total		6	403	311	720		
Type of school	Private	5	125	65	195	17.434*	.000
	Government	1	278	246	525		
Total		6	403	311	720		
Medium of education	English	5	158	92	255	12.720*	.001
	Punjabi	1	245	219	465		
Total		6	403	311	720		
School affiliation	PSEB	6	384	296	686	.093^{NS}	1.00
	CBSE	0	19	15	34		
Total		6	403	311	720		
Type of family	Nuclear	4	196	161	361	1.342 ^{NS}	.499
	Joint	2	207	150	359		
Total		6	403	311	720		
Caste	General	6	218	126	350	21.493*	.000
	Backward caste	0	88	70	158		
	Scheduled Caste	0	97	115	212		
Total		6	403	311	720		

*($p < 0.05$), NS (non- significant)

noticeable trend emerged in which government school respondents expressed more positive perception toward stubble management as compared to private school respondents. Fisher's exact test (17.434; p = 0.000) indicated that the association between type of school and respondents perception was statistically significant at 5 per cent level of significance.

Among the respondents studying in English-medium schools, 2.00 per cent respondents had negative, 62.00 per cent of respondents had neutral, and 36.10 per cent respondents had positive perception. Whereas data from respondents studying in Punjabi-medium school revealed that 0.20 per cent respondents had negative, 52.70 per cent of respondents had neutral, and 47.10 per cent respondents had positive perception. Thus, respondents from Punjabi-medium school demonstrated a higher overall positive perception. The association between medium of education and perception of respondents was statistically significant (Fisher's exact test = 12.720; p = 0.001) at 5 per cent level of significance.

Among respondents studying in schools affiliated with PSEB, 0.90 per cent respondents had negative, 56.00 per cent respondents had neutral perception, and 43.10 per cent respondents had positive perception. Almost similar distribution of respondents was noted in CBSE affiliated schools, where zero respondents reported negative, 55.90 per cent respondents had neutral, and 44.10 per cent respondents had positive perception. Fisher's exact test (0.093; p = 1.00) confirmed that there was no significant association between school affiliation and perception towards stubble management.

Data in Table 1 also shows that 1.1 per cent respondents from nuclear families reported negative, 54.30 per cent respondents had neutral, and 44.60 per cent respondents had positive perception. In joint families, 0.60 per cent respondents had negative, 57.70 per cent respondents had neutral perception, and 41.80 per cent respondents had positive perception. The percentage differences were minimal, supported by a non-significant Fisher's exact value (1.342; p = 0.499) suggesting no significant association between family type and perception of respondents.

When looking at the social stratification distribution from the lens of caste the data reveals that 62.30 per cent respondents from General category had neutral perception, 36.0 per cent respondents had positive, and 1.70 per cent respondents had negative perception. Among Backward Caste, 55.70 per cent respondents had neutral, and 44.30 per cent respondents had positive perception. Less than half of the respondents (45.80%) from Scheduled Caste had neutral, and 54.20 per cent had positive perception towards stubble management. No respondents from Backward caste and scheduled caste reported negative perception. Positive perception increased progressively from General to Backward Caste to Scheduled Caste respondents. Fisher's exact test (21.493; p = 0.000) confirmed a statistically significant association between caste and perception of farm youth towards stubble management at 5 per cent level of significance.

Association of socio-personal variables and knowledge of respondents regarding effects of stubble burning and management of stubble

Data in Table 2 presents the association between socio-personal variables and the knowledge levels of respondents regarding the effects of stubble burning and the management of stubble. Among male respondents almost equal half of the respondents had low and medium level of knowledge i.e. 49.40 per cent and 49.90 per cent respectively. A very small fraction of respondents i.e. 0.70 per cent had high knowledge level. In contrast, majority (68.1%) female respondents reported low knowledge level, 31.90 per cent medium

Table 2. Association of socio-personal variables and knowledge of respondents regarding effects of stubble burning and management of stubble

Variables		Knowledge			Total	Fisher's exact test	p-value
		Low	Medium	High			
Gender	Male	204	206	3	413	26.159*	.000
	Female	209	98	0	307		
Total		413	304	3	720		
Type of school	Private	100	93	2	195	5.958^{NS}	.045
	Government	313	211	1	525		
Total		413	304	3	720		
Medium of education	English	149	103	3	255	5.150^{NS}	.062
	Punjabi	264	201	0	465		
Total		413	304	3	720		
School affiliation	PSEB	392	291	3	686	0.703^{NS}	.761
	CBSE	21	13	0	34		
Total		413	304	3	720		
Type of family	Nuclear	231	129	1	361	13.185*	.001
	Joint	182	175	2	359		
Total		413	304	3	720		
Caste	General	181	166	3	350	11.684*	.009
	Backward caste	105	53	0	158		
	Scheduled Caste	127	85	0	212		
Total		413	304	3	720		

*($p < 0.05$), NS (non- significant)

knowledge level, and no respondent had high knowledge level. This clearly shows that low knowledge level was more concentrated among females, whereas males had a relatively balanced distribution across low and medium knowledge levels. The Fisher's exact test value (26.159; $p = 0.000$) confirmed a statistically significant association between gender and knowledge level.

Slightly more than half of the respondents (51.30%) from Private school reported low level of knowledge followed by 47.70 per cent respondents with medium level of knowledge, and only 1.0 per cent respondents had high level of knowledge. Among government school respondents, 59.60 per cent respondents had low level of knowledge, 40.20 per cent respondents had medium, and 0.20 per cent had high knowledge level. Although both groups had a majority in the low-knowledge category, private school respondents demonstrated a slightly higher proportion of medium and high knowledge levels. Fisher's exact test (5.958; $p = 0.045$) indicated that the association between school type and knowledge was statistically significant.

Knowledge levels among respondents varied slightly by medium of education. Majority of respondents (58.40%) from English-medium school showed low knowledge level followed by 40.40 per cent respondents with medium knowledge level and merely 1.20 per cent respondents had high knowledge level. Whereas from Punjabi-medium schools 56.80 per cent respondents had low level of knowledge, 43.20 per cent medium, and no respondents had high knowledge level. While English-medium students showed a marginally higher proportion in the high-knowledge category, the overall distribution was very similar. This was confirmed by a non-significant Fisher's exact test value (5.150; $p = 0.062$), indicating no meaningful relationship between medium of education and knowledge levels.

Among respondents from schools affiliated with PSEB, 57.1 per cent respondents had low knowledge level followed by 42.40 per cent respondents having medium knowledge level and 0.40 per cent at high knowledge level. The majority (61.80%) of CBSE respondents reported low knowledge level followed by 38.20 per cent respondents who had medium knowledge level and there was no respondent in the high knowledge level category. No association was found out between school affiliation and respondents' knowledge level as statistically validated by a non-significant Fisher's exact test result (0.703; $p = 0.761$).

The majority (64.00%) respondents from nuclear families showed low knowledge level followed by 35.70 per cent respondents with medium knowledge level and just 0.30 per cent respondents having high knowledge level. Half of the respondents (50.70%) from joint families had low knowledge level followed by 48.70 per cent respondents having medium knowledge level and only 0.60 per cent respondents at high knowledge level. Joint family respondents demonstrated a visibly higher proportion of medium knowledge level when compared to nuclear families. The Fisher's exact test value (13.185; $p = 0.001$) confirmed a statistically significant association between family type and knowledge level.

In terms of caste, 51.70 per cent respondents from general category had low knowledge level and a little less than half (47.40%) respondents had medium knowledge level and merely 0.90 per cent respondents had high knowledge level. The distribution of Backward Caste shows that 66.50 per cent respondents showed low knowledge level and 33.50 per cent medium knowledge level. In Scheduled Caste 59.90 per cent respondents reported low knowledge level and 40.10 per cent respondents had medium knowledge level. No respondent in backward and schedule caste had high knowledge level. Although high knowledge was reported

Table 3. Association of family variables and stubble burning

Variables		Family burns stubble		Total	χ^2	p-value
		No	Yes			
Caste	General	218	132	350	7.743*	0.021
	Backward caste	118	40	158		
	Scheduled Caste	144	68	212		
Total		480	240	720		
The minimum expected count is 52.67.						
Family size	Small	165	69	234	2.571^{NS}	0.276
	Medium	277	153	430		
	Big	38	18	56		
Total		480	240	720		
The minimum expected count is 18.67.						
Family Educational status	Low	114	63	177	0.997^{NS}	0.607
	Medium	349	171	520		
	High	17	6	23		
Total		480	240	720		
The minimum expected count is 7.67						
Number of earning members	One	354	165	519	2.112^{NS}	0.348
	Two-three	116	68	184		
	Four and above	10	7	17		
Total		480	240	720		
The minimum expected count is 5.67						

*($p < 0.05$), NS (non- significant)

only within the General category, the broader pattern shows differing proportions of low and medium knowledge across caste groups. Fisher's exact test (11.684; p = 0.009) indicated a statistically significant association between caste and knowledge level.

Association of family variables and families' involvement in stubble burning

The perusal of Table 3 reveals the association between family variables and families' involvement in stubble burning. The respondents were asked whether their family was involved in stubble burning or not. Score 1 was given to respondents whose families engaged in stubble burning and score 2 was given to respondents whose families did not engage in stubble burning. The data shows a statistically significant association between caste and the practice of stubble burning among respondents' families (χ^2 = 7.743; p = 0.021). Among respondents belonging to the General category 37.70 per cent of the respondents reported that their family burns stubble, whereas 62.30 per cent respondent reported that their family did not burn stubble. In the Backward Caste category 25.3 per cent respondents revealed that their family burned stubble, while 74.70 per cent respondents reported their family refrained from it. Among Scheduled Caste respondents 32.10 per cent respondents reported that their family blaze stubble and 67.90 per cent respondents' families did not burn stubble. A comparison of proportions indicates that the incidence of stubble burning was highest among General category respondents, followed by Scheduled Caste respondents, and lowest among those in the Backward Caste category. The statistically significant chi-square value supports that caste background had a meaningful influence on the likelihood of stubble burning.

Family size did not show a statistically significant association with stubble burning (χ^2 = 2.571; p = 0.276). Among respondents belonging to small families 70.5 per cent respondents reported no participation in stubble burning whereas, 29.5 per cent respondents reported family participation in practiced stubble burning. The majority (64.4%) of respondents from medium-sized families reported that their family did not burn stubble while 35.6 per cent respondents revealed their family involvement in stubble burning. Similarly, 67.9 per cent respondents from big families said their family refrained from the practice followed by 2.1 per cent respondents whose family burned stubble. Although medium-sized families showed a slightly higher proportion of stubble-burning households, the overall distribution across all three categories remained similar. The non-significant chi-square test indicates that family size did not meaningfully influence stubble burning behaviour.

Family educational status also did not exhibit any significant association with stubble burning (χ^2 = 0.997; p = 0.607). Among families with low educational status 64.4% families did not burned stubble while35.6 per cent respondents said their family burned stubble. In a similar fashion the 67.1% respondents with medium family educational status reported their families did not engage in stubble burning and 32.9 per cent families engaged in stubble burning. For families with high educational status majority (73.9%) of respondents said their family did not set their fields on fire compared to 26.1 per cent respondents who said their families burned stubble. The percentages across the three family educational status categories remained largely comparable. The non-significant chi-square value suggests that the educational status of the family did not substantially affect their stubble-burning practices.

The number of earning members in the family also showed no statistically significant association with stubble burning (χ^2 = 2.112;

Table 4. Association of land ownership and stubble burning

Variables		Family burns stubble		Total	Fisher's exact test	p-value
		No	Yes			
Land owned	Marginal	140	47	187	13.110*	0.010
	Small	137	70	207		
	Semi-medium	125	70	195		
	Medium	75	46	121		
	Large	3	7	10		
Total		480	240	720		

*($p < 0.05$)

p = 0.348). Among families with a single earning member, 68.2 per cent respondents said their families did not practiced stubble burning whereas 31.8 per cent respondents said their families practiced stubble burning. Families with two to three earning members reported that 63.0 per cent families did not burned stubble and 37.0 per cent families who did burn stubble. In households with four or more earning members, 58.8 per cent respondents said their families did not burn stubble, while 41.2% respondents said their families burned stubble. Although an increasing trend is visible with more earning members, the chi-square test revealed no significant relationship. This indicates that the number of earning members does not meaningfully influence whether a family engages in stubble burning.

Association of land ownership and stubble burning

Table 4 examines the relationship between landholding size and the practice of stubble burning among respondents' families. A clear gradient was observed when proportions were compared across land ownership categories. Among marginal landholdings, 74.9 per cent respondents said their families did not burn stubble, while 25.1 per cent respondents reported that their families burned stubble. In the case of small landholder families, 66.2 per cent respondents reported their families did not burn stubble compared to 33.8 per cent respondents whose families burned stubble. Similarly, among semi-medium landowners, 64.1 per cent abstained and 35.9 per cent practiced stubble burning. For medium landowners, 62.0 per cent respondents said their families did not engaged in stubble burning, while nearly 38.0 per cent respondents reported their families engaged in stubble burning. The highest proportion was observed among large landowners, where 70.0 per cent respondents reported families burning stubble, compared to 30.0 per cent respondents who did not.

The percentage pattern indicates that the likelihood of stubble burning increased progressively with landholding size. Families owning medium and particularly large tracts of land displayed substantially higher involvement in burning, likely due to greater residue volume requiring quick clearance. The Fisher's exact test value (13.110; p = 0.010) confirmed that land ownership and stubble burning were significantly associated. Therefore, the results demonstrate that larger landowners were considerably more likely to engage in stubble burning, and this association was not due to random variation.

DISCUSSION

The association of gender with both perception and knowledge reflects a meaningful divide in stubble management, suggesting that males, particularly in agrarian states, tend to have greater exposure to farm operations, crop residue handling, and informal agricultural learning. Huria et al. (2021), in a study conducted in the Malwa region of Punjab, reported that most agricultural activities are carried out by men, while women are primarily engaged in household and other non-farm activities. Female respondents, although equally affected by the consequences of stubble burning, may have limited interaction with farm-level decision-making, which could restrict knowledge acquisition. Bora et al. (2023) also highlighted that women's participation in agricultural decision-making is constrained by limited knowledge of advanced farming techniques, mobility restrictions, and reduced exposure to the outside world. This gendered divergence emphasizes the need for school-based and community-level sensitization efforts that intentionally include girls in agricultural and environmental education.

The lack of significant association between school affiliation (PSEB/CBSE) and both perception and knowledge suggests that board-level curricular differences may not be as influential as school-level implementation and resource availability. Interestingly, family type did not significantly influence perception but was significantly associated with knowledge. Findings from a study conducted by Nain et al. (2019) and Bisht (2023) also highlighted the role of family size, media exposure, and participation in activities organized by schools in shaping perception.

The role of caste emerged strongly, being significantly associated with perception, knowledge, and family involvement in stubble burning. Khurana et al. (2024) reported that social factors such as gender (female), religion (non-Hindu), and caste (marginalized groups) inversely influence the likelihood of crop residue burning. Among the family variables, family size, families' educational status, and number of earning members showed no significant association with stubble burning behaviour, indicating that household socio-economic capacity may not directly determine residue management choices. Whereas, Jambagi et al. (2025) revealed that, the higher rural male literacy rate was associated with an increase in the area of burning. This indicated that as literacy rates increased, individuals sought to capitalize on the economic benefits of the paddy–wheat cropping system by reducing the turnaround time through stubble burning. In contrast, land size was significantly associated with family involvement in stubble burning, with larger landholding families more likely to burn stubble, Parthiban et al. (2019) and Khurana et al. (2024) reported that total landholding and the share of cultivated area show mixed effects on behaviour. According to Kumar et al. (2024), smaller farmers are often more inclined to diversify their cropping patterns possibly to enhance

soil health, implement crop rotation, or respond to market conditions behaviour that aligns with sustainable agricultural practices and long-term resilience.

CONCLUSION

Stubble management behaviour is influenced by a complex interplay of individual attributes, household factors, and broader structural constraints within the agricultural system. Enhancing perception and knowledge among rural youth particularly youth enrolled in Punjabi-medium and government schools, and those belonging to general caste and large land holdings are essential for fostering long-term behavioural change. Youth having larger landholdings should be encouraged to motivate their families to prioritize sustainable resource utilization by adopting practices that convert stubble into economic or on-farm assets, such as fodder, bedding, or soil amendments. At the same time, addressing systemic barriers, including limited access to machinery, the cost of alternative practices, and pressures from tight crop cycles, remains critical for reducing the prevalence of stubble burning. Taken together, the results underscore the need for targeted, inclusive, and context-sensitive interventions that account for both social inequities and the practical realities of Punjab's farming landscape.

DECLARATIONS

Ethics approval and informed consent: The study adhered to established ethical principles of social science research. Informed consent was sought from the respondents for the study.

Competing Interest: The Authors have no competing interests.

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

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

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Research Article

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Coverage of Agricultural Issues in Leading Indian Hindi Dailies: A Content Analysis

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HIGHLIGHTS

- India's highest circulated Hindi newspapers, *Dainik Bhaskar* and *Amar Ujala*, published a limited number of agricultural issues.
- The majority of the agricultural news items published in both dailies were situation based.
- National level agricultural issues received the highest priority in both newspapers.

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ABSTRACT

The majority of India's population is directly or indirectly engaged in the agricultural sector. Currently, Indian agriculture is facing various challenges, but timely information dissemination is one of them. The present study was conducted to examine the agricultural issues published in two leading Hindi newspapers, i.e. *Dainik Bhaskar* and *Amar Ujala*. Editorials, opinion columns, and feature articles published in the Panipat edition of Haryana State during January 2023 and December 2023 were selected for the study. The study concluded that India's highest-circulated Hindi newspapers, *Dainik Bhaskar* and *Amar Ujala*, published a limited number of agricultural issues. Both dailies have given the highest importance to national-level agricultural issues.

INTRODUCTION

Agriculture has played a crucial role in the development of human civilization. For many years, agriculture and allied sectors have been a significant source of employment and income in many developing countries, including India. India's rural economic life has revolved around agriculture. Agriculture is considered a way of life for farmers and peasants (Jodhka, 2018). According to the 2011 census, about 54.6 per cent of India's total workforce is still engaged in agriculture and allied sectors (Annual Report of Ministry of Agriculture and Farmers Welfare, 2022-23). Despite a declining share of agriculture in India's national income and employment, it remains an important sector of the Indian economy (Jodhka, 2023). The agriculture sector globally is facing several challenges (Rosegrant et al., 2021). In India, low productivity, lack of irrigation facilities, untimely dissemination of information, inadequate capital inflow, lack of farm laborers, scarcity of cold storage, less income, problem of land, lack of new technology, soil degradation, lack of subsidies, farmers' suicide, climate change and marketing problems are major agricultural issues (Nandkarni, 2018; Kumar, 2019; Patel & Nagaich, 2021 & Jodhka, 2023). According to a NITI Aayog report, the share of agriculture in India's gross domestic product (GDP) is declining due to the growth of the secondary and tertiary sectors of the economy. However, it still remains an important sector in India as this sector provides livelihood opportunities to millions of rural people (Patel et al., 2022). Despite their crucial economic contribution, Indian farmers, especially those in rural and remote areas, consistently face difficulty in obtaining timely and reliable agricultural information (Amar et al., 2025).

Previous studies indicated that issues related to agriculture have not received much importance in the Indian media (Mudgal, 2011; Venkatesha & Kamble, 2019). Agriculture only makes news when commercial interests are involved. Mass media have considerable power to shape public opinion on any issue. Among print media, newspapers occupy a significant position. Despite the rapid proliferation of digital media in India, newspapers remain a

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crucial source of information and knowledge for dissemination (Sharma et al., 2023). This medium considered an important part of the lives of millions of Indians as their day begins with newspapers. Different contents of newspapers viz. news stories, opinion columns, editorials, and feature articles serve different purposes. Newspaper can play an important role in raising awareness on agricultural issues among the masses and farmers. Agricultural development in India is a matter of concern, so it is the responsibility of journalists to provide adequate coverage on different aspects of agricultural issues. Content analysis being powerful tool to analyse various dimensions of coverage has been used by authors for different purposes (Nain, 2003; Sondarava et al., 2019; Nain et al., 2019; Kobba et al., 2019). The main objectives of this study were to categories various themes of agricultural issues and to make a comparative analysis of agricultural news content between selected newspapers. In addition, the aim of this study was to know the different approaches to agricultural news content published in the selected newspapers.

METHODOLOGY

To achieve the objectives of this study, the content analysis method was adopted. Content analysis is considered a very popular and appropriate method for the interpretation of media content. Social science scholars and media researchers consider content analysis as a flexible method for analyzing text data. Researchers also defined content analysis as a research technique for making replicable and valid inferences from data to their context (Krippendorff, 2004). In this study, an attempt was made to analyze the agricultural news content published in selected newspapers. Only those agricultural news items published on editorial pages were analyzed. Editorials, opinion columns, and feature articles concerning agricultural issues were analyzed in this study. Letters to the editor and advertorials were not part of the study.

The Hindi newspapers have seen exponential growth in India in the last few years. The largest number of dailies were published in Hindi language (4,424), followed by Urdu (1,107), Telugu (1,065) and English (825). Hindi newspapers had the highest circulation with a total of 10,34,83,185 copies per publishing day, followed by English dailies (2,09,14,036) and Urdu dailies (1,97,81,900) (RNI, 2021-22). According to the Audit Bureau of Circulations July-December (2022) report, three Hindi newspapers were among the top five highest circulated daily newspapers in the country. Among Hindi dailies, *Dainik Bhaskar* and *Amar Ujala* ranked first and second, respectively, in terms of circulation. *Dainik Bhaskar* newspaper circulates daily 3,229,365 copies, while *Amar Ujala* circulates daily 1,638,534 copies at the national level (2023).

The nature of farming varies with the seasons, and agricultural schemes are initiated accordingly. Therefore, keeping the situation in mind, researchers decided not to select samples of a particular period of the year, rather to include all the issues published in a year for the study. Hence, all the issues of both newspapers published from Haryana state from January 1st to December 31st, 2023 were selected for the study. During the selection of newspapers, it was noted that both dailies are published from various cities of Haryana. Finally, it was decided to include newspapers published in the Panipat district of Haryana due to convenience, as they were easily accessible within the available time and resources.

RESULTS

Number of agricultural issues

The details of the number of agricultural issues (agricultural editorials, agricultural opinion columns and agricultural feature articles) published by both newspapers presented in Table 1.

Table 1 shows that both newspapers published 547 editorials during the study period, *Amar Ujala* newspaper published 308 editorials, while *Dainik Bhaskar* published 239 editorials. Only, 22 (4.02%) of the total number of editorials came up under the agricultural category together from these two newspapers. *Dainik Bhaskar* has published 19 agricultural editorials (7.95%) of its total number of editorials, whereas *Amar Ujala* has published only three agricultural editorials (0.97%) of its total number of editorials. It is very clear that the number of agricultural editorials published by *Dainik Bhaskar* is higher than that of the editorials published by *Amar Ujala*. *Dainik Bhaskar* provided satisfactory coverage to agricultural editorials, while *Amar Ujala* gave only a minuscule proportion of its total editorials (less than 1%) to agricultural editorials. Further, the study shows that both newspapers published 1384 opinion columns, in which 760 opinion columns were published by *Dainik Bhaskar* and 624 opinion columns were published by *Amar Ujala*. Out of 1384 opinion columns, only 33 (2.38%) opinion columns were published by both newspapers on agricultural subjects. *Amar Ujala* published 25 agricultural opinion columns (4.01%) of its total number of opinion columns, while *Dainik Bhaskar* published only 8 agricultural opinion columns (1.05%) of its total number of opinion columns. It is evident from Table 1 that the number of agricultural opinion columns published by *Amar Ujala* is higher than that of the opinion columns published by Dainik Bhaskar.

During the period under study, 1619 feature articles were published by both newspapers. *Amar Ujala* published 916 feature articles, while *Dainik Bhaskar* published 703 feature articles. Only 10 (0.62%) of the total number of feature articles were on agricultural subjects. *Amar Ujala* published 8 agricultural feature articles (0.87%) and *Dainik Bhaskar* has published only 2 agricultural feature articles

Table 1. Number of agricultural issues

Name of Newspaper	Total No. of Editorials	Total % of Agricultural Editorials	Total No. of Opinion Columns	Total % of Agricultural Opinion Columns	Total No. of Feature Articles	Total % of Agricultural Feature Articles
Amar Ujala	308	0.97	624	4.01	916	0.87
Dainik Bhaskar	239	7.95	760	1.05	703	0.28
Total	547	4.02	1384	2.38	1619	0.62

(0.28%) of its total number of feature articles. Table 1 clearly shows that the number of agricultural feature articles published by *Amar Ujala* is higher than that of the feature articles published by *Dainik Bhaskar*.

Subject-wise categorisation of agricultural issues

All agricultural editorials, agricultural opinion columns, and agricultural feature articles were categorised into 19 different categories based on their coverage. The number of these categories described in Table 2.

Table 2. Subject-wise categorisation of agricultural issues

Content Category	*Amar Ujala* (%)	*Dainik Bhaskar* (%)
Marketing, Transport & Storage	11.11	10.34
Irrigation	2.78	00.00
Agricultural Finance	08.33	00.00
Supporting Services & Incentives	02.78	17.24
Agricultural Administration	13.89	03.45
Climate Change	05.56	20.69
Agricultural Production	05.56	10.34
Agricultural Technology and Innovation	05.56	06.90
Forestry	08.33	00.00
Agricultural Employment	02.78	00.00
Farmer's Suicide	05.56	00.00
Cooperative Farming	08.33	00.00
Natural Disaster	02.78	00.00
Stubble Burning	02.78	00.00
Fertilizer	05.56	00.00
Fisheries	02.78	00.00
Miscellaneous	05.56	13.79
Agricultural Schemes & Policies	00.00	13.79
Animal Husbandry	00.00	03.45
Total	100.00	100.00

The study depicts that both newspapers covered diverse aspects of agricultural issues. Out the 65 agricultural issues, 36 were published by *Amar Ujala* newspaper, while 29 published by *Dainik Bhaskar*. Out of 65 agricultural issues, 15 (about 23%) were related to marketing, transport, storage and climate change categories. The table further reveals that *Amar Ujala* gave the highest priority to agricultural administration (about 14%), while *Dainik Bhaskar* gave the highest priority to climate change (about 21%). *Amar Ujala* did not publish single news item on agricultural schemes and policies and animal husbandry, whereas *Dainik Bhaskar* published 4 and 1 agricultural issues respectively on the same. Not even a single news item related to irrigation, agricultural finance, forestry, agricultural employment, farmers' suicide, cooperative farming, natural disaster, stubble burning, fertiliser, and fisheries was published by *Dainik Bhaskar*. Furthermore, each of the two newspapers published 2 agricultural issues on agricultural technology and innovation. *Dainik Bhaskar* published 3 agricultural news items on agricultural production, while *Amar Ujala* published 2 on the same subject. Both dailies published a few miscellaneous news items related to agriculture.

Purpose-wise categorisation of agricultural issues

Five purposes of the agricultural issues (agricultural editorials, agricultural opinion columns and agricultural feature articles) were identified in both newspapers (Table 3).

Table 3. Purpose-wise categorisation of agricultural issues

Approach	*Amar Ujala* Frequency (%)	*Dainik Bhaskar* Frequency (%)
Situation-based	21 (58.33)	12 (41.38)
Achievement-based	00 (00.00)	02 (06.90)
Advisory-based	06 (16.67)	11 (37.93)
Research-based	03 (08.33)	00 (00.00)
Policy-based	16.67	04 (13.79)
Total	36 (100.00)	29 (100.00)

Table 3 shows that five purposes, viz., situation-based, achievement-based, advisory-based, research-based, and policy based agricultural issues were identified during the period under study. A total of 65 agricultural news items, 33 (50.77%) were describing situations or related to events, 17 (26.15%) dealt with advisory, and 10 (15.38%) focused on policy related subjects in agricultural areas. Some agricultural issues highlighted achievements (2), while some were research-based in the agricultural sector. Table 3 further depicted that both newspapers have given the highest importance to situation based agricultural issues. *Amar Ujala* published 21 situation-based agricultural news items (58.33%), whereas *Dainik Bhaskar* published only 12 (41.38%). Both dailies gave advisory based agricultural news items as a second priority. *Dainik Bhaskar* published 11 advisory-based agricultural issues (37.93%) while, *Amar Ujala* published only 6 (16.67%) on the same. As far as policy based agricultural news items are concerned, Dainik Bhaskar published slightly more policy based agricultural news items than *Amar Ujala*. *Dainik Bhaskar* published 6 policy related agricultural issues (16.67%), while *Amar Ujala* published only 4 policy based agricultural news items (13.79%). It is evident from Table 3 that *Dainik Bhaskar* did not publish even single achievement based agricultural news item, whereas *Amar Ujala* did not publish single research-based agricultural news item.

Geographical coverage of agricultural issues

All agricultural issues (agricultural editorials, agricultural opinion columns and agricultural feature articles) were categorised geographically into five different categories based on their geographical importance. The details of the geographical coverage of agricultural issues are presented in Table 4.

Table 4 showed that both newspapers gave the highest importance to national-level agricultural issues. Out of 65 agricultural issues, 45 published by both newspapers were related to national-level agricultural news items. *Amar Ujala* published 27

Table 4. Geographical coverage of agricultural news contents

Geographical Categories	*Amar Ujala* (%)	*Dainik Bhaskar* (%)
District	05.56	00.00
State	02.78	03.45
Regional	2.78	06.90
National	75.00	62.07
International	13.89	27.59
Total	100.00	100.00

agricultural news items (75%) related to national level, while *Dainik Bhaskar* published 18 agricultural news items (62.07%), which were of national importance. The table further reveals that both newspapers gave the second priority to international level agricultural news items. *Dainik Bhaskar* published 8 agricultural news items (27.59%), whereas *Amar Ujala* published only 5 (13.89%), which were related to an international level. *Dainik Bhaskar* published 2 agricultural issues, which were of regional importance, while *Amar Ujala* published only 1 agricultural news item, which was related to regional importance. Each of the two leading newspapers published only 1 agricultural news item related to the state level. It demonstrates that both newspapers did not show interest in covering state related agricultural news items. Not a single agricultural news item pertaining to the district level was published by *Dainik Bhaskar*, whereas *Amar Ujala* published 2 such items. It indicates that *Dainik Bhaskar* completely ignored district-level agricultural news item.

DISCUSSION

The findings of this study reveal significant variations related to agricultural issues published by both newspapers. It is important to note that the central government runs various agricultural schemes to support farmers, yet the *Amar Ujala* published no news items related to agricultural schemes and policies and animal husbandry. The Indian agricultural sector is facing several challenges, including inadequate irrigation facilities, farmers' suicides, natural disasters, and the issue of stubble burning, but *Dainik Bhaskar* completely ignored them. According to the recent report of the National Crime Records Bureau (NCRB), 10,786 farmers and agricultural labourers committed suicide in the country in 2023 (Bhagirath, 2025). For a long time, stubble burning has been a major cause of air pollution. In recent years, climate change has affected the agricultural productivity (Kumar & Saxena, 2024). It seems that these agricultural issues do not matter to the editor and senior journalists of *Dainik Bhaskar* newspaper. The overall coverage of agricultural news items in both leading Indian Hindi dailies was inadequate. Previous scholarly studies also confirm that India's leading Hindi newspapers provide low coverage to agricultural news items (Nain & Trikha, 2001; Mudgal, 2011; Yadav, et al., 2012; Singh, 2022). The findings of this study are consistent with Jain et al. (2023), who highlighted that agriculture receives meagre coverage in India's national newspapers. The majority of agricultural news items in both newspapers were situation-based, and national- level agricultural issues received the highest priority. India is predominantly an agricultural society, where a large proportion of its population remains engaged in agriculture and allied activities for their livelihood and income generation. Editors and senior journalists of both newspapers should enhance agricultural news coverage in their newspapers. Editorials, opinion columns, and feature articles published in newspapers can play a significant role in educating and sensitising farming communities on various agricultural issues.

CONCLUSION

The study concluded that India's popular Hindi dailies, i.e., *Dainik Bhaskar* and *Amar Ujala*, published a limited number of agricultural issues. The majority of agricultural news items published in both newspapers consisted of situation-based reporting. Both dailies predominantly focused on national level agricultural news items. Editors and senior journalists of both newspapers should enhance the coverage of agricultural news items in their newspapers, as more than half of India's population is directly or indirectly involved in the agricultural sector.

DECLARATIONS

Competing Interest: The authors have no competing interests.

Conflict of interest: The authors declare that during the preparation of this work, newspapers reviewed very carefully. The authors take full responsibility for the final content of this publication. The authors also 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.

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Research Article

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Critical Factors Hindering the Millet Entrepreneurial Sector: Strategic Interventions for Enterprise Development

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HIGHLIGHTS

- Inadequate millet processing facilities and insufficient farmer trainings were identified as major barriers, restricting value addition and profitability.
- Low price realization and limited access to credit constrained technology adoption and enterprise expansion due to a weak value chain
- Study highlighted tool-bank models and targeted subsidies as effective measures to reduce capital constraints and improve enterprise viability
- Experts prioritised machinery subsidies, strengthened buyer linkages, and recognition of resilient entrepreneurs as the most impactful strategies.

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Keywords: Entrepreneurial climate, Millet enterprises, Millet entrepreneurs, Constraints, Strategies.

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ABSTRACT

The study was conducted to develop strategies in the context of the entrepreneurial climate of the millet-based enterprises on the basis of identified constraints faced by millet entrepreneurs and in the state of Telangana. The data were collected using a structured interview schedule from 35 millet entrepreneurs, 150 millet growers and 30 research scientists comprising 215 respondents from Telangana during the 2023-24. The constraints and strategies were divided into four categories, i.e., technical, financial, marketing and personal. The major constraints revealed were a lack of millet processing, non-remunerative prices for the produce, farmers getting minimal shares and significant stress due to uncertain returns, respectively. The strategies using analytical hierarchical process like setting up processing centres, advocating subsidies on the purchase of machinery and raw materials, integrating millets into government programmes and recognising and rewarding resilient millet entrepreneurs, respectively emerged. The study identified unique scenarios indicating the valuable perspectives of all stakeholders included in the study.

INTRODUCTION

Millets are a diverse group of small-seeded grasses belonging to the Poaceae family, traditionally cultivated in semi-arid tropical regions. They are valued for their high nutritional content, climate resilience, low input requirements, and short growing period. Major millets include pearl millet, sorghum, finger millet, foxtail millet, kodo millet, little millet, barnyard millet, and proso millet. Most of these crops are indigenous to India and are collectively termed "Nutri-cereals" due to their significant health benefits and adaptability to adverse climatic conditions. India is the world's largest producer of millets, accounting for approximately 38–41%

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of global production. Millets are cultivated over an area of about 12.19 million hectares, with an annual production of nearly 11.5 million tonnes. Their ability to withstand drought, thrive in poor soils, and require minimal external inputs makes them ideal for sustainable, economically viable, and climate-resilient agriculture (Naik and Bhavani, 2022). Millets also provide small and marginal farmers with a stable source of income by diversifying farm revenue and reducing economic risks.

In recent years, there has been a renewed interest in millet-based enterprises in India, driven by increasing awareness of their nutritional benefits and their role in addressing food security, environmental sustainability, and lifestyle-related health concerns. Millet-based entrepreneurship plays a crucial role in enhancing crop value, promoting sustainable business models, and strengthening rural livelihoods. Against this national backdrop, Telangana emerges as a suitable case for examining millet production and the growth of value-added enterprises. Millet cultivation in Telangana is primarily focused on sorghum, pearl millet, and bajra. The state's semi-arid climate and average annual rainfall of 1049.5 mm provide favorable conditions for millet farming (DOA, 2024). Although Telangana is not among the top three millet-producing states in India, it remains an important contributor. The state's emphasis on value addition and supportive institutional environment reinforces the role of millets in food security, rural employment, and inclusive agri-business growth (Banerjee et al., 2024).

Telangana has also witnessed increasing momentum in millet-based entrepreneurship, supported by policy initiatives and institutional backing. Organizations such as the Indian Institute of Millet Research (IIMR), Hyderabad, provide training, incubation, and technical support to millet entrepreneurs producing ready-to-eat and health-oriented products (Gecheo et al., 2023). Government initiatives have encouraged the participation of women-led self-help groups, rural innovators, and youth-led agri-startups across the millet value chain (Gopi, 2025). Millet entrepreneurship contributes to employment generation, promotes agro-processing for value addition, enhances supply chain efficiency, and supports sustainable farming and technological innovation (Gupta et al., 2023; Das et al., 2025; Kiran et al., 2025).

Issues like low farm-gate prices, limited consumer awareness, market access barriers, competitive pressures, and empowerment gaps continue to hinder the growth of millet-based enterprises (Harish et al., 2024). In this context, the present study aimed to examine the constraints faced by millet growers and entrepreneurs and suggesting appropriate strategies for promoting and strengthening millet-based enterprises. Addressing and implementing targeted interventions are crucial to ensure the benefits of the millet revolution reach all stakeholders, making millet enterprises both sustainable and economically viable.

METHODOLOGY

The study was conducted purposively in Telangana state in the year 2023-24, as the state constitutes the highest number of millet enterprises according to the secondary data collected from the reports by ICAR-Indian Institute of Millets Research and MANAGE, Hyderabad. The sampling procedure differed across respondent categories. Millet-based entrepreneurs were selected based on enterprise listings and reports published by ICAR–IIMR. Millet growers were selected from districts identified as predominant millet-growing regions namely Mahabubnagar, Ranga Reddy, and Adilabad based on the Directorate of Economics and Statistics, Telangana (2023). Research scientists were selected randomly from among scientists working at ICAR–IIMR, Hyderabad. Accordingly, sample comprised of 35 millet based enterprises, 150 millet growers and 30 research scientists resulting in a total sample size comprising of 215 respondents, were personally interviewed for the study. The constraints were categorised under four categories vis., technical, financial, marketing and personal constraints. The identification of constraint items under each category was based on an extensive review of relevant literature, preliminary interactions with respondents during the pre-testing phase, and expert opinions from scientists and subject matter specialists. Responses were elicited for each identified constraint to assess their relevance and severity as perceived by them. The data collected was recorded and analysed by using the Garett ranking. The percent position estimates were transformed into Garrett scores using Garrett's Table, which was provided by Garret and Woodworth (1969).

Furthermore, strategies to address the identified constraints were formulated through a review of the literature and subsequently validated by experts, including scientists from ICAR-IIMR. The categorization of strategies was aligned with the corresponding classification of constraints and supported by empirical evidence from earlier studies, thereby ensuring conceptual consistency and enabling a systematic analysis of intervention measures across various dimensions affecting millet-based enterprises.

Further, prioritisation of strategies was done using the analytical hierarchical process (AHP) as given by Saaty (1980). AHP is a multi-criterion decision- making tool used for making optimal choices. The selected components and their strategies were prioritised using priority weights, where higher weights indicated greater importance. Global ranks were derived by multiplying the priority of components by their respective strategies. Overall consistency of the preference matrix was assessed using the consistency ratio, which should be less than 0.1. The strategies were also categorised under four categories, namely technical, financial, marketing and personal strategies. With the use of a systematic, pre-tested interview schedule, the data were obtained through personal interaction. The data were then categorised, tabulated, and analysed in accordance with the stated objective and to provide a meaningful interpretation of the findings.

RESULTS

It is indicated in Table 1, that in case of technical constraints, the highest-ranked constraint was the lack of millet processing units, with an average Garrett score of 50.92, followed by inadequate training, demonstrations, and exposure opportunities for farmers, which scored 50.20. In the category of financial constraints, the topmost concern was non-remunerative prices for the produce, with a score a of 52.00, followed by limited access to funding, with a mean score of 50.60. Regarding marketing constraints, the primary issue identified was that despite rising retail prices, millet farmers receive only a small share, leading to financial dissatisfaction, with

Table 1. Constraints faced by the respondents

I	Technical constraints	AGS	Rank
1	Farmers experience labour shortages during peak seasons, which hampers timely agricultural operations	49.69	IV
2	Inadequate training, demonstrations, and exposure opportunities for farmers	50.20	II
3	Limited use of digital tools for marketing, logistics, and supply chain management hampers competitiveness	49.48	VI
4	Lack of millet processing units hinders value addition, impacting product quality and reducing shelf life	50.92	I
5	Non-availability of quality inputs in the required time and in the required quantities	49.60	V
6	Lack of modern packaging and controlled storage affects product shelf life and marketability	50.08	III
II	Financial Constraints		
1	Non-remunerative prices for the produce make farming financially unviable and discourage farmers	52.00	I
2	High input costs, expenses of machinery & infrastructure are unaffordable for small-scale farmers and startups.	50.30	III
3	Limited government financial support or subsidies for millet-related businesses affects growth potential.	50.05	IV
4	Limited access to funding makes it difficult to expand operations and scale up processing units	50.66	II
5	Demand for millets is still niche and inconsistent, leading to price volatility and uncertain returns	48.03	VI
6	Delayed payments from buyers create cash flow problems for millet entrepreneurs	48.93	V
III	Marketing Constraints		
1	Despite rising retail prices, millet farmers receive only a small share, causing financial dissatisfaction	51.38	I
2	Most startups have very small marketing teams, which limits their ability to reach more customers	49.83	IV
3	Millets often compete with grains like rice/wheat, having greater consumer familiarity and stronger supply chains.	49.49	V
4	Proper connections to buyers and larger markets are often missing	50.91	II
5	Millet Market information is often limited or inaccurate, making it hard to plan sales	50.03	III
6	Many startups struggle to use e-commerce and social media effectively due to lack of skills or resources	48.33	VI
IV	Personal Constraints		
1	Women entrepreneurs face social barriers that restrict their participation and progress	48.88	V
2	Fear of future risks and potential failure discourages bold decision-making	50.18	III
3	Involves significant stress due to uncertain returns and the need to repay loans taken for the enterprise	51.06	I
4	Limited business experience and low confidence hinder entrepreneurial growth	50.86	II
5	Managing both business and family duties is often overwhelming	49.00	IV

*AGS=Average Garret Score

a score of 51.38 followed by the lack of proper connections to buyers and access to larger markets, which scored 50.91. In terms of personal constraints, the most significant challenge was that millet entrepreneurship involves significant stress, with a score of 51.06, followed by limited business experience and low confidence scored 50.86, respectively.

As indicated in Table 2, under technical strategies, the most important strategies suggested by the experts were the setting up of processing centres equipped with modern facilities with a criteria weight of 0.185, followed by the launch of tool banks to make modern machinery more affordable, with a weight of 0.177. In terms of financial strategies, experts highlighted that the top priority was to advocate subsidies for the purchase of raw materials and machinery with a weight of 0.230, followed by the importance of establishing stronger buyer contracts, with a weight 0.207. For marketing strategies, the majority of experts emphasised the need to integrate millets into government programmes, with a weight of 0.191, closely followed by building partnerships to expand market reach, which scored 0.189. Under personal strategies, experts noted that the most significant component was recognising and rewarding resilient millet entrepreneurs with a weight of 0.238, followed by the importance of engaging experienced entrepreneurs for guidance and motivation, which received the highest weight of 0.247.

From the Table 3, it was highlighted that hierarchy of strategies considered effective for advancing millet based enterprises were advocating subsidies on purchasing machinery with global weight (0.068) followed by making strong buyer contacts (0.061), recognizing and rewarding awards (0.059), encouraging farmer groups to pool resources (0.058), connect startups with investors and crowdfunding platforms (0.056), integrating millets into government programmes (0.055), building partnerships with super markets, online platforms to widen market reach (0.054), providing training on budgeting, cost management, and profit maximization for entrepreneurs (0.052) and so on.

DISCUSSION

As revealed by table 1, study of constraints suggests that the technical constraints respondents faced by respondents were due to limited units, high equipment costs and need for specialized machinery for different millet types were making it unaffordable for many small scale operators which lead to forceful selling of unprocessed millet at low prices (Naik and Bhavani, 2022) and unequitable focus in extension services hindered their ability to penetrate and support stakeholders at the grassroots level services. In case of financial constraints, respondents felt that due to a poorly organised value chain, weak policy support (Chapke et al., 2022) and lack of capital and tailored credit products restricting their ability to invest for expanding operations and technological aspects. The marketing constraints, the respondents faced were due to the disparity between farm gate and retail pricing resulting from the existence of several middlemen, their impact on distribution and processing, and the scarcity of options to sell directly to consumers (Vadlapatla, 2023a). The personal constraints the respondents felt were due to inconsistent and poor returns driven by market and

Table 2. Strategies to promote millet-based enterprises

S.No.	Strategies	Criteria weights	Rank
I	Technical (CI=0.041; CR=0.033)		
1	Setting up processing centres equipped with modern facilities for cleaning, milling, and packaging	0.185	I
2	Partnering with agriculture influencers to create and spread content in local languages.	0.142	VI
3	Use mobile apps to give farmers updates on weather, pests, and prices.	0.165	IV
4	Exposure visits to successful millet farms, FPOs, and processing enterprises for enhanced learning	0.154	V
5	Organising workshops to teach millet processing, quality checks, and new tech	0.174	III
6	Launch tool banks to make modern machines affordable and accessible	0.177	II
II	Financial (CI=0.084; CR=0.075)		
1	Encourage farmer groups to pool resources for primary processing units	0.195	III
2	Make buyer contracts stronger with clear payment rules and penalties.	0.207	II
3	Provide training on budgeting, cost management, and profit maximisation for entrepreneurs	0.175	V
4	Advocate subsidies on the purchase of machinery, raw materials, and transportation	0.230	I
5	Connect startups with investors and crowdfunding platforms	0.190	IV
III	Marketing (CI=0.069; CR=0.056)		
1	Integrate millets into government programmes to normalise consumption	0.191	I
2	Collaborate with KVKs and NGOs to provide updates on market demand/price trends	0.121	VI
3	Build partnerships with retail chains, supermarkets, and online platforms to widen market reach	0.189	II
4	Awareness campaigns to educate people about millet's health benefits.	0.150	V
5	Promoting direct-to-consumer (D2C) models through local markets and websites	0.175	III
6	Developing unified brand identity, like "Telangana Millets," to support collective marketing and visibility	0.171	IV
IV	Personal (CI=0.024; CR=0.027)		
1	Provide training on fundamental risk analysis, contingency planning and budgeting to strengthen confidence in decision-making	0.238	III
2	Recognising & rewarding resilient millet Entrepreneurs particularly women, youth, and FPO leaders	0.286	I
3	Organising community exhibitions/sales events to provide women with opportunities to display and promote their products.	0.227	IV
4	Reaching out to experienced entrepreneurs for mentorship & engaging with peer support groups for advice and encouragement.	0.247	II

*CI= Consistency Index; CR= Consistency Ratio

Table 3. Overall weights for the strategies to promote millet-based entrepreneurs

S.No.	Strategies	Global Weight	Global rank
1	Setting up processing centres equipped with modern facilities for cleaning, milling, and packaging	0.038	XV
2	Partnering with agriculture influencers to create and spread content in local languages.	0.029	XXI
3	Use mobile apps to give farmers updates on weather, pests, and prices.	0.034	XVIII
4	Exposure visits to successful millet farms, FPOs, and processing enterprises for enhanced learning	0.032	XX
5	Organising workshops to teach millet processing, quality checks, and new tech	0.036	XVII
6	Launch tool banks to make modern machines affordable and accessible	0.036	XVI
7	Encourage farmer groups to pool resources for primary processing units	0.058	IV
8	Make buyer contracts stronger with clear payment rules and penalties.	0.061	II
9	Provide training on budgeting, cost management, and profit maximisation for entrepreneurs	0.052	VIII
10	Advocate subsidies on the purchase of machinery, raw materials, and transportation	0.068	I
11	Connect startups with investors and crowdfunding platforms	0.056	V
12	Integrate millets into government programmes to normalise consumption	0.055	VI
13	Collaborate with KVKs and NGOs to provide updates on market demand/price trends	0.034	XIX
14	Build partnerships with retail chains, supermarkets, and online platforms to widen market reach	0.054	VII
15	Awareness campaigns to educate people about millet's health benefits.	0.043	XIV
16	Promoting direct-to-consumer (D2C) models through local markets and websites	0.050	X
17	Developing a unified brand identity, like "Telangana Millets," to support collective marketing and visibility	0.049	XI
18	Provide training on fundamental risk analysis, contingency planning and budgeting to strengthen confidence in decision-making	0.049	XII
19	Recognising & rewarding resilient millet entrepreneurs particularly women, youth, and FPO leaders	0.059	III
20	Organising community exhibitions/sales events to provide women with opportunities to display and promote their products.	0.047	XIII
21	Reaching out to experienced entrepreneurs for mentorship & engaging with peer support groups for advice and encouragement.	0.051	IX

weather risks, insufficient business experience (Yadav et al., 2023) and weak ecosystem support hampering entrepreneurial growth.

From the Table 2, as far as strategies are concerned, it can be inferred that under technical strategies emphasis was made by addressing infrastructure gaps and lowering capital barriers by taking up the tool bank approach which makes them feasible for small and marginal farmers, leading to boosting income through value addition. Regarding financial measures, the focus was on providing subsidies to make millet-based enterprises more affordable for small farmers and emerging entrepreneurs. Additionally, emphasis was placed on ensuring better price realisation by establishing direct connections between producers and buyers (Lahiri et al., 2024). In the context of marketing strategies, focus was primarily on incorporating millets into government initiatives that assist shift in consumer perceptions and support public health. On the other hand, collaborations were highlighted for their role in increased brand exposure and market access (Pravallika et al., 2020). Regarding personal strategies, the prominence was on acknowledging and rewarding resilient entrepreneurs as it helps in a greater sense of confidence, motivates them to persevere in the face of difficulties and validates their efforts (Vadlapatla, 2023b). Furthermore, it was believed that offering mentorship was essential to assist them with business planning and scaling up their enterprises.

Findings from Table 3 further indicate that the overall global ranking emphasises the critical role of financial support in addressing core constraints and in strengthening networks necessary for enterprise growth (Tashi et al., 2022). This highlights the need to prioritise financial inclusion, targeted subsidies, and enterprise-level credit mechanisms that can effectively support emerging entrepreneurs in the millet sector. Strong buyer contacts and partnerships with supermarkets and online platforms underline the significance of reliable market access for improving sales and price realization. Additionally, recognising and encouraging entrepreneurial innovation and perseverance, as well as the value of resource pooling helps in enhancing economies of scale (Shah et al., 2023). This highlights the significance of collective action, as encouraging farmer groups to pool resources can reduce operational costs and improve bargaining power. Connecting startups with investors and crowdfunding platforms also reflects the necessity of improving access to finance tailored to enterprise needs. In this context, policy and institutional frameworks that promote innovation grants, incubation services, and structured mentorship programs become essential for fostering a culture of creativity and sustained entrepreneurial engagement. Furthermore, integrating millets into government programmes and providing training on budgeting, cost management, and profit maximization are crucial for improving institutional support and managerial capabilities. Overall, the coordinated application of financial, market, and collective strategies is vital for strengthening millet-based entrepreneurship. Such a holistic approach is necessary for fostering an enabling environment that supports sustainable enterprise development both locally and globally (Tinsley, 2018).

CONCLUSION

The study concluded that millet entrepreneurs and growers in Telangana encountered a complex array of constraints ranging from technical hurdles to personal. Addressing these constraints in the millet sector needs a coordinated, comprehensive and multi-dimensional approach that combines infrastructural enhancement, financial support, market linkage and capacity building. The study recommends adopting integrated strategies, including machinery subsidies, strengthened market linkages, collective action among farmer groups, improved access to finance, integration of millets into government programmes, and financial management trainings, effectively harness the potential of millet-based entrepreneurship. Furthermore, fostering collaboration among stakeholders and encouraging innovation within the millet ecosystem are essential for strengthening enterprise sustainability. Encouraging and empowering local stakeholders can boost entrepreneurship at grassroots and ensures inclusive participation of women, youth and small scale farmers across the millet value chain. Sustained policy support, awareness initiatives, training programs and capacity development will be crucial for achieving long term impacts.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the entrepreneurs, farmers and scientists respondents during the course of the research.

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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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Protected Vegetable Cultivation in Haryana: An Analysis of Marketing Efficiency and Major Constraints

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HIGHLIGHTS

- Direct-to-consumer channels recorded the highest marketing efficiency across cucumber, tomato, and capsicum.
- Commission agent routes yielded the lowest efficiency and the widest price spread in protected vegetable cultivation.
- High price fluctuation and absence of MSP emerged as the most critical marketing constraints, followed by infrastructural and institutional gaps.
- Marketing efficiency and farmer profitability are jointly influenced by both marketing and production constraints under protected cultivation.

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ABSTRACT

The study presents channel-wise marketing efficiency, the major marketing and production constraints faced by protected vegetable cultivators in Haryana. Using the Yamane sampling formula, a sample of 300 farmers cultivating cucumber, tomato, and capsicum was selected and primary data was collected through a pre-tested interview schedule during 2024. Marketing efficiency across major marketing channels was estimated using Acharya Modified Method, while Garrett Ranking technique was employed to prioritise key marketing and production constraints. The results revealed that direct to consumer marketing channels consistently recorded the highest marketing efficiency and farmer's share, whereas channels involving commission agents were the least efficient due to higher marketing costs and intermediary margins. The Garrett Ranking analysis indicated that absence of minimum support price (MSP), high price fluctuations and lack of organised markets were the most severe marketing constraints. On the production side, labour shortages, high input costs, limited lifespan of polyethylene sheet and environmental pressures significantly affected profitability. The paper highlights that the issues of marketing and production are interlinked and jointly influences income stability and decision-making of protected vegetable cultivators. Strengthening market linkages, infrastructure and technical support is therefore is essential to enhance the economic viability of protected vegetable cultivation in Haryana.

INTRODUCTION

Vegetable cultivation is one of the fastest-growing components of Indian agriculture, contributing significantly to food and nutritional security, farm diversification, and rural livelihoods. India is the world's second-largest producer of vegetables (FAO, 2023), and the area under vegetable crops has increased steadily over the past two decades owing to rising consumer demand, urbanisation,

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and improvements in supply chains (Kumar et al., 2019). The perishable nature of vegetables required timely harvesting, and the need for rapid market disposal expose farmers to substantial production risks, price volatility, and post-harvest losses that often exceed 15.00-25.00 per cent under open-field conditions (Chand et al., 2020).

Protected cultivation has emerged as an important technological alternative to mitigate these risks. Structures such as polyhouses and net houses create controlled environments that reduce climatic uncertainties and enable off-season production of high-value crops including cucumber, capsicum, and tomato. Evidence shows that protected cultivation enhances yield, improves quality, increases resource-use efficiency, and raises profitability compared to open-field farming (Nimbrayan et al., 2021; Anamika et al., 2023). Chiphang et al. (2021) reports higher market responsiveness and resource-use efficiency in regulated horticultural environments, highlighting the potential of protected structures for smallholder.

Haryana has emerged as a leading state in adopting protected cultivation due to favourable agro-climatic conditions and its proximity to the National Capital Region (NCR), which provides assured market access (State Horticulture Department, 2024). Vegetable marketing differs significantly from the marketing of conventional crops. High perishability, frequent harvesting, and rapid deterioration require immediate and efficient market disposal. Intermediary-dominated channels often widen the price spread and reduce farmers' share in the consumer's rupee (Chand et al., 2020; Thakur et al., 2023). Vegetable markets are also characterised by price fluctuations, weak regulation, and asymmetric market information (Pareek et al., 2024; Birthal et al., 2021). Earlier studies confirm that shorter and organised channels improve price realisation and reduce transaction losses (Chand et al., 2020; Ogutu et al., 2020; Nuthalapati et al., 2024).

In addition to marketing challenges, protected cultivation is constrained by several production-related issues. High initial investment, scarcity of skilled labour, high seed and fertiliser costs, limited technical knowledge significantly affect productivity and profitability (Kumar et al., 2019; Ansari, 2020; Singh et al., 2022). Lack of MSP, inadequate cold storage and high transportation further restrict economic viability (Pareek et al., 2024; Birthal et al., 2021). Integrated assessment of production and marketing constraints provides a more comprehensive understanding of farmer profitability (Kumari et al., 2023; Verma, 2025).

Although protected cultivation is expanding rapidly in Haryana, limited studies have examined marketing efficiency together with production and marketing constraints. Much of the existing literature focuses on cost-benefit aspects and open-field vegetable marketing, leaving a critical gap. Against this background, the present study analyses the marketing efficiency of major marketing channels and identifies key production and marketing constraints faced by protected vegetable growers in Haryana. The findings help stakeholders strengthen market access and improve the viability of protected cultivation in the state.

METHODOLOGY

The study was conducted in Haryana in the year 2024 and in the regions where protected vegetable cultivation has grown tremendously over the last few years. Eight districts of the state - Karnal, Kaithal, Kurukshetra, Ambala, Bhiwani, Hisar, Jind, and Mahendragarh, were chosen purposely on the basis of predominance of the vegetable cultivation. These districts cover 73.46 per cent total area (1358 ha) in protected vegetable production (Department of Horticulture, Haryana, 2024). Three crops that were more adopted and had more economic value i.e. cucumber, capsicum, and tomato were selected due to their market demand and profitability in the protected environment. The District Horticulture Offices provided the list of the protected vegetable growers, which was used as the sampling frame. A sample of 300 farmers representing the selected districts and crops was determined using the Yamane (1967) formula with a precision level of 5.00 per cent. The primary data gathered by use of a pre-tested interview schedule, which contained information about the production practices, marketing channels, marketing costs, price realization, and significant constraints. The study area was studied through field investigations where three overpowering marketing channels were found. These channels were commission agents, supermarket and direct selling to the customers. The benefits of these channels were analysed crop-wise to ascertain which channel had the best benefit to the producers. The efficiency of marketing was determined using the (Acharya & Agarwal, 2019) modified method which express the net price received by the farmer to the price spread of consumer and producer price reflecting combined influence of marketing cost and margin on producer share. Study also focused on key marketing and production constraints experienced by the protected vegetable growers. Ten primary marketing constraints were defined, based on literature and field consultations (Kumar et al., 2019; Pareek et al., 2024). On the same note, ten production constraints were discovered through farmer contacts and existing literature (Kumar et al., 2019; Singh et al., 2022). In order to put constraints into perspective Garrett ranking technique was used where individual farmer rankings were converted into Garrett scores using the percent position and mean scores were used to rank the constraints (Garrett & Woodworth, 1969). This gave a clear picture of the relative significance of the various constraints to the profitability of the farmers and their marketing efficiency.

RESULTS

Channel-wise marketing share

The analysis is based on primary data collected from 300 farmers, comprising150cucumber growers, 90 tomato growers and 60 capsicum growers who sold their produce through three major marketing channels. The channel distribution of farmers showed significant differences between crops (Table 1). Commission Agent-Wholesaler-Retailer-Consumer (Channel I) appeared to be the best channel by all vegetable growers and especially in the case of capsicum, two-thirds of the growers (66.67%) used this middleman-managed channel. This over-dependence implies that the high-value and low-volume crop growers will tend to use existing mandi networks to ensure their sales are guaranteed. The participation pattern in cucumber and tomato was more distributed in channels. Commission agents received about 40.00 per cent of the growers in each crop, and the corresponding number of growers sold to the

Table 1. Distribution of farmers by marketing channel across crops under protected cultivation

Crop	Channel I (F–CA–W/R–C)	Channel II (F–SM–C)	Channel III (F–C)	Total
Cucumber	64 (42.67%)	62 (41.33%)	24 (16.00%)	150
Tomato	37 (41.11%)	20 (22.22%)	33 (36.67%)	90
Capsicum	40 (66.67%)	15 (25.00%)	5 (8.33%)	60
Total	141 (47.00%)	97 (32.33%)	62 (20.67%)	300

Source: Author's calculation: F= Farmer, CA= Commission agent, W/R= Wholesale/retail, SM= Supermarket, C= Consumer

supermarkets or under contractual agreements, as a measure of their increasing involvement with organised purchasers. Cucumber was the dominant in case of supermarket channels as 40.00 per cent sold their produce through this channel whereas tomato and capsicum were more than 20.00 per cent in this channel. Direct-to-consumer sales (Channel III) were only used by 20.70 per cent of the total farmers, so it was the least used in general. The tomato growers were however a relatively higher inclination towards direct marketing (36.70%), probably because of high frequency of harvests, stable demand and appropriateness to local retail markets. On the contrary, 16.00 per cent of cucumber growers and 8.30 per cent of capsicum growers embraced this channel.

Although traditional mandi-based or commission-agent based channels continue to prevail in protected vegetable marketing, the emerging participation in contract- linked and direct sales channels indicates a gradual diversification of marketing practices across certain crops and areas.

Channel wise marketing efficiency

The differences in performance of the major marketing channels between cucumber, tomato and capsicum are depicted in Table 2 through the comparative level of marketing efficiency. Direct-to-consumer sales (Channel III) had always the highest in producer share in consumer price, which was about 80.00 per cent for all three crops, and the highest values of marketing efficiency, which varied between 3.53 in capsicum, 3.80 in cucumber and 3.93 in tomato. These high values in channel were the results of the low marketing costs and the fact that there were no intermediary margins, thus farmers were left with higher portions of the end consumer price. This channel, especially to tomato growers, was the most benefiting of all, due to high frequency of harvesting and local demand which favours direct marketing. Supermarkets or contract-based sales (Channel II) occupied an intermediate position with farmers received about 70.00 per cent of the consumer price and recorded moderate marketing efficiency across crops, such as 2.31 for cucumber, 2.08 for tomato and 2.16 for capsicum. This proposes that organised buyers provide a comparatively better price consistency and decrease transaction expenses compared with conventional markets in spite of the fact that the implication of procurement procedures and quality assessment still creates moderate expenses.

Commission agent channel (Channel I) was the least effective in all crops. The share of Farmer was down to 54.60 per cent in tomato and the efficiency index was 1.13 indicating high commission fee, loading/unloading expenses, and numerous intermediaries. In case of capsicum and cucumber marketing efficiency were higher but not as much the other channels. So shorter channel is more beneficial in selling of vegetable crops in case of protected field. Altogether, the efficiency pattern is one of the strongest arguments in favour of shorter marketing chains, which proves that direct and organised marketing channels have a significant positive impact on income results of the protected vegetable growers.

Marketing constraints

In addition to changes in the efficiency of marketing, the outcomes show that a variety of structural and institutional constraints significantly limit the capacity of farmers to get into more lucrative avenues. In the ranking analysis, (Table 3) it was found that Minimum Support Price (MSP) was the major marketing constraint, indicated that farmers were not sure of their income and were vulnerable to the market-based price drops. Right behind this was the high price fluctuation which puts protected vegetable cultivators who already have high production costs at risk to large amounts of funds. Constraints of moderate severity included the absence of organised markets, high transportation and commission fee, and poor market information and information that affects the

Table 2. Producer's share in consumer price and marketing efficiency across crops and channels

Crop	Channel	NFp (Rs./q)	Cp (Rs./q)	Fs (%)	ME
Cucumber	Channel I	1296.88	2171.88	59.71	1.41
	Channel II	1560.48	2198.39	70.98	2.31
	Channel III	1752.08	2187.50	80.19	3.80
Tomato	Channel I	795.95	1462.16	54.56	1.13
	Channel II	1000.00	1445.00	69.29	2.08
	Channel III	1201.52	1487.88	80.80	3.93
Capsicum	Channel I	1892.50	2852.50	66.37	1.85
	Channel II	2120.00	3040.00	69.76	2.16
	Channel III	2450.00	3080.00	79.56	3.53

Source: Author's calculation; NF_p= Net Price received to farmer, C_p= Consumer price, F_s= Farmer Share, ME= marketing efficiency

Table 3. Marketing constraints faced by Protected Vegetable farmer

Constraints	Mean Garrett Score	Rank
Absence of MSP	82	1
High Price Fluctuation	70	2
Lack of Organized Market	63	3
High Marketing Costs (Transport & Comm.)	57	4
Lack of Market Information	52	5
Long Chain of Intermediaries	47	6
Inadequate Cold Storage & Transport	41	7
Limited Selling Options	35	8
Heavy Market Losses	29	9
Malpractices in Weighing & Grading	23	10

capacity of farmers to attain good prices. Lack of organised marketing platforms compel most growers to use traditional mandis where the intermediaries are dominant. Farmers also complained that the infrastructure related constraints especially the unavailability of cold storage and the inaccessibility of refrigerated transport directly led to the decline in quality and increase of post-harvest losses hence lower net returns. Despite the relatively low ranking, issues like malpractices in weighing, low selling alternatives and chain of intermediaries still undermine the bargaining power of farmers. These limitations proved that marketing environment of the vegetable industry in protection is characterized by complex problems of price volatility, inadequate infrastructure, and institutional deficiency.

In general, the evidence showed that the marketing limitations are based on an inter-dependent group of risks like prices, infrastructural, and institutional constraints that all are contributing factors to the ambiguity and complexity of selling perishable produce under protected agriculture. These similar problems inform the marketing choices of farmers and eventually determine the profitability and sustainability of protected vegetable farming in Haryana.

Production constraints

It was found that the biggest constraints to production faced by the growers of protected vegetables were the lack of skilled labour and labour shortage, because the process of protected cultivation is time-sensitive, to ensure that the activities conducted are accurate (i.e. irrigation, pruning, fertigation, pest control, etc.),

Table 4. Production constraints faced by Protected vegetable farmers

Constraint	Mean Garrett Score	Rank
Lack of skilled labour	77.76	1
Scarcity of labour	75.89	2
High cost of seed	68.74	3
High cost of fertilizer	63.70	4
High cost of labour	59.36	5
Weed infestation	55.76	6
Short life of polythene sheet	52.06	7
High weather fluctuation	48.58	8
Insect and nematode infestation	45.64	9
Lack of technical knowledge	42.23	10

the absence of trained workers directly impacts the productivity and may even result in the loss of crops. Growers complained about high cost of seed, fertilisers and labour, which came after labour related problems. Such issues associated with inputs greatly increase the production cost, especially on crops such as cucumber and capsicum where hybrid seeds with good hybrids and special nutrient solutions are required. Moreover, there was weed infestation, low life of polythene sheets, and frequent changes in the weather among the farmers that made the operations a challenge and augmented the risks involved in production. Polythene sheets used to make parts of the polyhouses are not as durable as they should be, and thus they decay easily, contributing to the cost of maintaining them. The weather inconsistency, e.g., abrupt temperature increase or hailstorms, also compromised the stability which protecting structures are expected to offer. Crops were still impacted by lower-ranked constraints (e.g., insect and nematode infestation and a deficiency of technical knowledge) that were not considered the worst ones but had still an influence on the adoption of the best management practices. Combined, these limitations underscore the complexity of the issues that covered vegetable growers encounter to continue with an effective and profitable production.

In general, the issues of production recorded by farmers are a complex of labour shortage, high costs of inputs, and technical and environmental constraints, which affect the sustainability and effectiveness of the protected cultivation. All these constraints impact on crop management, continuity in operations, and stability of yield. The findings underscore the fact that to enhance the performance of production systems in the protected vegetable systems the resource availability and technical capacity of the farm level should be addressed.

Overall, the combined analysis of marketing efficiency and the major constraints indicated that profitability in protected vegetable cultivation is shaped by multiple interlinked factors. Farmers' ability to realise better prices depends not only on channel performance but also on the severity of production and institutional challenges they face. This is particularly relevant for Haryana, where diversification is increasingly necessary and farm profits are constrained by issues such as rising input costs, declining groundwater, and higher production risks. The results underscore that improving profitability and sustaining adoption of protected cultivation requires addressing market inefficiencies and production-level bottlenecks together.

DISCUSSION

The findings of the present study are consistent with existing literature which highlights that that the marketing efficiency of perishable crops is largely determined by the choice of marketing channels and the extent of intermediary involvement. Previous studies by Nain et al. (2019); Kumar et al. (2020) & Villacis et al. (2024), demonstrated that shorter marketing chains allow farmers to keep a larger part of the rupee of the consumer. Similar patterns were observed in the present study, where growers are better off when the channels are direct selling or organised procurement systems than the conventional mandi networks. Chand et al. (2020) also reported that marketing efficiency changes negatively with an increase in the number of handlers, commissions, and transportation

stages. Crop-wise variations in channel preference further align with earlier research. For tomato cultivation, Thakur et al. (2023) noted that frequent harvesting, high perishability, and high rate of local consumption make the short chains favourable supported the presented findings. In the case of cucumber, moderate efficiency in organised retail is similar to the outcomes of Ogutu et al. (2020) and Kundu et al., (2019), who found out that the contact and supermarket associations ensure stabilisation of the prices of crops with homogenous grading and stable demand. The continued reliance of capsicum growers on the intermediaries-based channels mirrors the findings of Pareek et al. (2024), who reported that high-value crops with small distribution in the local retail markets often marketed through wholesale mandis.

The pattern of marketing constraints identified in the study is also consistent with the persisting issues documented in the Indian vegetable marketing research. Price related constraints, particularly price volatility and the absence of minimum support price (MSP), corroborate the findings of Kumar et al. (2019) & Chand et al. (2020), who highlighted the greater income vulnerability of horticultural farmers compared to cereal producers in terms of daily fluctuation of prices and seasonal harvests. The present results further authenticate that in protected cultivation where the production costs and market sensitivity based on quality and quality make the supplement of the storage and transportation facilities more important. Studies by Singh et al. (2022) & Birthal et al. (2021) similarly reported institutional constraints like absence of organised markets, lack of selling options and malpractices in weighing and grading, which have been cited to be the primary drivers behind farmers being dependent on intermediaries. These findings are reflected in the present study, where the vegetable growers are under protection and there are alternative avenues of marketing, the growers still use commission agents mainly due to the lack of accessibility or underdeveloped nature of organised structures.

Production-related constraints observed in the study further demonstrate the close interlinkage between production conditions and marketing performance. Labour scarcity and the lack of skilled labour identified as major constraints, have also been emphasised by Kumar et al. (2019) & Ansari (2020), who noted that protected cultivation presupposes specific knowledge and time and requires suitable interventions, and such measures cannot be made without skilled labour. High price of seed and fertiliser, which was also discussed in previous research, has been brought up of as one of the key hindrances to vegetable production maintenance. The limited lifespan of polythene sheets and stress due to weather conditions support the report of other studies on the protected cultivation in other regions where structural erosion and climate conditions decrease the stability of operation. Earlier studies have also reported technical and environmental limitations like pest and nematode infestation, weed pressure and insufficient technical knowledge. Effectiveness of protected cultivation is firmly conditioned by the ability of farmers to control microclimatic conditions, soil health, and pests is also the cause of technical shortcomings in the present study.

Overall, the results underscore that marketing performance cannot be assessed independently of production related constraints. The interdependence aligns with the observations of Birthal et al. (2021) & Chand et al. (2021), who emphasised the need to jointly consider production and market dynamics when evaluating horticultural profitability. The present study contributes to the literature by demonstrating how the interaction between production and marketing constraints shapes the profitability of protected vegetable cultivation in Haryana.

CONCLUSION

This study examined the efficiency of major marketing channels and the key marketing and production constraints faced by protected vegetable growers in Haryana. The findings revealed that direct-to-consumer channels were the most efficient, providing higher farmer share, whereas commission-agent channels were the least efficient as they involved multiple intermediaries and higher transaction costs. Lack of MSP, excessive variability in price, lack of market information and poor market infrastructure were some of the major marketing constraints. On the production side, lack of skilled labour, expensive inputs and environmental tensions were the significant factors that constrained profitability. The outcome of the research indicates the interdependence of production and marketing issues, which together influences the income and decision-making of farmers. The enhancement of market connections, better storage and transport facilities and better technical support can help in improving the feasibility and viability of the protected vegetable cultivation and sustainability in Haryana.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents for the study.

Competing Interest: The authors have no competing interests.

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

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

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Research Article

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Assessing Climate Change Adaptation Strategies among Livestock Rearers in Bundelkhand Region, India

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HIGHLIGHTS

- Scientific livestock adaptations showed very low adoption in the region.
- Education, herd size and livelihood diversification emerged as key adaptation enablers.
- Socioeconomic capacity and social engagement play a more influential role in shaping how livestock rearers in Bundelkhand respond to climatic risks through adaptation strategies.

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ABSTRACT

The study was conducted in the year 2024-25, assessing both the degree of implementation of adaptation measures and the factors that influence these strategies among livestock rearers in the Banda district of Uttar Pradesh and Chhatarpur district of Madhya Pradesh. A total of 320 livestock rearers were chosen as respondents using a multi-stage sampling method. Eighteen adaptation strategies were identified using a Climate Change Adaptation Index (CCAI), and subsequently analysed through factor analysis and ordinal logistic regression to ascertain the determinants of adaptation behaviour. Findings revealed that maintaining fodder banks (mean score: 1.825), seasonal livelihood diversification (1.6906), and vector control measures (1.4625), were the most frequently adopted strategies. Conversely, preventive healthcare, low-cost housing improvements, and feeding adjustments reflected lower levels of adoption. Factor analysis identified three components, accounting for 72.22 per cent of the total variation. Ordinal logistic regression showed that herd size, community participation and education levels were favourably correlated with enhanced adaptation, but family size showed negative significance. A majority of respondents (66.87%) exhibited a moderate level of adaptability. The results highlighted the disparate adaptive capacities among livestock rearers and the need for targeted extension interventions in the Bundelkhand region.

INTRODUCTION

Climate change has become one of the most significant global challenges of the 21st century, profoundly affecting agriculture and livestock production systems. According to the IPCC Sixth Assessment Report AR6, 2023, warming trends in South Asia are progressing more rapidly than the world average, with the occurrence of heatwaves, droughts, and irregular rainfall patterns. These climatic stressors impact smallholder livestock producers, who depend significantly on climate-sensitive natural resources for feed, water, and pasture. Livestock is a vital element of mixed farming systems in India, offering nourishment, financial security, draught power, and cultural significance; thus, any disturbance in animal productivity and health poses a direct threat to rural livelihoods (IPCC, 2023). India remains one of the most climate-vulnerable countries because rural livelihoods depend heavily on

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climate-sensitive natural resources, and farmers' adaptation decisions are strongly shaped by rainfall variability, temperature stress, and access to institutional support (Jatav & Singh, 2023). The cattle sector in India, while making a substantial contribution to agricultural GDP, is very susceptible to climate variations due to its reliance on rain-fed feed resources and inadequate adaptive infrastructure. Several studies have reported that rising temperatures, diminishing water resources, and increased disease prevalence are adversely affecting livestock productivity throughout the country's agro-climatic region. According to (Maiti et al., 2014) it was found that dairy producers in coastal Odisha and West Bengal increasingly depended on short-term coping methods.

The Bundelkhand region experiences extreme temperatures, unpredictable rainfall, and chronic water scarcity, making dairy farming in the region highly vulnerable to climate variability (Mishra et al., 2025). Irregular rainfall pattern, water shortages, deteriorated pastures, and repeated drought cycles have intensified livelihood insecurity among the livestock-dependent communities. Similar findings have been documented by (Pathak et al., 2024), who reported that livestock rearers face considerable exposure to drought, erratic rainfall and groundwater depletion. The region's significant dependence on indigenous knowledge, restricted access to veterinary services, and inadequate extension systems further hinder livestock rearers from implementing sustainable climate-resilient methods (Tripati et al., 2023). Prior evaluations have highlighted that although livestock rearers in drought-stricken areas employ various practical and economical coping strategies, more substantial and investment-intensive approaches are inadequately utilized owing to financial limitations and insufficient institutional support (Shanthya & Meena, 2024; Singh et al., 2012).

Recent studies show that livestock rearers' adaptation behaviour is shaped by climate exposure, along with socioeconomic and institutional conditions, and that limited technical knowledge can restrict adoption (Pankaj, 2013; Sejian et al., 2015). The growing focus on short-term coping strategies and reactive measures such as heightened watering frequency. altered feeding schedules, and vector control shows the dominance of immediate relief operations over systemic resilience-building initiatives. The IPCC AR6 emphasizes that livestock systems in tropical areas must focus on mitigating heat stress, developing robust feed systems, and enhancing water-use efficiency to maintain productivity and minimize climate-related losses. This study was conducted in Banda (UP) and Chhatarpur (MP), aims to comprehensively assess the adaptation strategies employed by livestock rearers in Bundelkhand and identify the factors influencing their adaptive behaviour.

METHODOLOGY

The study was conducted in the Bundelkhand region of India, focusing specifically on the Banda district in Uttar Pradesh and Chhatarpur district in Madhya Pradesh. These two districts were selected purposively on the basis of highest population of milch animals in the region (Livestock Census, 2019) and because a large share of rural households depend directly on livestock for their livelihoods. The study adopted a descriptive and diagnostic approach to document the adaptation strategies currently practised by livestock rearers and to examine the factors influencing their adoption. A multi-stage sampling method was used to obtain a representative sample from the two districts. In the first stage, two blocks were randomly selected from each district, comprising a total of four blocks. In the second stage, four villages were randomly chosen from each selected block, resulting in sixteen villages. In the third stage, twenty livestock rearers were randomly selected from each village based on two criteria: (i) at least fifteen years of experience in livestock rearing and (ii) ownership of a minimum of four milch animals. This procedure produced a final sample size of 320 respondents. Data were collected using a Climate Change Adaptation Index (CCAI) developed specifically for this study. The index was designed after conducting a pilot survey with 40 livestock rearers from non-sampled villages in the study area. Based on the pilot and expert inputs, eighteen adaptation strategies covering heat stress management, feed and water security, breed selection, housing modifications, milk handling, and animal healthcare were identified. These strategies were further grouped into components through exploratory factor analysis. Respondents indicated their level of adoption for each strategy using three ordered categories: "never adopted (0)," "adopted but discontinued (1)," and "adoption continued (2)." This coding made the dataset suitable for ordinal logistic regression. The explanatory variables included demographic, socioeconomic, and institutional factors such as age, family size, total annual income, herd size, level of education (four categories), farmer-to-farmer extension, social participation, gender, assistance from external agencies, experience of extreme climatic events, and a composite community participation score. Data analysis was carried out using SPSS and Microsoft Excel. Descriptive statistics were used to determine adoption, non-adoption, and discontinuation patterns for each strategy, while mean CCAI scores were employed to rank the strategies according to their relative importance.

RESULTS

Adaptation strategies

The significant variance in Table 1 shows the extent to which livestock rearers implement various methods. The most highly regarded adaptation practices were the maintenance of fodder banks (WMS = 1.8250), followed by seasonal livelihood diversification (1.6906) and vector control and mastitis prevention (1.4625). These approaches were predominantly favoured due to their cost-effectiveness, ease of implementation, and provision of immediate advantages during drought or heat events. In contrast, the methods with the lowest rankings comprised preventative healthcare (0.7781), feeding cattle during cooler hours (0.8063), and structural housing enhancements (0.8281), suggesting that livestock rearers paid significantly less attention to long-term or investment-intensive measures. A significant result is that coping-oriented techniques prevail over planned adaptation measures.

The summary of the factor analysis, in Table 2 presents the latent dimensions underlying the 18 adaptation strategies. The KMO value of 0.721 and a highly significant Bartlett's Test ($x^2 = 2304.987$; $p < 0.001$) confirmed the suitability of the dataset for principal component analysis. Three components with eigenvalues greater than one were extracted, together explaining 72.22% of the total variance. The rotated component matrix (Varimax) revealed clear

Table 1. Ranking of adaptation strategies

S.No.	Statements	WMS	RANK
1.	Extra bathing of cattle and buffaloes	1.4000	4
2.	Search for alternate sources of income (out migration)	0.9063	11
3.	Grow drought or heat resilient green fodders	0.9031	12
4.	Add extra concentrate during heat/drought periods (beyond normal ration)	0.8938	13
5.	Seasonal livelihood diversification (short-term wage/migration, fodder trading, value addition like ghee/khoya)	1.6906	2
6.	Strengthen vector control (ticks/flies) and mastitis prevention (shade at milking, teat dipping, insect repellent smoke, Animal hygiene)	1.4625	3
7.	Adopt low-cost housing improvements (floor drainage, non-slip)	0.8281	16
8.	Provide mineral mixture or feed additives, electrolytes/buffers during heat stress (e.g, ORS, Sodium bicarbonate, salt and urea molasses block	1.1750	5
9.	Improve milk handling in heat (shift milking to cooler hours; shade at collection; insulated cans)	1.1281	7
10.	Prefer local breeds suited to heat or water stress as per local advisories	1.1500	6
11.	Maintain fodder banks (silage/hay) for drought periods	1.8250	1
12.	Instant actions on local weather/heat-cold wave alerts (IMD SMS alerts/KVK/KCC)	1.0500	9
13.	Adjust herd structure seasonally (destocking of chronic low producers before peak drought)	0.9500	10
14.	Seek paravet /veterinary/cooperative advice specifically on heat and drought operations for cattle and buffaloes	1.0750	8
15.	Shift feeding to cooler hours (early morning/late evening); split feeding	0.8063	17
16.	Increase watering frequency; ensure clean, shaded drinking water	0.8344	15
17.	Reduce midday exposure, reschedule grazing/animal movements away from 11:00 AM–04:00 PM	0.8844	14
18.	Preventive Health care (timely vaccination, deworming)	0.7781	18

Table 2. Factor analysis summary for adaptation strategies

KMO and Bartlett's Test			
Test		Value	
KMO Measure of Sampling Adequacy		0.721	
Bartlett's Test of Sphericity (χ^2)		2304.987	
df		55	
Sig.		< 0.001	
Total Variance Explained			
Component	Eigenvalue	% of Variance	Cumulative %
1	4.397	39.97%	39.97%
2	2.006	18.23%	58.20%
3	1.542	14.02%	72.225
Rotated Component Matrix (Varimax)			
Adaptation Strategy	Comp 1	Comp 2	Comp 3
Increase watering frequency	0.939	—	—
Reduce midday exposure	0.936	—	—
Extra concentrate feeding	0.919	—	—
Grow drought resistant fodder	0.846	—	—
Shift feeding to cooler hours	0.597	—	—
Seasonal livelihood diversification	—	0.872	—
Maintain fodder banks	—	0.808	—
Prefer local breeds	—	0.754	—
Alternate income (migration)	—	—	0.841
Weather alert–based actions	—	—	0.747
Low-cost housing improvements	—	—	0.629

and interpretable groupings of adaptation practices. Component 1 represented immediate heat-stress and feeding-water management actions such as increased watering, reduced midday exposure, feeding adjustments, and use of concentrate supplements. Component 2 captured resource-buffering and livelihood security measures, including maintaining fodder banks, preferring heat-tolerant breeds, and engaging in seasonal livelihood diversification. Component 3 included structural and advisory-based strategies such as housing improvements, weather-alert responses, and migration-based income alternatives.

The scree plot, Figure 1 illustrates the eigenvalues corresponding to each component derived from Principal Component Analysis (PCA). An evident inflexion point ("elbow") emerges after the third component, signifying that only the initial three components possess eigenvalues exceeding 1 and significantly contribute to variance explanation. Components 1, 2, and 3 exhibit

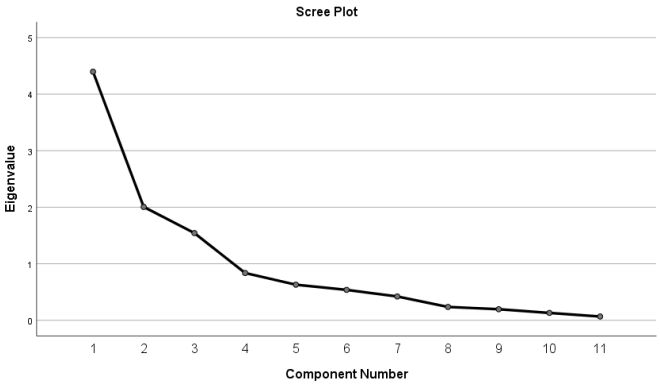

Figure 1. Scree plot for adaptation strategies

significant decreases in eigenvalue magnitude, justifying their preservation, whereas the subsequent components display a generally horizontal trajectory, signifying little explanatory capacity. This visual pattern confirms the factor-analytic findings presented in Table 2, substantiating the extraction of three significant adaption factors from the dataset.

Determinants of adaptation behaviour

The determinants of adaptation behaviour and the underlying structure of adaptation strategies were examined using ordinal logistic regression. The consolidated regression results in Table 3 show the socioeconomic and demographic factors shaping climate adaptation among livestock rearers. The overall model was statistically significant ($\chi^2 = 105.291$, $p < 0.001$), indicating that the selected predictors meaningfully improved the model compared to the intercept-only specification. Both Pearson and Deviance goodness-of-fit tests were non-significant, confirming that the model fits the data well, and the proportional odds assumption was

Table 3. Coefficient estimates for determinants of adaptation

Explanatory Variables		Estimate (β)	Exp (β) Point Estimate	Sig. (p)
Location	Community Participation Total	0.478	0.6200222	0.007**
	Herd Size	0.460	1.58407398	0.000**
	Age	0.015	1.01511306	0.304
	Income Total	5.003E-7	1.0000005	0.644
	Family Size	-0.346	0.70751249	0.000**
	[Education=.00]	-1.205	0.299692	0.020*
	[Education=1.00]	-2.513	0.0810248	0.000**
	[Education=2.00]	-1.347	0.26001915	0.001**
	[Education=3.00]	0[a]	-	.
	[Farmer to farmer extension =.00]	0.068	-	0.888
	[Farmer to farmer extension =1.00]	0[a]	1.07036531	.
	[Social Participation=.00]	-0.518	-	0.175
	[Social Participation=1.00]	0[a]	0.59571078	.
	[Gender=1.00]	0.872	-	0.145
	[Gender=2.00]	0[a]	2.39168945	.
	[Assistance from external agency=.00]	-0.313	-	0.479
	[Assistance from external agency =1.00]	0[a]	0.73124991	.
	[Extreme climatic events experienced=.00]	-0.053	-	0.914
	[Extreme climatic events experienced =1.00]	0[a]	0.94838001	.

**Indicates significant at 1 % level of significance, in a two-tailed test
*Indicates significant at 5 % level of significance, in a two-tailed test

Model fit statistics	
-2 Log Likelihood (Intercept only)	527.766
-2 Log Likelihood (Final model)	422.475
Chi-square	105.291
df	13
p-value	< 0.001

Goodness-of-Fit	Pearson	Deviance
Chi-square	711.828	417.741
df	607	607
Sig.	0.846	1.000

Test of Parallel Lines (Proportional Odds Assumption)	
Statistic	Value
-2 Log Likelihood (Null model)	422.475
-2 Log Likelihood (General model)	400.210
Chi-square	22.265
df	13
Sig.	0.251 (NS → assumption holds)

satisfied ($p > 0.05$), supporting the use of the ordinal logit framework. Among the significant predictors, herd size had a strong positive effect, suggesting that households managing larger herds are more inclined to adopt multiple adaptation strategies, likely due to a higher stake in protecting productive assets. Community participation also showed a positive and significant influence on adaptation, meaning individuals who are more actively involved in local groups or collective activities tend to adopt a wider set of climate-related strategies, possibly because such networks facilitate knowledge exchange, collective learning, and better access to information. Family size, on the other hand, had a negative association with adaptation, indicating that households with more dependents may face constraints in reallocating labour or resources toward new practices. Education further displayed a clear gradient; lower schooling levels were strongly linked with reduced adaptation when compared to the most educated category (0a), which is the baseline category, as shown in the table, indicating higher adaptation in highly educated categories. Other variables such as age, income, gender, extension contact, and exposure to extreme climate events were not statistically significant in predicting adaptation levels. Taken together, the findings suggest that socioeconomic capacity and social engagement, rather than basic demographic attributes, play a more influential role in shaping how livestock rearers in Bundelkhand respond to climatic risks through adaptation strategies.

DISCUSSION

The adaptive behaviour of livestock rearers in Bundelkhand shows a strong reliance on practical, low-cost, and experience-based responses to climate stress, a pattern widely observed across climate-affected regions of India. Similar to the present findings, Pathak et al. (2024) reported that livestock rearers in Bundelkhand preferred easily adoptable, low-investment measures. Comparable behaviour was also documented by Sejian et al. (2015), who noted that livestock rearers generally prioritise immediate heat-stress relief, shade, wallowing, modified grazing schedules, and more water, while long-term structural solutions receive less emphasis. Similar short-term preferences were also observed in semi-arid regions, where adjustments in feeding time and water provision were common, despite sometimes reducing productivity (Mishra et al., 2025). As noted by Das (2017), rising temperature-humidity levels provoke quick adjustments cooling, shading, feeding changes, rather than scientific housing improvements or preventive healthcare. The limited adoption of high-investment measures such as water harvesting, livestock insurance, improved ventilation, and preventive veterinary care reflects financial and technical constraints similar to those noted by (Choudhary, 2020). Chronic issues like weak extension services and persistent fodder scarcity, as highlighted by (Singh et al., 2012 & Das, 2017), also contribute to the reliance on fodder storage, crop residue use, and feeding modifications as key adaptation strategies. Evidence from the Indo-Gangetic Plain also shows that livestock rearers value low-cost climate-smart measures but lack confidence in expensive innovations due to financial risk (Shitu & Nain, 2024). The medium adaptation level among most respondents indicates a partially developed adaptation profile, moderate awareness and practice, but limited depth, similar to the fragmented climate-resilient packages reported in Tamil Nadu by Shanthya and Meena (2024). Socioeconomic factors strongly influence adaptation behaviour. Larger herd ownership had a positive association with adaptation, consistent with the IPCC report, which argues that households with more livestock have greater incentive to protect their assets. In contrast, the negative effect of large family size supports the "financial dilution effect" described by Pankaj (2013), where higher dependency ratios reduce capacity for climate-related investments. Education emerged as a key enabler, supporting (Sejian et al., 2015), who found that educated livestock rearers interpret weather advisories better and adopt improved feeding and health strategies. Similar patterns were observed among tribal dairy farm women in Jammu & Kashmir, where limited education and low empowerment checked the adoption of improved livestock practices (Singh et al., 2017). These studies collectively demonstrate that limited resources, low awareness, and weak access to services suppress long-term adaptation in Bundelkhand as well. Community participation also showed a positive association with adaptation. This aligns with Olawuyi et al. (2021), who found that involvement in social-capital networks significantly increases the likelihood of adopting a wider set of climate-adaptive practices. Likewise, (Chen & Tang, 2025) showed that social networks, trust, and participation all promote multiple adaptation behaviours. These findings suggest that community-based learning and shared support systems enable livestock rearers in Bundelkhand to expand their adaptation behaviour. Factor analysis in this study grouped adaptation strategies into three clusters: (i) heat-stress management, (ii) feed and water security, and (iii) structural or advisory interventions. This aligns with the typology proposed by Prasad et al. (2015), which distinguishes short-term physiological coping, resource buffering, and long-term systemic strategies. The dominance of the first two clusters shows that adaptation in Bundelkhand remains mostly reactive. Along with the regression results, this indicates that adaptation is shaped by financial limits, feasibility, indigenous knowledge, and access to veterinary and advisory services. Enhancing climate-adaptive extension, ensuring fodder and water security, and improving credit access are essential for moving livestock rearers from short-term coping to sustainable, climate-resilient practices.

CONCLUSION

Livestock rearers in the drought-prone Bundelkhand region rely mainly on short-term, experience-based practices to manage rising climate stress. Measures such as fodder storage, seasonal livelihood adjustments, vector control, frequent watering, and altered grazing routines are widely used, while long-term strategies that require higher investment, improved housing, preventive healthcare, water harvesting, or advanced feeding remain limited due to financial and structural constraints. The analysis shows that adaptation is strongly shaped by socioeconomic conditions. Households with larger herd size, better education, and stronger community participation adopt more measures, whereas resource-poor families face greater hurdles. Factor analysis confirms that adaptation is multidimensional, involving heat-stress management, resource buffering, and structural improvements, though the first two dominate. Overall, the study indicates that adaptation in the

Bundelkhand region is still largely reactive, underscoring the need for stronger institutional support through veterinary services, climate-smart extension, drought-resilient fodder options, and accessible credit.

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

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Global Research on Digital Platforms in Rural Knowledge Transfer During 2003-2025: A Bibliometric Analysis

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HIGHLIGHTS

- Research output on digital platforms for rural knowledge transfer increased rapidly after 2015.
- USA, China, and UK lead global contributions with strong institutional collaborations.
- Major themes include digital agriculture, mobile advisory tools, AI learning, and knowledge management.
- Emerging topics involve digital literacy and participatory knowledge systems.
- Bibliometric mapping highlights the need for inclusive digital ecosystems in rural extension.

ARTICLE INFO

Keywords: Agricultural extension, Bibliometric analysis, Digital platforms, Knowledge management, Knowledge transfer.

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ABSTRACT

The study mapped global research on digital platforms in rural knowledge transfer using Scopus-indexed publications published between 2003 and 2025. A total of 251 peer-reviewed documents were analysed using descriptive indicators, citation patterns, and network visualisations. The analysis indicated a consistent increase in research output after 2015, with notable peaks in 2021 and 2023, reflecting the growing adoption of ICTs, mobile applications, and e-learning in agricultural extension. Highly cited publications demonstrated strong scholarly influence in digital learning and technology-enabled advisory frameworks. Country-level analysis identified the United States, China, and the United Kingdom as leading contributors, supported by key institutions such as Wageningen University and the International Institute of Tropical Agriculture (IITA). Keyword co-occurrence mapping revealed dominant themes related to digital agriculture, mobile-based extension, AI-enabled learning, and knowledge management, alongside emerging areas such as digital literacy and participatory knowledge systems. Despite India's extensive digital agriculture initiatives, the limited presence of high-impact Indian studies highlights a critical research gap. The findings underscore the need for context-specific and inclusive digital extension research in India, while outlining future prospects focused on impact evaluation, digital literacy, and participatory platform design.

INTRODUCTION

Rural knowledge transfer remains a cornerstone of agricultural development and extension education, yet many smallholder and marginal farmers in India lack timely and relevant information on agronomic practices, market behaviour, weather advisories, and emerging agricultural technologies, which are essential for productivity and resilience. Surveys indicate that only about 40% of farmers have access to any agricultural information, and fewer than one in ten receive advice from state extension agents, leaving the majority without adequate technical guidance (Singh et al., 2023; Khatri et al., 2024; Krishna & Naik, 2020). Digital platforms including mobile advisory applications, interactive web portals, and social media channels offer mechanisms to enhance information

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dissemination, reach marginalized farmers, and support evidence-based decision-making (Sharma et al., 2025; Yuan & Sun, 2024; Wang & Dong, 2023).

In India, policy initiatives such as the Digital Agriculture Mission, e-NAM, and Kisan Call Centres have accelerated the integration of information and communication technologies into agricultural extension systems, enabling wider access to real-time data, expert guidance, and decision-support tools. Despite these advances, persistent challenges related to digital literacy, connectivity gaps, affordability constraints, and socio-economic disparities continue to influence how rural communities engage with and benefit from digital platforms (Suman et al., 2025; Anteneh & Malek, 2024). Consequently, while digital technologies offer significant opportunities for strengthening advisory services, they also present limitations that necessitate systematic assessment of their research evolution and implications for extension practice (Roy et al., 2024).

Although numerous studies have examined ICT adoption and digital interventions in agriculture, research on digital platforms for rural knowledge transfer remains fragmented across geographical contexts, theoretical perspectives, methodological approaches, and thematic priorities. In India, evidence on the effectiveness, reach, and adoption of these platforms among smallholder farmers is limited, with few studies systematically analysing publication trends, collaborative networks, and thematic directions specific to the country (Ayim et al., 2022; Vishwakarma et al., 2025). Addressing these gaps requires a comprehensive synthesis to identify productivity trends, influential contributors, collaboration patterns, and emerging themes, particularly in India, to inform context-specific strategies and policy interventions (Khatri et al., 2024; Pippi et al., 2025).

Bibliometric analysis provides a rigorous and systematic approach for mapping the intellectual structure and developmental trajectory of a research field. By examining publication patterns, citation influence, co-authorship networks, and keyword co-occurrence relationships, bibliometric techniques offer valuable insights into the evolution of research on digital platforms and rural knowledge transfer (Suman et al., 2025; Roy et al., 2024; Vishwakarma et al., 2025). Such insights are particularly relevant for extension education, as they help identify underexplored themes and inform the design of inclusive, evidence-based digital advisory interventions.

Against this background, the present study undertakes a comprehensive bibliometric analysis of global literature on digital platforms in rural knowledge transfer, with the aim of examining publication and citation trends, identifying leading countries, institutions, and authors, and exploring the thematic structure of the research domain. The findings are expected to provide meaningful insights for researchers, extension professionals, and policymakers seeking to strengthen digital knowledge systems for rural development.

METHODOLOGY

The study adopted a bibliometric approach to analyse global research on digital platforms in rural knowledge transfer. Bibliographic data were retrieved from the Scopus database, a widely used source for large-scale quantitative analysis of scientific publications. A structured search strategy was applied using the following query: (TITLE-ABS-KEY (“digital platform” OR “online platform” OR “ICT platform” OR “mobile application” OR “e-learning” OR “digital technology”) AND TITLE-ABS-KEY (“rural knowledge” OR “knowledge transfer” OR “extension education” OR “agricultural extension” OR “knowledge dissemination “farmer learning”). The initial search covered publications from 2000 to 2025, yielding 1,360 documents. However, the analysis considered only publications from 2003 onwards, as the first relevant study appeared in that year. The dataset was further refined by including only peer-reviewed journal articles and review papers, while conference papers, book chapters, editorials, and other document types were excluded. Subject-area filtering was applied to retain publications indexed under Agricultural and Biological Sciences and Social Sciences, resulting in a final dataset of 251 English-language documents used for analysis. It is acknowledged that Scopus coverage may not include all regional journals or gray literature, which could limit the comprehensiveness of the dataset.

The bibliographic data were exported in CSV format and analysed using VOSviewer and the Biblioshiny interface of the Bibliometrix R-package (Aria & Cuccurullo, 2017; Van Eck & Waltman, 2014). Analyses included publication and citation trends, co-authorship networks, country and institutional contributions, keyword co-occurrence, and thematic structures. Co-occurrence mapping and network visualization techniques were applied to identify collaborative patterns, influential contributors, and emerging thematic directions. This approach allows the identification of underexplored themes, knowledge gaps, and the intellectual structure of research on digital platforms in rural knowledge transfer.

The methodology provides a systematic, transparent, and reproducible framework for mapping the evolution of global research, which is particularly relevant for informing extension strategies and digital advisory interventions, including insights applicable to India and other developing-country contexts.

RESULTS

Publication and citation trends

Research on digital platforms in rural knowledge transfer commenced in 2003 with a single publication receiving 19 citations. Between 2003 and 2006, publication activity remained limited, with typically one article per year. A gradual increase was observed from 2007, with intermittent fluctuations until 2014, which recorded 10 publications generating 348 citations. From 2015 to 2020, annual outputs ranged from 4 to 21 publications, reflecting steady growth. A notable peak occurred in 2021, with 23 publications contributing 750 citations, indicating heightened scholarly engagement. Subsequent expansion was observed in 2023 and 2024, with 37 and 32 publications, respectively, and the highest output occurred in 2025 with 41publications; citation counts for these recent years remain low due to the shorter citation window.

Globally, research activity reflects increasing academic attention to this area, with India contributing 25 publications over 2003–2025, representing approximately 9.2% of the total output. Indian research exhibited gradual growth, with notable contributions

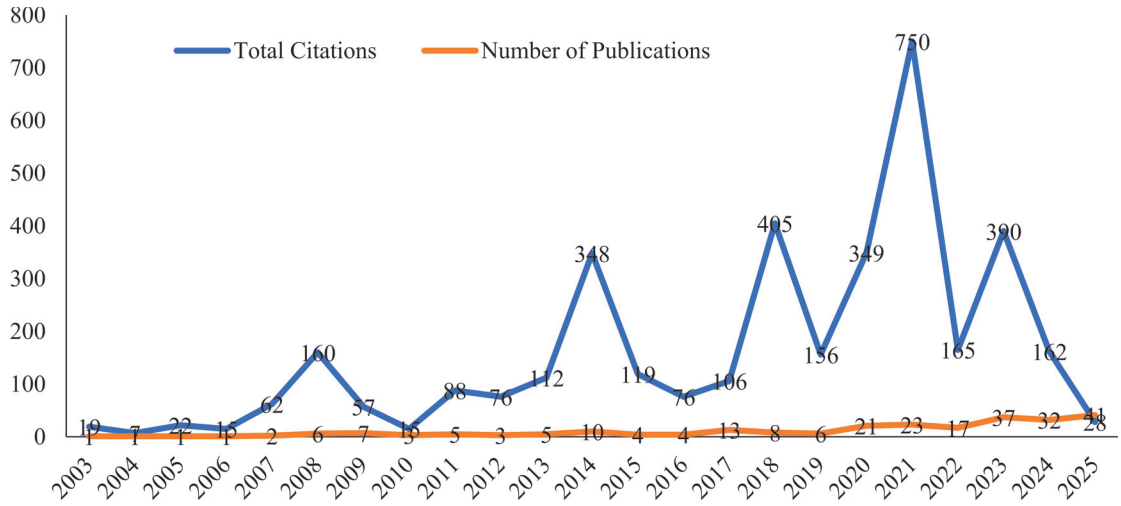

Figure 1. Annual trends in publications and citations in digital platforms for rural knowledge transfer

emerging in recent years, highlighting a growing national interest in digital agricultural advisory systems.

Citation trends revealed early peaks in 2008 (160 citations), 2011 (88 citations), and 2014 (348 citations), followed by substantial increases in 2018 (405 citations) and 2021 (750 citations). The decline in citations during 2023–2025 reflects recency effects rather than reduced research interest. Overall, the results indicate sustained growth in both publication and citation activity globally, alongside an emerging focus in India.

Table 1 presents the most highly cited publications in the field. Zhao et al. (2014) received the highest number of citations (184), followed by Christiaensen et al. (2021) with 155 citations. Other influential contributions included studies by Baceviciute et al. (2021); Demetriadis et al. (2008) and Leszczynski et al. (2017), reflecting the prominence of research on digital learning technologies, multimedia applications, and technology-enabled knowledge dissemination.

Productivity of countries, institutions, and authors

The distribution of research output across countries, institutions, and authors is summarized in Table 2 and 3. At the country level, the United States emerged as the leading contributor with 81 publications and 322 citations, demonstrating both high productivity and scholarly impact. China ranked second with 45 publications and 95 citations, followed by the United Kingdom with 43 publications and 180 citations. Canada contributed 29 publications with 86 citations. Notably, India produced 25 publications with 55 citations, representing approximately 9% of the global research output and highlighting its emerging role in digital platforms for rural knowledge transfer. This indicates a growing research interest in India, but also points to potential for increasing the visibility and impact of Indian studies in the field.

Institutional analysis showed that Wageningen University ranked highest in terms of citation influence, with five publications generating 256 citations. King Khalid University and the International Institute of Tropical Agriculture (IITA) also demonstrated notable scholarly impact despite a smaller number of publications, with citation counts of 177 and 198, respectively. Other institutions, including the University of Zambia and the University of Belgrade, exhibited emerging contributions with fewer

Table 2. Country-Level Productivity

Country	Number of Publications	Number of Citations
USA	81	322
China	45	95
United Kingdom	43	180
Canada	29	86
India	25	55

Table 1. Most cited documents on digital platforms in rural knowledge transfer

Author(s)	Title of the article	Year of publication	Journal	Total citations
Zhao et al. (2014)	Online Transfer Learning	2014	*Artificial Intelligence*	184
Christiaensen et al. (2021)	Viewpoint: The Future of Work in Agri-Food	2021	*Food Policy*	155
Baceviciute et al. (2021)	Remediating Learning from Non-Immersive to Immersive Media: Using EEG to Investigate the Effects of Environmental Embeddedness on Reading in Virtual Reality	2021	*Computers & Education*	123
Demetriadis et al. (2008)	The Effect of Scaffolding Students' Context-Generating Cognitive Activity in Technology-Enhanced Case-Based Learning	2008	*Computers & Education*	110
Leszczynski et al. (2017)	Multimedia and Interactivity in Distance Learning of Resuscitation Guidelines: A Randomised Controlled Trial	2017	*Interactive Learning Environments*	92

Source: Compiled from Scopus database (authors' analysis)

Table 3. Affiliation Productivity

Affiliations	Number of Publications	Number of Citations
Wageningen University	5	256
King Khalid University	4	177
International Institute of Tropical Agriculture (IITA)	3	198
University of Zambia	3	39
University of Belgrade	2	27

publications and citations. Notably, no Indian institutions appeared among the top contributors, indicating an opportunity for Indian research organizations to increase both output and visibility in the area of digital platforms for rural knowledge transfer. This underscores a research gap in India and highlights the potential for strengthening institutional participation and scholarly impact in this domain.

Analysis of authors' contributions revealed that Zhang X, Wang Y, and Chen Y were the most productive, each publishing three articles. These authors are recognized experts in innovation systems and agricultural extension, and their work emphasizes the importance of contextualized approaches to rural knowledge transfer. Leeuwis C and Van Mele P, with two publications each, demonstrated high scholarly impact, receiving 139 and 57 citations, respectively. Notably, no Indian authors appeared among the top contributors, highlighting a research gap and an opportunity for Indian researchers to increase both productivity and influence in the field. This underscores the potential for strengthening India's contribution to global research on digital platforms in rural knowledge transfer.

Table 4. Author productivity

Author	Number of Publications	Number of Citations
Zhang X	3	21
Wang Y	3	12
Chen Y	3	3
Leeuwis C	2	139
Van Mele P	2	57

Thematic structure of research based on keyword co-occurrence analysis

The thematic structure of the literature was examined using keyword co-occurrence analysis, and the resulting clusters are illustrated in Figure 2. The analysis revealed ten distinct thematic clusters representing the major research streams in digital platforms for rural knowledge transfer. Cluster 1 (red) focuses on digital platforms, extension, higher education, information and communication, internet, and social networks, highlighting the role of digital infrastructures in facilitating knowledge dissemination. Cluster 2 (green) emphasizes agricultural extension, digital agriculture, ICT, rural development, and technology adoption, representing the application of digital tools in agricultural and rural contexts. Cluster 3 (blue) links digitalization, sustainability, smallholder farmers, and COVID-19, indicating research attention to technology adoption and resilience in crisis situations.

Education-oriented themes dominate several clusters. Cluster 4 (yellow) centers on e-learning, distance learning, mobile learning, and educational technology, while Cluster 5 (purple) captures online learning, social media, Facebook, and medical education, reflecting platform-specific learning environments, particularly during the COVID-19 pandemic. Cluster 6 (light blue) integrates knowledge management, knowledge sharing, and tacit knowledge, underscoring organizational and cognitive dimensions of knowledge exchange. Cluster 7 (orange) highlights emerging pedagogical approaches through artificial intelligence, blended learning, and digital technologies in education. Cluster 8 (light grey) connects digital literacy, knowledge transfer, and organizational learning, reinforcing capacity-building perspectives. Finally, Clusters 9 (light pink) and 10 (light yellow) represent niche but evolving themes related to lifelong learning, pedagogical issues, and Moodle, respectively.

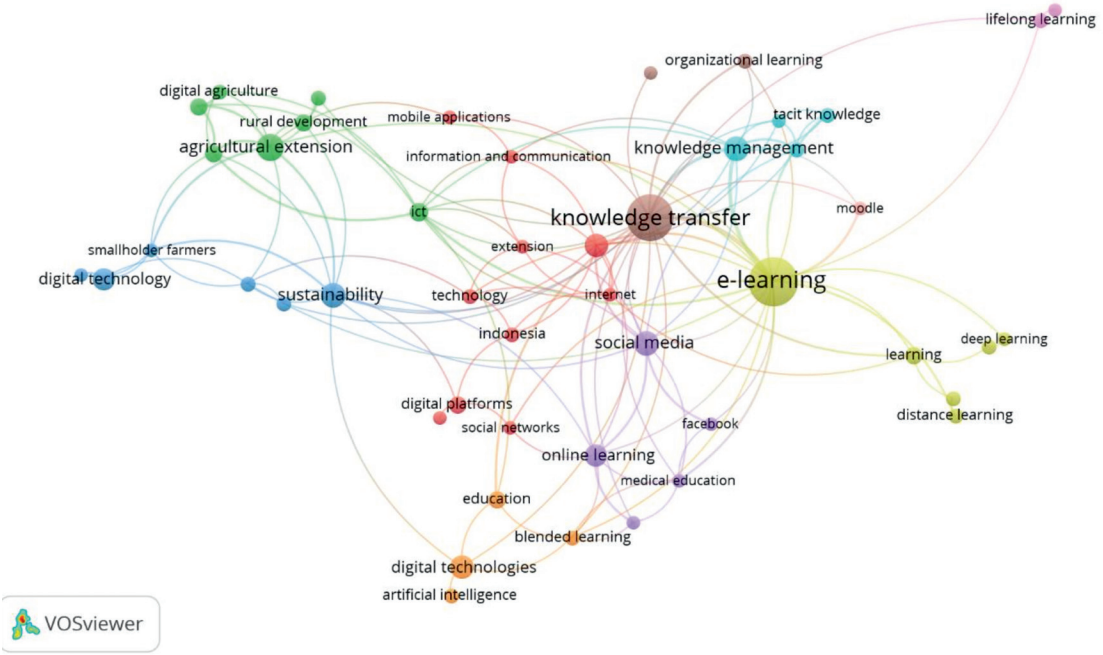

Figure 2. Network visualization of keyword co-occurrence clusters

Keyword density visualization of research themes

The keyword density visualization further reveals the intellectual hotspots of the field. The highest-density areas are centered on "knowledge transfer" and "e-learning," confirming their centrality in the literature. Strong concentrations around knowledge management, social media, online learning, and digital platforms indicate sustained scholarly focus on digital-mediated knowledge dissemination. Moderate-density themes such as agricultural extension, digital agriculture, sustainability, and smallholder farmers highlight applied research in rural and agricultural settings. In contrast, lower-density but emerging themes including artificial intelligence, blended learning, organizational learning, and lifelong learning point to evolving research directions. The density map demonstrates a convergence of education, agriculture, and digital technologies, reinforcing the growing role of digital platforms in rural knowledge transfer.

DISCUSSION

The study demonstrates a clear evolution in global research on digital platforms for rural knowledge transfer, highlighting how technological advancements continue to reshape extension discourse. Research output, which gradually emerged in the early 2000s and accelerated after 2015, reflects the increasing centrality of ICTs in agricultural knowledge systems, driven by the rapid expansion of mobile connectivity, declining data costs, and policy initiatives promoting digital agriculture and e-governance in rural development. These findings are consistent with prior evidence that mobile platforms, web-based systems, and AI tools improve accessibility and timeliness of advisory information for farmers, despite persistent structural challenges such as the digital divide and infrastructure gaps (Priya et al., 2025). The notable increase in publications during and after the COVID-19 pandemic corresponds with global shifts toward remote advisory services and virtual learning, reinforcing the observation that ICT adoption in agriculture accelerates under constrained traditional information channels (Aker, 2011). This surge also indicates the responsiveness of extension research to external disruptions, as conceptual frameworks adapt to new technological and societal conditions.

Differences in country-level contributions further illustrate uneven but widening global engagement with digital extension. While technologically advanced countries such as the United States, the United Kingdom, and China dominate output, growing contributions from Africa and Asia reflect broader recognition of digital platforms' role in strengthening advisory ecosystems. However, effective ICT integration depends not only on technological availability but also on institutional capacity, enabling policies, and user-oriented extension structures responsive to local needs (Khatri et al., 2024; Mukherjee et al., 2025), echoing extension scholarship that emphasizes innovation, localized knowledge, and continuous outreach (Nain, 2015). Authorship patterns further reveal distinctions between consistent publication output and citation influence, highlighting how sustained contributors shape empirical discourse while highly cited authors guide theoretical development, including technology adoption frameworks relevant to digital extension systems (Wang & Dong, 2023).

Thematic analysis of keywords indicates a shift from conventional dissemination models toward interactive, personalized, and data-driven advisory services. Prominent clusters related to digital agriculture, mobile technologies, artificial intelligence, and e-learning demonstrate that ICTs increasingly facilitate two-way communication, improve decision-making, and expand information access in rural contexts (Khwidzhilli et al., 2025; Reed et al., 2020). Knowledge management and organizational learning perspectives further suggest that digital platforms support participatory and networked systems, moving beyond one-way extension delivery toward collaborative learning environments. Nevertheless, persistent challenges such as digital literacy gaps, uneven connectivity, and socio-economic disparities continue to shape differential access and outcomes (Salemink et al., 2017), underscoring the need for context-sensitive digital interventions.

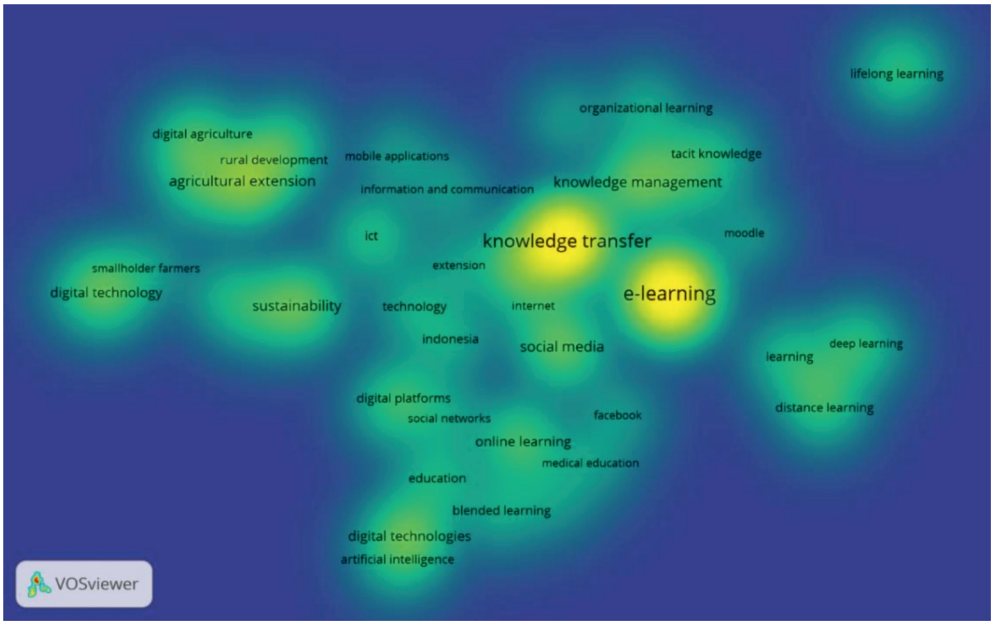

Figure 3. Density visualization of keyword occurrences in digital platforms in rural knowledge transfer (VOSviewer)

The findings suggest that future rural advisory systems will increasingly depend on hybrid knowledge environments that blend traditional extension approaches with digital intelligence. Strengthening digital competencies among extension professionals and farmers, designing locally relevant and user-friendly platforms, and integrating participatory feedback mechanisms are critical to ensuring inclusivity and effectiveness. For countries such as India, aligning digital extension initiatives with grassroots institutions and supportive policy frameworks can enhance scalability and sustainability. By synthesizing thematic evolution and contextual implications, this study provides actionable insights for policymakers, extension agencies, and researchers seeking to build resilient, inclusive, and equitable digital knowledge ecosystems.

CONCLUSION

Research on digital platforms for rural knowledge transfer has expanded substantially over the past two decades, reflecting the growing integration of technology in agricultural extension services. Thematic trends indicate a shift from traditional extension practices to technology-mediated, learner-centred approaches, including digital agriculture, mobile technologies, artificial intelligence, and e-learning systems. Despite these advancements, challenges such as digital literacy gaps, connectivity limitations, and socio-economic disparities continue to influence equitable access and adoption. These findings provide practical guidance for policymakers and extension practitioners to design scalable, hybrid advisory systems that combine conventional methods with innovative digital tools, enhancing knowledge access, community empowerment, and sustainable rural development while ensuring extension services remain inclusive, effective, and responsive to evolving technological and societal needs.

DECLARATIONS

Ethics approval and consent to participate: This study is based entirely on bibliometric analysis using the Scopus database accessed through IMI, Delhi. Publications were selected according to predefined inclusion and exclusion criteria. As no human or animal subjects were involved, formal ethical approval or informed consent was not required.

Conflict of interest: The author confirms 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 Tool

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A Scale for Measuring Entrepreneurial Orientation of Farmers' Producer Companies towards Secondary Agriculture

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HIGHLIGHTS

- Scale was constructed for measuring the entrepreneurial orientation of FPCs engaged in secondary agriculture.
- Scale consisting 38 items distributed across eight dimensions, namely innovativeness, proactiveness, risk-bearing ability, achievement motivation, self-confidence, management orientation, market orientation, and leadership orientation with a Cronbach's alpha of 0.938 and further standardised through Split-half and Pearson's correlation values 0.824 and 0.907, respectively.
- The instrument facilitates policymakers, extensionists, and researchers in diagnosing and strengthening agripreneurship among farmer-led organisations.

ARTICLE INFO

Keywords: Entrepreneurial orientation, Farmer-producer companies, Scale construction, Secondary agriculture, Reliability and Validity.

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ABSTRACT

The Farmers' Producer Companies in India play an important role in secondary agriculture (an entrepreneurial endeavour) through collective action. The study was conducted in 2025 and aimed to construct a scale measuring the entrepreneurial orientation of FPCs' member farmers in the context of secondary agriculture. Sixty statements were shortlisted after screening of 84 statements using Edwards' criteria for relevancy test. Consequently, 38 items were observed as relevant by following the criteria RW $\geq$ 0.80 and MRS $\geq$ OMRS. The discriminatory power of scale was further tested using the t-test with a cut-off value of 1.75. The final scale covered 38 items grouped under eight dimensions, namely innovativeness, proactiveness, risk-bearing ability, achievement motivation, self-confidence, management, market, and leadership orientation. The scale showed an excellent reliability, evidenced by Cronbach's alpha value of 0.938. Split-half and Pearson correlation results obtained 0.824 and 0.907, respectively, which also confirmed high reliability. Validity was established through expert judgment. The scale may help policymakers and researchers design evidence-based interventions to strengthen agripreneurship and rural development.

INTRODUCTION

Entrepreneurial Orientation (EO) refers to a firm's propensity toward innovation, proactiveness, and risk-taking when pursuing new opportunities (Lumpkin & Dess, 1996; Miller & Le Breton-Miller, 2011; Irwin et al., 2018; Wales et al., 2021). In the context of agriculture, EO influences farmers' willingness to adopt new technologies, diversify production, and explore value-added activities, thereby enhancing their income and resilience (Wiklund & Shepherd, 2003). Secondary agriculture encompasses endeavors that add value through the primary processing of agricultural products, using locally sourced materials and engaging rural manpower, skills, and inputs, and ultimately contributing to wealth creation at the rural level (DFI report volume IX, 2018). At the individual level, however, practicing secondary agriculture, which represents an entrepreneurial endeavor, is more challenging for small

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and marginal farmers, who account for over 86.1 percent of the farming population of India (Saha et al., 2023; Mukherjee et al., 2025). This situation underscores the need for collective approaches, which are promoted through Farmers' Producer Companies (FPCs). FPCs are farmer-led enterprises that aim to strengthen the collective capacity of farmers to access markets, credit, technology, and training (Yadav et al., 2022). By enabling aggregation, collective decision-making, and shared ownership, FPCs act as catalysts for rural economic development (NABARD, 2020; Agarwal & Goyal, 2022; Gupta et al., 2022, Gupta et al., 2023). Accordingly, their role in facilitating value addition, particularly through secondary agriculture, is significant. More specifically, secondary agriculture encompasses post-harvest processes such as grading, processing, packaging, and marketing of agricultural products; these activities help reduce wastage, improve shelf-life, and create new income streams for farmers (FAO, 2017). Chengappa (2013) defined secondary agriculture as all practices and processes that add value to primary agricultural commodities by using efficient technologies, market information, and consumer preferences. Therefore, the integration of EO within FPCs engaged in secondary agriculture holds immense potential to promote agripreneurship and rural entrepreneurship. An entrepreneurial orientation enables FPCs to actively explore opportunities in value addition, innovate in marketing strategies, and invest in processing technologies. As a result, they enhance product differentiation, generate employment, and improve farmers' income (Kumar et al., 2021).

However, despite the recognized importance of EO in secondary agricultural contexts, existing tools for measuring EO among farmer collectives remain limited. Most studies focus on individual-level entrepreneurship or broader organizational settings without accounting for the unique challenges and dynamics within FPCs involved in secondary agriculture (Kuratko et al., 2017). Earlier scales lack contextual relevance such as collective decision-making, market access challenges, or technology adoption barriers faced by FPCs (Covin & Slevin, 1989). This gap highlights the urgent need for a validated scale typically designed to assess EO of FPCs' member farmers operating in Secondary Agriculture. A reliable measurement tool may be helpful to identify the entrepreneurial orientation of these organizations, guiding capacity-building efforts and policy interventions. It also enables following researchers to assess how EO contributes to the sustainability and scalability of agripreneurial activities. In this regard, constructing and validating an EO scale tailored to the secondary agriculture context provides a foundation for evidence-based decision-making. It ensures that interventions are rooted in an accurate understanding of the entrepreneurial mindset and behaviors prevalent among FPCs. Furthermore, it contributes to academic literature by providing a standardized tool that can be adapted and used across diverse rural settings. By addressing the measurement gap, this study aims to facilitate more robust research and informed policymaking in rural entrepreneurship, thus promoting the sustainable development of farmer-led enterprises.

METHODOLOGY

In the present investigation (conducted in 2025), Entrepreneurial Orientation (EO) of FPCs in Secondary Agriculture was operationalized as the collective tendency member farmers to adopt innovations, take risks, explore opportunities, set goals, manage resources, respond to markets, and lead efforts for value addition and organizational growth. The EO scale was constructed by utilizing summated rating method developed by Likert (1932). In the beginning, a total of 84 statements were collected under eight different dimensions followed by screening based on 14 informal criteria advocated by Edwards (1957) and 60 statements were selected out of the initial 84 for further relevancy testing using the following formulas:

$$RW = \frac{MR + R + SWR + LR + NR}{MPS}$$

$$MRS = \frac{MR + R + SWR + LR + NR}{n}$$

$$OMRS = \frac{MR + R + SWR + LR + NR}{n \times s}$$

Whereas, RW = Relevancy Weightage, MRS = Mean Relevancy Weightage, OMRS = Overall Mean Relevancy Weightage, MR = Most relevant (5) R = Relevant (4), SWR = Somewhat Relevant (3), LR = Less Relevant (2), NR = Not Relevant (1); MPS = Maximum Possible Score (60 × 5 = 300); n = Number of judges (46); s = Number of Statements (60).

Experts were asked to rate each item on a five-point continuum. Based on the responses received from 46 judges, a total of 38 statements were found to be relevant for the study. These 38 statements were then used for calculating t-value and statements had a t-value ≥ 1.75 finally selected in the scale. For computing t-value, following formula was used:

$$t = \frac{\bar{X}H - \bar{X}L}{\sqrt{\frac{\Sigma(X_H - \bar{X}_H)^2 + \Sigma(X_L - \bar{X}_L)^2}{n(n-1)}}}$$

Whereas,

$\Sigma(X_H - \bar{X}_H)^2 = \Sigma(X_H)^2 - (\Sigma(X_H)^2/n$ and $\Sigma(X_L - \bar{X}_L)^2 = \Sigma(X_L)^2 - (\Sigma(X_L)^2/n$

$\bar{X}_H$ = Mean score of given statements in the high group,

$\bar{X}_L$ = Mean score of given statements in the low group,

$\Sigma(X_H)^2$ = Sum of squares of individual scores on a given statement for the high group,

$\Sigma(X_L)^2$ = Sum of squares of individual scores on a given statement for the low group,

ΣX_H = Summation of scores on a given statement for the high group,

ΣX_L = Summation of scores on a given statement for the low group, and

t = The extent to which a particular statement discriminate between the high and low group.

The scale's reliability was assessed using the split-half technique, and its validity was established through a content validity. The reliability coefficient (R) of the entire scale was calculated using the formula:

$$R = \frac{2r}{1+r}$$

Where "*r*" represents the Pearson's product-moment correlation between the two halves. Data analysis was carried out with the help of MS Excel and SPSS software.

RESULTS

The statistics shown in Table 1 includes 38 statements measuring Entrepreneurial Orientation of Farmers' Producer Companies (FPCs) in Secondary Agriculture. These items were finalized for the scale after carrying out the relevancy test followed by reliability and validity analysis.

Table 1. RW, MRS, OMRS and t-value of each selected statement

S.No. Statements	RW	MRS	t-value
I. Innovativeness			
1. I actively seek information on emerging opportunities in secondary agriculture.	0.809	4.043	5.167
2. I actively explore innovative solutions to overcome challenges in secondary agriculture.	0.813	4.065	6.089
3. I invest in modern technologies to enhance post-harvest processing and value addition.	0.830	4.152	6.283
4. I take the initiative to launch new agricultural products before others in the market.	0.809	4.043	5.553
II. Proactiveness			
5. I frequently experiment with new farming techniques to improve product quality.	0.817	4.087	3.466
6. I am usually first in my community to implement new Secondary agricultural practices.	0.800	4.000	6.626
7. I consistently monitor agricultural trends to maintain a forward-looking approach.	0.865	4.326	5.252
8. I routinely update my farming, processing and marketing practices to stay competitive.	0.839	4.196	7.370
9. I properly allocate resources to identify and explore untapped markets for my products.	0.813	4.065	3.929
II. Risk-Bearing Ability			
10. I am willing to invest in new secondary agricultural ventures despite potential losses.	0.830	4.152	4.668
11. I am comfortable with the possibility of failure when trying new methods.	0.835	4.174	4.870
12. I assess the risks and benefits before making significant investments.	0.817	4.087	4.331
13. I have contingency plans in place for potential setbacks.	0.822	4.109	3.704
IV. Achievement Motivation			
14. I set measurable goals to increase our farm's profitability.	0.843	4.217	6.579
15. I seek recognition for our firm's achievements in secondary agriculture.	0.848	4.239	3.128
16. I am motivated by the success stories of other innovative farmers.	0.839	4.196	3.945
17. I set challenging yet attainable targets for farm expansion.	0.843	4.217	5.392
18. I use setbacks as motivation to work harder towards our objectives.	0.830	4.152	5.379
V. Self-Confidence			
19. I trust my skills in implementing secondary agricultural practices.	0.826	4.130	4.379
20. I believe I can overcome challenges in value-added production.	0.817	4.087	4.311
21. I am confident in teaching fellow farmers in innovative secondary agricultural techniques.	0.804	4.022	2.009
22. I trust my judgment in selecting high-potential agricultural ventures.	0.848	4.239	2.361
23. I am self-assured in marketing our farm's value-added products.	0.809	4.043	6.497
VI. Management Orientation			
24. I develop detailed plans for integrating secondary agriculture into our operations.	0.809	4.043	4.347
25. I organize resources efficiently and delegate tasks appropriately to enhance productivity and accomplishing targets.	0.813	4.065	5.529
26. I make strategic decisions that align with our long-term goals in secondary agriculture.	0.848	4.239	4.710
27. I regularly review and update our farm's business plan to adapt to changing circumstances.	0.822	4.109	2.750
28. I allocate time for regular team meetings to discuss farm operations and address any issues.	0.813	4.065	3.098
VII. Market Orientation			
29. I adjust our product offerings based on feedback from buyers and market trends.	0.848	4.239	3.685
30. I explore new markets to expand the reach of our firm's value-added products.	0.809	4.043	4.488
31. I participate in agricultural fairs and exhibitions and other platforms for promoting our products among potential buyers.	0.813	4.065	5.367
32. I gather customer feedback to improve the quality and appeal of our products.	0.804	4.022	3.166
33. I stay updated on pricing trends to competitively price our value-added products.	0.861	4.304	5.185
VIII. Leadership Orientation			
34. I inspire and motivate team members to achieve our firm's objectives in secondary agriculture.	0.843	4.217	4.077
35. I provide clear direction and guidance to ensure alignment with our firm's vision.	0.878	4.391	5.511
36. I foster a collaborative environment where team members feel valued and heard.	0.826	4.130	3.188
37. I encourage open communication to share ideas, address challenges, manage conflicts.	0.822	4.109	2.319
38. I recognize and reward team members' contributions to our firm's success.	0.804	4.022	2.784

RW = Relevancy Weightage; MRS = Mean Relevancy Score; OMRS = Overall Mean Relevancy Score OMRS = 3.992

Relevancy analysis

In the present study, an initial pool of 84 statements was developed for measuring the entrepreneurial orientation of Farmers' Producer Companies (FPCs) in the context of secondary agriculture. These statements were first screened using the fourteen informal criteria proposed by Edwards (1957), which are widely applied in scale development to ensure clarity, relevance, and non-redundancy of items. After this screening, 60 items were retained for further analysis and proposed for relevancy testing by a panel of experts. A total of 160 experts from different professional backgrounds were approached, including academicians, extension professionals, researchers, and officials working in relevant fields. However, out of the 160 experts contacted, 46 judges possessing desirable subject knowledge and adequate professional experience responded within the stipulated time frame of one month. The responses of these judges were carefully compiled, and each statement was analyzed with the help of Microsoft Excel to determine its Relevancy Weightage (RW) and Mean Relevancy Score (MRS). These two parameters ensured that only the items meeting both statistical and conceptual criteria were selected. Specifically, statements with a relevance weightage of 0.80 or higher, along with an MRS equal to or greater than the overall mean relevance score (OMRS), were considered suitable for inclusion (Panigarhi et al., 2024; Vavilala et al., 2024; Singh et al., 2025). As a result of this rigorous analysis (Table 1), 38 statements out of the original 60 were retained for subsequent testing. These 38 items were then subjected to a t-test to examine their discriminatory power between respondents with high and low levels of entrepreneurial orientation. As suggested in previous methodological studies (Lal et al., 2014), the t-value is an effective measure for assessing the extent to which each statement distinguishes between the two groups. Considering the earlier researches of Shitu et al. (2018); Vijayan et al. (2022); Chandra et al. (2024); Panigarhi et al. (2024); Vavilala et al. (2024); Kademini et al. (2025) for computation of t-statistics, data were collected from 60 FPC's member farmers of non-sampled area through personal interviews for each item, and the items found a t-value of 1.75 or higher were finalized, which is the criteria determined by Edwards (1957). This ensured that only the most relevant and discriminating items were included in the final scale.

Table 2. Reliability Statistics of Entrepreneurial Orientation of Farmers' Producer Companies (FPCs) in Secondary Agriculture

Cronbach's Alpha	Part 1	Value	.923
		N of Items	19[a]
	Part 2	Value	.862
		N of Items	19[b]
	Total N of Items		38
Correlation Between Forms			.701
Spearman-Brown Coefficient	Equal Length		.824
	Unequal Length		.824
Guttman Split-Half Coefficient			.796

a. The items are: S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19.

b. The items are: S20, S21, S22, S23, S24, S25, S26, S27, S28, S29, S30, S31, S32, S33, S34, S35, S36, S37, S38.

Reliability and validity analysis

Reliability means how consistent the results are when the same thing is measured many times. In this study, the Cronbach's alpha coefficient was used to check internal consistency of the tool (Shukla et al., 2024; Bandhavya et al., 2025). Table 2 that the Cronbach's alpha value was 0.938, which indicates excellent level reliability of the scale. To further confirm reliability, the split-half method was used, where the Spearman-Brown coefficient was 0.824 and Pearson's correlation was 0.907, both showing strong consistency (Prabex et al., 2025). Validity shows whether a scale measures what it is meant to measure. Content validity (also employed by Chandra et al., 2024; Mallappa & Gadde, 2025; Shanila & Helen, 2025) focuses on whether the items in the scale properly cover the subject area. In this study, content validity was ensured by selecting items from related literature and by taking opinions from experts in extension who have good experience in this field (Lal et al., 2015).

DISCUSSION

The present study constructs and validates a reliable scale to measure Entrepreneurial Orientation (EO) of Farmers' Producer Companies (FPCs) in the context of secondary agriculture. The findings indicate that the developed instrument demonstrates both high reliability and validity, thereby confirming its suitability for assessing EO in farmer-led collectives (Chandra et al., 2024; Mallappa & Gadde, 2025; Shanila & Helen, 2025). The Cronbach's alpha coefficient of 0.938 reflects excellent internal consistency, suggesting that the items included in the scale consistently capture the underlying construct of EO. The strong split-half and Pearson correlation values further strengthen the robustness of the tool, aligning with recommendations of Edwards (1957). The study highlights the multidimensional nature of EO among FPCs, encompassing innovativeness, proactiveness, risk-bearing ability, achievement motivation, self-confidence, management orientation, market orientation, and leadership orientation. These dimensions aligned with the conceptualization of EO by Lumpkin and Dess (1996), who emphasize the role of innovation, proactiveness, and risk-taking in entrepreneurial success. The high relevancy scores and significant t-values of the selected items indicate that farmers perceive these orientations as critical for value addition, risk management, and organizational sustainability. The inclusion of 38 refined statements out of an initial pool of 84 ensures both contextual relevance and conceptual clarity, consistent with earlier research on scale adaptation in organizational studies (Covin & Slevin, 1989). The results indicate that FPCs are progressively embracing entrepreneurial approaches that correspond to the evolving requirements of value-added agriculture. Farmers recognize the importance of experimenting with new technologies, exploring market opportunities, and developing systematic management strategies. In agricultural contexts, Kumar et al. (2021) and FAO (2017) emphasize that innovation in post-harvest processing and market integration plays a crucial role in strengthening rural entrepreneurship. The present study confirms that such orientations are reflected in the collective decision-making and practices of FPCs.

The strong reliability and validity of the tool also imply its potential use in future research and policy interventions.

Policymakers and extension professionals can apply the findings to design capacity-building programs that strengthen leadership, encourage innovation, and improve market orientation. This aligns with NABARD, (2020) and Wales et al. (2021), which stresses the role of FPCs as vehicles of rural economic empowerment. The scale provides a standardized framework to assess the entrepreneurial mindset of FPCs member famers across regions and commodities. The tool can further serve as a diagnostic mechanism for identifying areas where FPCs require targeted support, such as risk assessment, marketing skills, or managerial efficiency. Overall, the study contributes to bridging a significant methodological gap in agricultural extension and rural entrepreneurship research. By offering a validated EO scale tailored to secondary agriculture, it facilitates evidence-based planning and supports the promotion of agripreneurship in India. The findings reaffirm the importance of fostering entrepreneurial orientation in farmer collectives to enhance their resilience, profitability, and long-term sustainability.

CONCLUSION

The study develops and validates a reliable and context-specific scale for measuring Entrepreneurial Orientation (EO) of member farmers of Farmers' Producer Companies (FPCs) engaged in secondary agriculture. The Entrepreneurial Orientation scale consists of 38 statements and has been empirically tested for reliability and validity. It is broadly categorized into eight key dimensions. The results confirm that EO plays a decisive role in enhancing collective decision-making, value addition, and sustainability of FPCs. The present scale has significant implication across the researchers, policymakers, and extension professionals. It provides a validated tool for assessing EO in farmer-led organizations, enabling evidence-based interventions. Policymakers can use it to design targeted programs that strengthen managerial capacity, innovation, and market integration. Extension agencies can apply the tool as a diagnostic measure to identify gaps in entrepreneurial behaviour and provide tailored support. Ultimately, the scale contributes to promoting agripreneurship, improving farm profitability, and advancing rural economic development.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the 46 judges of the statements/ items 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 Tool

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Construction of a Knowledge Test on Papaya Ring Spot Virus Management Practices

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HIGHLIGHTS

- Developed and validated a 25-item knowledge test on PRSV management for papaya farmers in Bihar.
- Item analysis ensured high reliability (KR-20 = 0.92; Cronbach's α = 0.968) and strong content validity.
- It enables assessment of knowledge gaps and supports targeted training to improve PRSV management practices.

ARTICLE INFO

Keywords: Knowledge test, Papaya ring spot virus, PRSV management, Item analysis, Reliability, Content validity.

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ABSTRACT

The study was conducted during 2024–25 to develop and standardise a scientifically sound knowledge test for assessing papaya farmers' knowledge of Papaya Ring Spot Virus (PRSV) management practices in Bihar. An initial pool of 35 dichotomous items was prepared through an extensive literature review, expert consultation, and extension manuals. These items were pre-tested with 30 non-sample farmers, and item analysis was performed using the Difficulty Index, Discrimination Index, and Point-Biserial Correlation. Based on psychometric evaluation, 25 items representing preventive, cultural, chemical, and biological management practices were retained. The finalised test demonstrated high reliability, as indicated by KR-20 (0.92), split-half reliability (0.928), and Cronbach's alpha (0.968), while content validity was confirmed through expert judgment. The standardised tool provides an objective and reliable method to assess knowledge gaps, facilitate targeted training programmes, and evaluate extension interventions. It holds potential for broader application in papaya-growing regions to strengthen PRSV management and promote sustainable papaya cultivation.

INTRODUCTION

Accurate assessment of farmers' knowledge is a critical component of extension research, as knowledge provides the cognitive foundation for adoption of improved agricultural technologies and behavioral change. Psychometrically constructed knowledge tests are widely used to objectively measure farmers' understanding, as they ensure validity, reliability, and discriminatory power compared to unstructured surveys (Kesänen et al., 2014; Chandraker et al., 2021). Such tools are essential for identifying gaps, designing farmer-centric training programmes, and evaluating the effectiveness of extension and policy interventions. In the context of crop protection, where disease management practices often involve complex, multi-component strategies, reliable measurement of farmer knowledge becomes particularly important for ensuring technology dissemination and adoption.

Papaya (*Carica papaya* L.) is a highly significant horticultural crop in India due to its short gestation, high yield potential, and dual economic value as both a nutritional fruit and an industrial raw material. Though India remains the world's largest producer of papaya, with production of 5.24 million tones in 2023, yet disease pressures continue to limit its productivity (FAO, 2023; NHB, 2023). Among the biotic stresses, Papaya Ring Spot Virus (PRSV)

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is the most destructive, causing 50–80 per cent yield losses and threatening farmer livelihoods across major producing states, including Bihar (Chakraborty et al., 2019; Kumar et al., 2021). Transmitted in a non-persistent manner by several aphid species, PRSV spreads rapidly and is difficult to control with chemical measures alone, making integrated management strategies essential. Recommendations such as rouging of infected plants, use of border crops, raising seedlings under insect-proof nets, balanced nutrient application, and vector management using biological and chemical methods have been validated under research conditions (ICAR, 2021; Jacobsen et al., 2004).

Despite the availability of these integrated management practices, adoption among farmers remains inconsistent. Studies indicate that sub-optimal adoption is less a matter of technological availability and more the result of inadequate farmer knowledge, poor access to reliable advisory services, and dependence on pesticide dealers or informal networks for guidance (Myeni et al., 2019; Campenhout et al., 2020). While a few KAP (Knowledge, Attitude, and Practice) studies have attempted to assess farmer behavior in papaya cultivation, they often rely on non-standardized tools that lack precision and comparability. Without a validated and objective instrument, it is difficult to reliably measure actual knowledge levels, discriminate between low, medium, and high knowledge groups, or design targeted training programmes.

In this backdrop, the construction of a standardized knowledge test on PRSV management practices is essential. Although developed in Bihar, where PRSV incidence remains a major constraint to productivity, the tool has the potential for wider application in other papaya-growing regions of India facing similar challenges. By ensuring psychometric rigour in measuring knowledge, the study seeks to contribute both methodologically to extension research and practically to sustainable papaya production and farmer livelihood security.

METHODOLOGY

The study was conducted in Begusarai district of Bihar, with pre-testing carried out in Bachwara block, which was considered a non-sampling area to avoid bias in the main study. A preliminary pool of 35 knowledge items related to Papaya Ring Spot Virus (PRSV) management practices were initially developed through literature review, consultation with subject-matter specialists, and extension manuals. All items were framed as dichotomous questions, scored as "1" for a correct response and "0" for an incorrect response. The draft test was administered to 30 non-sample papaya farmers, and their responses were used for item analysis to refine the tool.

Item analysis was conducted using three statistical criteria: Difficulty Index, Discrimination Index, and Point-Biserial Correlation. The Difficulty Index (Garrett, 1996; Ray & Mondal, 2014; Vijayan et al., 2022; Vijayan et al., 2023) was defined as the percentage of respondents answering correctly, with an acceptable range of 30–80% for item retention. The Discrimination Index was computed using the E1/3 method (Mehta, 1958), which measures the ability of an item to differentiate between high- and low-scoring respondents, with acceptable values ranging between 0.30 and 0.75. Additionally, the Point-Biserial Correlation Coefficient (Garrett, 1996) was calculated to examine the relationship of each item with the total test score, ensuring that selected items had significant positive correlations at 5% and 1% levels of significance. Based on these criteria, 25 out of the 35 items were retained for the final test, representing preventive, cultural, chemical, and biological aspects of PRSV management.

The reliability of the knowledge test was assessed through internal consistency methods. The test was administered to 30 non-sample respondents, and all responses were found to be valid, ensuring 100% usable data for reliability analysis. The split-half method (odd–even division) was used, and the obtained correlation between the two halves was corrected using the Spearman–Brown prophecy formula. Additionally, the Guttman Split-Half Coefficient and Cronbach's Alpha were computed to determine internal consistency, following standard psychometric procedures adopted in earlier agricultural extension research (Lal et al., 2014; Lal et al., 2016; Kumar et al., 2016).

The validity of the knowledge test was established through content validation by a panel of experts comprising specialists in agricultural extension, plant pathology, and experienced farmers. The experts evaluated each item for clarity, relevance, and comprehensiveness, ensuring that the instrument adequately represented all dimensions of PRSV management and was both valid and reliable for measuring farmers' knowledge.

RESULTS

Psychometric item analysis

The item analysis revealed substantial variation in the performance of the preliminary 35 items. The difficulty index (P) of items ranged from 0.20 to 0.76. Items falling outside the acceptable range (i.e., <0.30 or >0.80) were excluded to ensure balanced representation of knowledge questions. Accordingly, 10 items were discarded as they were either too difficult (e.g. "Boerhaavia diffusa root extract effective for PRSV management" with DI = 0.13) or too easy (e.g., "Do oils like neem oil delay PRSV incidence?" with DI = 0.74). The remaining 25 items fell within the acceptable range (0.30–0.80) and were retained for the final scale.

The discrimination index (D) values of the items ranged between 0.10 and 0.55. Items with discrimination indices below 0.30 were eliminated, as they failed to effectively distinguish between high- and low-knowledge farmers. Out of 35 items, 25 items recorded D values between 0.30 and 0.55, and were therefore selected.

The point-biserial correlation (rpb) values ranged from 0.09 to 0.76. Items with rpb < 0.30 were considered weak and removed. Finally, 25 items with statistically significant correlations (at 5% and 1% levels) were retained, confirming that these items were consistent indicators of farmers' knowledge of PRSV management.

Validity of selected items

The validity of the items was established through point-biserial correlation analysis. Only those items with $rpb > 0.30$ were retained as valid. In addition, expert validation was undertaken by plant pathologists, extension scientists, and experienced papaya farmers to ensure that the selected 25 items comprehensively

Table 1. Item Analysis Outcomes: Difficulty, Discrimination, and Point-Biserial Metrics

S. No.	Items	Difficulty Index (%)	Discrimination Index	Point-Biserial Correlation (rpbi)
1	Was the use of Nylon net (40–60 mesh) effective in reducing PRSV incidence?	60.00	0.55	0.573**
2	Does the use of yellow sticky traps help in reducing aphid population & subsequently PRSV incidence?	46.67	0.50	0.573**
3	Is the eradication of infected plants and host plants of aphids a method used to control PRSV?	53.33	0.30	0.431*
4	Did the use of row covers show any significant difference in PRSV incidence?	60.00	0.30	0.573**
5	Can removal (rouging) of infected plants reduce disease incidence in the field?	30.00	0.30	0.502**
6	Are there PRSV-resistant or tolerant papaya varieties available?	30.00	0.30	0.609**
7	Was the use of two rows of maize/sesbania as a border crop effective in reducing PRSV incidence?	63.33	0.50	0.538*
8	Can crop rotation help break the PRSV disease cycle?	70.00	0.50	0.690**
9	Can planting papaya in isolated areas help prevent PRSV disease?	66.67	0.10	0.681**
10	Should papaya be planted in the month of October after the rainy season to manage PRSV?	56.67	0.20	0.645**
11	Is a chlorine solution (70–100 ppm) recommended for sanitizing installations and equipment?	30.00	0.30	0.551**
12	Can planting rows in the same direction as wind increase disease spread?	56.67	0.30	0.551**
13	Does balanced fertilization help manage PRSV?	66.67	0.40	0.655**
14	Can training and pruning improve airflow and reduce disease risk?	43.33	0.40	0.538*
15	Is spacing between plants important for PRSV disease reduction?	66.67	0.30	0.645**
16	Is regular field monitoring and decision-making based on thresholds practiced?	70.00	0.40	0.690**
17	Can planting disease-free seedlings help prevent initial infection?	66.67	0.40	0.655**
18	Can removing PRSV-infected papaya plants as soon as symptoms appear reduce the chances of infection in healthy plants?	73.33	0.30	0.725**
19	Was Dimethoate (1.05%) effective in reducing PRSV incidence?	73.33	0.40	0.717**
20	Can Urea, Zinc Sulphate induce resistance against PRSV in papaya?	73.33	0.30	0.725**
21	Can Boron application prevent PRSV disease spread?	66.67	0.50	0.655**
22	Is Acephate effective in controlling aphid vectors of PRSV?	60.00	0.50	0.586**
23	Is Imidacloprid used to reduce aphid populations and PRSV spread?	70.00	0.50	0.690**
24	Do oils like Neem oil cake and Groundnut oil delay PRSV appearance?	73.67	0.50	0.760**
25	Can Neem Oil (7%) + sticker be used as foliar protection against PRSV?	73.33	0.50	0.725**

Legend: rpbi=Point-biserial correlation coefficient; ** "Correlation is significant at the 0.01 level (2 tailed)". "* Correlation is significant at the 0.05 level (2-tailed)"

represented the domain. Their critical review confirmed that the tool adequately covered the technical, cultural, and chemical management dimensions of PRSV, thereby establishing strong content validity.

Reliability of the knowledge tool

The internal consistency of the tool was assessed through multiple approaches, including KR-20 reliability coefficient, split-half method, and Cronbach's alpha. The KR-20 coefficient was found to be 0.92, indicating high internal consistency. The split-half method yielded a correlation of 0.869 between odd–even items, which, when adjusted using the Spearman-Brown prophecy formula, gave a reliability value of 0.928. Similarly, the Guttman Split-Half Coefficient was 0.927. Cronbach's Alpha of the final 25-item scale was 0.968, which demonstrates excellent reliability, far exceeding the minimum threshold of 0.70 recommended for social science research instruments (Lal et al., 2016).

Thus, the final PRSV knowledge test comprising 25 items was found to be both valid and reliable for assessing the knowledge of papaya farmers regarding Papaya Ring Spot Virus (PRSV) management practices.

DISCUSSION

The present study successfully developed and standardized a 25-item knowledge test to assess papaya farmers' knowledge of Papaya Ring Spot Virus (PRSV) management practices. The psychometric evaluation of the items revealed that the Difficulty Index values of the selected items were within the acceptable range of 30–80 percent, ensuring that the questions were neither overly easy nor too difficult. This balance is critical for achieving discrimination among respondents and aligns with the recommended standards for knowledge test construction in agricultural extension research (Ray & Mondal, 2014; Sinha et al., 2020). The Discrimination Index values (0.30–0.55) indicated that the retained items were effective in differentiating between farmers with high and low levels of knowledge, a finding consistent with earlier test development studies (Lal et al., 2015; Mehta, 1958).

The strong point-biserial correlation coefficients further established item validity, suggesting that each retained question contributed meaningfully to the overall measurement of PRSV knowledge. This finding is supported by previous works in psychometric tool construction, where point-biserial analysis has been emphasized as a robust method for identifying valid knowledge items (Garrett, 1996; Hopkins, 1998). Importantly, the incorporation of technical, cultural, and chemical control practices into the test ensured comprehensive coverage of PRSV management strategies, reflecting expert validation and contextual relevance.

The reliability analysis further strengthened the credibility of the tool. The KR-20 coefficient (0.92), split-half reliability (0.928), and Cronbach's Alpha (0.968) demonstrated excellent internal

consistency, exceeding the generally accepted threshold of 0.70 for social science research instruments (Lal et al., 2016; Kline, 2000). These values also compare favorably with earlier studies on knowledge test construction in agriculture (e.g., Lal et al*.,* 2014; Sharma & Singh, 2023), underscoring the robustness of the PRSV-specific tool. The triangulation of multiple reliability measures further confirms that the instrument is stable and dependable for assessing farmers' knowledge.

The study makes a significant contribution to extension research by addressing a critical gap in plant disease management. While several knowledge tests have been developed for crop management practices, few have specifically targeted viral diseases in horticultural crops. By focusing on PRSV a major constraint in papaya cultivation the tool not only provides a standardized measure of farmer knowledge but also offers a practical basis for designing targeted capacity-building programs. Moreover, the inclusion of practices such as roguing, resistant varieties, border cropping, reflective mulching, and safe pesticide use ensures that the tool is aligned with integrated pest and disease management approaches, thus promoting sustainable solutions.

In summary, the developed knowledge test is a scientifically validated, reliable, and context-specific instrument for assessing farmers' knowledge of PRSV management.

CONCLUSION

This study developed and standardized a 25-item knowledge test specifically designed to assess papaya farmers' understanding of Papaya Ring Spot Virus (PRSV) management practices. The tool, validated through expert judgment and psychometric analysis, demonstrated excellent reliability and internal consistency, ensuring its scientific soundness. By encompassing cultural, preventive, biological, and chemical control measures, it provides a comprehensive means of evaluating farmer knowledge. Beyond research utility, the test can serve as a practical tool for extension professionals to identify knowledge gaps, design targeted training programmes, and monitor the effectiveness of interventions. Thus, the standardized knowledge test represents a valuable contribution to extension research and practice, with the potential to strengthen PRSV management, enhance technology adoption, and support sustainable papaya cultivation and farmer livelihoods.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the 30 non-sampled farmer judges of the statements/ items 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 Tool

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Development and Validation of a Nutrition Literacy Scale for Rural Women in India

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HIGHLIGHTS

- A 57-item nutrition literacy scale (NLS RW) was developed and validated for rural women in India (2024–25).
- The scale demonstrated excellent internal consistency (Cronbach's $\alpha = 0.948$) and content validity.
- The tool captures multidimensional aspects of nutrition literacy, including cognitive, functional, interactive, and critical skills.
- Provides a culturally relevant instrument for assessing and improving nutrition literacy in rural communities.

ARTICLE INFO

Keywords: Nutrition literacy, Rural women, Scale development, Psychometrics, Women's health.

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ABSTRACT

Nutrition literacy (NL) is essential for fostering and sustaining healthy dietary behaviours. However, data on NL among rural women in India are limited, and existing measurement tools lack cultural appropriateness for this population. To address this gap, this study conducted during 2024–2025, developed and validated the Nutrition Literacy Scale for Rural Women (NLS-RW), measuring; cognitive, functional, interactive, and critical domains of NL. An initial pool of 100 statements was generated and then refined to 95 items. Relevancy testing with 60 subject matter experts using a five-point scale informed retention decisions was performed based on relevancy percentage (RP), relevancy weightage (RW), and mean relevancy score (MRS). Item analysis with a sample of 64 rural women aged 15–49 years from three districts of Jharkhand (Chatra, Ranchi, and Khunti) was conducted. Reliability was assessed using split-half correlation (Spearman–Brown adjustment) and Cronbach's alpha. Content validity yielded a scale-level content validity index (S-CVI/Ave) of 0.92, indicating excellent content validity. The final scale comprised 57 items and showed excellent internal consistency (Cronbach's $\alpha = 0.948$; Spearman–Brown coefficient = 0.968). The NLS-RW comprehensively captures multiple dimensions of nutrition literacy among rural women.

INTRODUCTION

Women play a pivotal role in ensuring food security at both household and global levels as primary food producers, processors, and distributors. Globally, they contribute nearly half of total food production, and in Asia, they provide approximately 65% of household food supply. In India, 73.2% of rural women engage in agricultural activities (Agriculture Census, 2015–16), and their participation continues to rise due to male migration to urban regions, a trend known as the feminisation of agriculture (Economic Survey, 2017–18).

Despite their central contribution to food production and nutrition management, rural women experience persistent challenges, including limited educational opportunities, inadequate healthcare access, and restrictive socio-cultural norms that negatively influence nutritional well-being. Malnutrition among Indian women remains

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a major public health concern, with 18.7% undernourished and 57.0% anemic (NFHS-5, 2021). Simultaneously, 41.3% of women are overweight or obese, illustrating the double burden of malnutrition (Economic Survey, 2023–24). Dietary patterns reflect further imbalance, as rural diets remain predominantly cereal-based, contributing 65.2% of total caloric intake compared to the recommended 45%, while consumption of protein (11%), vegetables (8.8%), and dairy products (8.7%) falls below recommended levels (ICMR-NIN, 2024). Additionally, increased consumption of ultra-processed foods in urban areas contributes to India's rising obesity and diabetes rates (Economic Survey, 2023–24).

Nutrition challenges stem from financial constraints (Darnton-Hill et al., 2005), limited access to diverse foods (Allen, 2005; Nguyen et al., 2012), cultural dietary beliefs (Briones, 2018), and an often overlooked but critical factor–nutrition literacy. Nutrition literacy refers to the ability to obtain, process, understand, and apply nutrition information to make informed dietary decisions (Zoellner et al., 2009) and includes functional, interactive, and critical domains based on Nutbeam's framework. Higher levels of nutrition literacy associated with healthier dietary practices and a reduced risk of chronic diseases (Carbone et al., 2012; Bauer et al., 2014). However, most existing nutrition literacy assessment tools, such as the Newest Vital Sign (NVS) and the Nutrition Literacy Assessment Instrument (NLit), originate from Western contexts and lack cultural relevance for rural Indian women. They do not reflect regional dietary patterns, food availability, socio-economic constraints, or linguistic diversity, limiting their applicability and accuracy.

The present study develops and validates the Nutrition Literacy Scale for Rural Women (NLS-RW), a context-specific assessment tool designed to measure functional, cognitive, interactive, and critical dimensions of nutrition literacy. It hypothesises that a culturally relevant and scientifically validated scale captures nutrition literacy more accurately than existing tools and supports targeted intervention strategies. By enabling more informed dietary choices, the scale has the potential to improve nutritional outcomes, break intergenerational cycles of malnutrition, and support India's public health priorities, aligning with global goals such as the FAO's advocacy for dietary diversity (2019) and the Global Nutrition Report (2021).

METHODOLOGY

Nutrition literacy in this study was defined following Silk et al. (2008) as the capacity to obtain, process, and understand nutrition information and apply it for appropriate dietary decisions. It was operationalized as a combined ability to acquire, comprehend, communicate, and critically evaluate food and nutrition information across cognitive, functional, interactive, and critical domains. The Nutrition Literacy Scale for Rural Women (NLS-RW) was developed using the summated rating method proposed by Likert (1932) with modifications as suggested by Edwards (1957) and Patil et al. (1996). An initial pool of 100 statements relating to nutrition knowledge, skills, practices, and decision-making was collected from literature, expert inputs, and field observations. After screening based on established criteria for statement construction (Thurstone & Chave, 1929; Edwards & Kilpatrick, 1948), 95 items were retained for expert evaluation.

Expert judgment was obtained from 60 subject specialists who rated each item on a five-point scale from 1 (not relevant) to 5 (most relevant). Relevancy Percentage was calculated as:

$$RP = (FS / N) \times 100,$$

Where, FS represented the frequency of responses marked "relevant" or "most relevant," and N was the number of experts.

Relevancy Weightage was calculated as:

$$RW = [(MR\times5 + R\times4 + SWR\times3 + LR\times2 + NR\times1) / MPS] \times 100,$$

Where, MR = most relevant, R = relevant, SWR = somewhat relevant, LR = less relevant, NR = not relevant, and MPS = maximum possible score (60×5 = 300).

The Mean Relevancy Score (MRS) was computed by dividing the total score by the number of judges, and the Overall Mean Relevancy Score (OMRS) was calculated across all items. Items with RP ≥ 80%, RW ≥ 0.80, and MRS greater than OMRS were retained, yielding 65 items.

Item analysis was conducted among 64 rural women aged 15–49 years from Chatra, Ranchi, and Khunti districts of Jharkhand selected through probability proportional to size (PPS) sampling. The top and bottom 25% scorers were compared using the t-test method described by Edwards (1957), retaining items with $t \geq 1.75$, resulting in a final scale with 59 items.

Reliability was assessed through the split-half method using Pearson's correlation and adjusted using the Spearman–Brown formula

$$R = 2r / (1 + r)$$

Where, r represented correlation between halves.

Cronbach's alpha was computed to determine internal consistency. Content validity was ensured through expert evaluation. Ethical approval was obtained from the Institutional Ethics Committee, and informed consent was collected from all participants prior to data collection.

RESULTS

The development of the Nutrition Literacy Scale for Rural Women (NLS-RW) involved a systematic refinement process from the initial pool of 100 statements to a final set of 57 items. Figure 1 summarizes the sequence from item generation, expert screening,

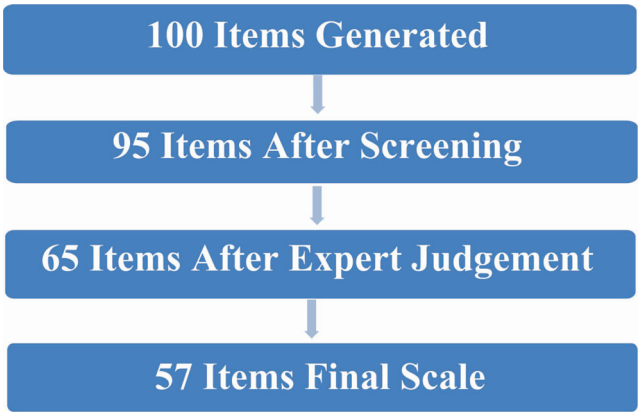

Figure 1. Flowchart of the scale development process for the Nutrition Literacy Scale for Rural Women (NLS-RW)

relevancy evaluation, and item discrimination testing. Of the 95 items screened through expert judgment, 65 met the predetermined cut-off values based on relevancy percentage, relevancy weightage (RW), and mean relevancy score (MRS). Subsequent item analysis using the top- and bottom-quartile comparison further refined the pool which resulted in a final NLS-RW comprising 57 items.

Across these 57 items, RW ranged from 0.81 to 0.92, MRS ranged from 4.03 to 4.62, and t-values ranged between 2.06 and 10.95, indicating that all retained items met the criteria for both content relevance and discriminating power. The items collectively covered seven sub-dimensions of nutrition literacy, reflecting a comprehensive conceptualization of dietary knowledge and behavior. The distribution of items across sub-dimensions was as follows: knowledge and understanding of food and nutrition (14 items), awareness of food safety and hygiene (6 items), understanding determinants influencing nutritional health (17 items), information search and practical meal-planning skills (7 items), interpersonal communication skills (2 items), critical evaluation of nutrition-related information and marketing (4 items), and willingness to act to improve nutrition behaviours (7 items). This balanced representation ensures that the scale captures both knowledge-based and behavior-oriented aspects of nutrition literacy.

A summary of mean RW, MRS, and t-value ranges for each sub-dimension is presented in Table 1, which is further organized into sub-tables (Tables 1A–1D) for improved readability. Table 1A presents items related to knowledge and understanding, Table 1B to food safety and hygiene, Table 1C to determinants of nutritional health, and Table 1D to practical skills, interpersonal communication, critical evaluation, and action-oriented behaviours. Within the determinants of nutritional health sub-dimension, RW values ranged from 0.81 to 0.90, MRS from 4.03 to 4.48, and t-values from 2.06 to 8.51. In the action-oriented sub-dimension, RW ranged from 0.81 to 0.88, MRS from 4.07 to 4.42, and t-values from 3.26 to 5.94. Table 2 provides a concise overview of the number of items under each sub-dimension.

The psychometric analysis demonstrated strong reliability and validity of the NLS-RW. The Cronbach's alpha value of 0.948 indicated excellent internal consistency, suggesting that the items measured a cohesive construct. The Spearman–Brown coefficient (0.968) and Pearson correlation coefficient (0.938) further confirmed

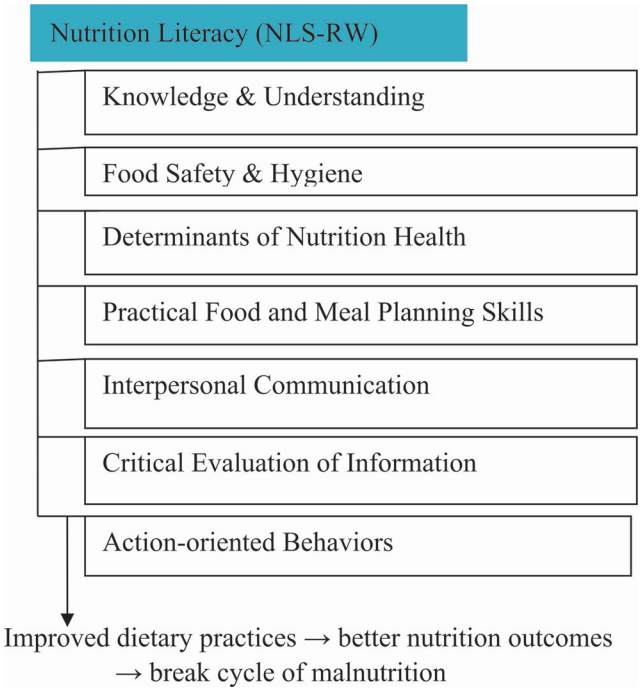

Figure 2. Conceptual Model

Table 1. Summary of retained items with mean RW, MRS, and t-value range

Item Example	RW Range	MRS Range	t-value Range
Knowledge & Understanding of Food and Nutrition (n = 14)			
Example: Vegetables and fruits provide vitamins and minerals	0.82–0.92	4.03–4.62	2.06–10.95
Food Safety & Hygiene (n = 6)			
Example: Boiling is a healthy cooking method	0.82–0.86	4.08–4.30	3.43–7.75
Determinants of Nutritional Health (n = 17)			
Smoking harms health; Sunlight improves Vitamin D absorption	0.81–0.90	4.03–4.48	2.06–10.95
Skills, Interpersonal Communication, Critical Evaluation & Action (n = 20 total)			
Practical food planning & selection (7)	0.81–0.86	4.03–4.30	3.74–6.43
Interpersonal communication m (2)	0.83–0.85	4.13–4.23	3.07–4.43
Critical evaluation of marketing info (40	0.83–0.89	4.15–4.47	4.45–9.60
Action & behaviour (7)	0.81–0.88	4.07–4.42	3.26–5.94

Table 2. Summary of Items by Sub-dimension

Sub-Dimension	Number of items	Interpretation
Knowledge & understanding	14	Awareness of essential nutrition concepts
Food safety & hygiene	6	Understanding of clean and safe food practices
Determinants of health	17	Ability to link nutrition, lifestyle & health
Practical nutrition skills	7	Hands-on food planning and preparation
Interpersonal communication	2	Sharing and discussing nutrition
Critical evaluation	4	Judging marketing and media claims
Action & behavior	7	Readiness to adopt healthy choices

high split-half reliability and internal stability of the scale. Content validity was supported through expert evaluation, with a scale-level content validity index (S-CVI/Ave) of 0.92, indicating excellent agreement among experts regarding item relevance. The consistently high t-values across items also confirmed good discriminatory capacity between respondents with higher and lower nutrition literacy.

Overall, the results indicate that the NLS-RW is a valid, reliable, and multidimensional tool for assessing nutrition literacy among rural women, with items that are both psychometrically sound and contextually appropriate for rural Indian settings.

DISCUSSION

The present study develops and validates a nutrition literacy scale tailored to rural women, structured across four domains: cognitive, functional, interactive, and critical. The final 57-item tool demonstrates strong psychometric properties, with excellent reliability and satisfactory validity, confirming its utility in assessing the multidimensional nature of nutrition literacy in rural contexts. The high relevancy weightages and mean relevancy scores across items reflect strong expert consensus regarding the appropriateness of the statements. This finding is consistent with previous work emphasizing the need for culturally grounded and contextually appropriate nutrition literacy instruments (Shitu et al., 2018; Gupta et al., 2022; Shelar et al., 2022; Vavilala et al., 2024; Singh et al., 2025). It also aligns with conceptualisations of Kickbusch et al. (2006) and Sørensen et al. (2012), who define nutrition literacy as extending beyond knowledge acquisition to include practical skills, interpersonal communication, and critical evaluation. The present tool integrates these dimensions, thereby expanding the scope of measurement compared to earlier unidimensional scales.

Reliability measures further reinforce the strength of the scale. The Cronbach's alpha coefficient of 0.948 far exceeds the recommended threshold of 0.70 (Nunnally & Bernstein, 1994), while the Spearman–Brown coefficient (0.968) and Pearson's correlation (0.938) indicate strong internal stability. These findings are comparable to those reported for global tools such as the Newest Vital Sign (Diamond, 2007) and the Nutrition Literacy Assessment Instrument (Gibbs et al., 2016), suggesting that the present scale meets international standards of methodological rigor while retaining contextual relevance.

The focus on contextual adaptation is a major contribution of this research. Expert validation ensured that the scale captured locally relevant concerns such as food hygiene, breastfeeding, dietary diversity, and the use of indigenous foods. Prior studies highlight that generic constructs often fail to reflect the realities of rural populations (Velardo, 2015; Vidgen & Gallegos, 2014). In India, for instance, Chakrabarti et al. (2019) observe that limited nutrition awareness constrains household and child health outcomes, while Ghosh-Jerath et al. (2016) note that women in Jharkhand, despite access to diverse local foods, often lack adequate dietary knowledge. Johri et al. (2016) further demonstrate that improving women's nutrition literacy directly enhances maternal and child health indicators. The present scale addresses these documented gaps by offering a structured and standardized assessment tool grounded in rural women's experiences.

The multidimensional nature of the instrument also deserves emphasis. By including domains related to interpersonal communication and critical evaluation of marketing and media claims, the tool reflects the socially embedded nature of nutrition decision-making. Similar findings are reported by Aihara and Minai (2011) and Zoellner et al. (2011), who stress the role of interactive and critical skills in empowering women to negotiate household food choices and resist misleading influences. The results suggest that nutrition literacy should not be viewed solely as an individual cognitive attribute but as a socially mediated competence.

At the same time, certain limitations should be acknowledged. The sample size, though sufficient for preliminary validation, is restricted to three districts of Jharkhand and may limit generalizability to broader geographic or cultural contexts. Self-reported responses may also introduce social desirability bias. Additionally, the study did not incorporate objective outcome measures such as dietary intake or biochemical indicators, which could further strengthen validation. Future research may consider larger, multi-state samples, longitudinal evaluations, and triangulation with behavioral or clinical indicators.

Despite these limitations, the study holds important practical implications. The scale can be used by health educators, frontline workers, and policymakers to diagnose literacy gaps, design tailored educational interventions, monitor program effectiveness, and prioritize resource allocation. It also offers valuable guidance for integrating nutrition literacy into community-based programs and schemes such as Integrated Child Development Scheme (ICDS), Prime Minister's Overarching Scheme for Holistic Nourishment (POSHAN Abhiyaan), and women's self-help group initiatives. Overall, the tool establishes a strong foundation for advancing research, program design, and policy interventions aimed at strengthening nutrition outcomes in rural communities.

CONCLUSION

By capturing cognitive, functional, interactive, and critical dimensions of nutrition literacy, the NLS-RW provides a culturally sensitive and comprehensive tool tailored to rural Indian contexts. Its application can facilitate the identification of literacy gaps, inform targeted interventions, and support policy actions aimed at strengthening community nutrition initiatives, promoting dietary diversity, and enhancing the effectiveness of government health programs, and self-help group–based nutrition campaigns. While the tool reflects rigorous validation, further testing across diverse socio-cultural regions is recommended to enhance generalizability. The NLS-RW holds significant potential for future research by enabling longitudinal evaluation of nutrition education strategies and assessing the impact of interventions on behavioral and health outcomes. Overall, the NLS-RW offers a robust foundation for advancing nutrition education and addressing the persistent double burden of malnutrition among rural women in India.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the 60 subject matter specialist and 64 women judges (for relevancy testing) of the statements/ items 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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APPENDIX

Final List of Items Included in the Nutrition Literacy Scale for Rural Women (NLS-RW)

Instructions: Respondents rate each statement on **a 5-point Likert scale:**

5 – Strongly Agree | 4 – Agree | 3 – Neutral | 2 – Disagree | 1 – Strongly Disagree

Higher scores indicate greater nutrition literacy.

Sub-Dimension 1: Knowledge and Understanding of Nutrition (14 items)

1. Vegetables and fruits are rich sources of vitamins and minerals.
2. No single food provides all the nutrients needed for good health.
3. Green leafy vegetables improve eye health and blood health.
4. Iodine deficiency can lead to goiter.
5. Calcium is essential for healthy growth and bone development.
6. Pregnant and lactating women need extra food and health care.
7. Obesity increases the risk of high blood pressure, heart disease, diabetes, and cancer.
8. Foods high in fiber help reduce constipation.
9. Early and exclusive breastfeeding for the first six months is essential for newborn health.
10. Milk is a rich source of essential nutrients for all age groups.
11. Iron-rich foods like green leafy vegetables, legumes, and meat prevent anemia.
12. Immunization of children and pregnant women is important.
13. Adequate water intake helps maintain good health.
14. A balanced diet includes grains, fruits, vegetables, milk, meat, and eggs.

Sub-Dimension 2: Food Safety and Hygiene (6 items)

15. Boiling is a healthy cooking method.
16. Properly cleaned and cooked green leafy vegetables are safe for infants.
17. Wash vegetables before chopping to conserve nutrients.
18. Cooking at very high temperatures may destroy nutrients.
19. Contaminated food can cause illness.
20. Eggs and meat should be thoroughly washed and cooked.

Sub-Dimension 3: Determinants of Nutritional Health (17 items)

21. Smoking harms health.
22. Excessive consumption of oil, red meat, ghee, butter, and cheese can lead to obesity and heart disease.
23. Milk provides quality protein and calcium and is essential for whole family.
24. Alcohol and tobacco should be avoided during pregnancy and breastfeeding.
25. Combining cereals with pulses improves protein quality in a meal.
26. Green leafy vegetables aid digestion.
27. Regular physical activity, yoga, and exercise keeps one physically and mentally fit.
28. Breastfeeding lowers the risk of infections in infants.
29. A diet rich in calcium, iron and essential nutrients is vital for growth.
30. Refined flour (*maida*) and hydrogenated fats (*dalda*) are unhealthy.
31. Soft drinks and soda are harmful to health.
32. Sunlight helps maintain Vitamin D levels.
33. Parboiled or unpolished rice is healthier than polished rice.
34. Artificial food colors and flavors may be harmful.
35. Oral rehydration solution (ORS) helps manage dehydration during diarrhea.
36. Too much sugar is harmful to health.
37. Fasting for long periods may affect health.

Sub-Dimension 4: Practical Meal-Planning and Selection Skills (7 items)

38. Selecting safe food is important for a healthy diet.
39. I eat a variety of foods to ensure balanced diet.
40. I prepare the right amount of food to avoid wastage.
41. I prepare, process and store food in a clean and hygienic way.
42. I check freshness and quality before buying fruits and vegetables.
43. I prefer fresh, locally available vegetables and fruits.
44. I use whole grains, nuts, and oilseeds in meals.

Sub-Dimension 5: Interpersonal Communication (2 items)

45. I discuss nutrition-related information with others.
46. I encourage my friends and family to eat healthy foods.

Sub-Dimension 6: Critical Evaluation of Nutrition Information (4 items)

47. I buy food products that are properly packed and certified.
48. I check expiry dates on food packets before buying.
49. I check certification logos such as FSSAI on food products.
50. I check if promotional messages are misleading.

Sub-Dimension 7: Action and Behavior (7 items)

51. I limit intake of fried, salty, and sugary foods.
52. I prefer home-cooked meals over processed ones.
53. I include vegetables in every meal.
54. I encourage children to eat food from all food groups.
55. I wash hands before preparing food.
56. I drink safe and clean water every day.
57. I prefer steaming and pressure cooking over deep frying.

Research Tool

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Advancing Digital Extension Education: Development and Validation of Digital Learning Engagement Scale

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HIGHLIGHTS

- Developed an 18-item Digital Learning Engagement Scale (DLES) measuring behavioural, emotional, cognitive, and psychological engagement, essential for modern digital education.
- Established a robust four-factor structure of digital learning engagement with strong reliability, model fit and validity.
- DLES effectively diagnoses engagement to improve learning outcomes in digital extension education and is a unique scale tailored for asynchronous and self-directed professional learning

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ABSTRACT

Digital transformation has revolutionized extension education and professional upskilling, revealing significant gaps in learning engagement assessment within digital contexts. Conventional classroom-based scales fail to capture multifaceted digital engagement in AI-augmented, asynchronous environments, overlooking self-regulation difficulties, learner isolation, and adaptive interactions. This hampers organizations and extension practitioners from identifying disengagement early and designing evidence-based interventions. Addressing this, an 18-item Digital Learning Engagement Scale (DLES) was developed through robust psychometric evaluation, content validation by eight experts. Data was collected from 461 digital learning platform users. Exploratory factor analysis (n=227) using principal axis factoring is chosen to handle correlated engagement dimensions, identified a stable four-factor structure (behavioural, emotional, cognitive and psychological engagement) explaining 66.93 per cent of variance (KMO=0.937, Bartlett's $p < 0.001$). Confirmatory factor analysis confirmed excellent model fit (χ^2//df = 1.34, CFI = 0.945, TLI = 0.935, RMSEA = 0.065, SRMR = 0.057) with strong internal consistency (α = 0.86 -0.91), composite reliability (CR = 0.87- 0.91), convergent and discriminant validity. The DLES enables extension professionals, educators, and organizations to assess engagement, identify barriers, and implement targeted data-driven interventions, improving retention and learning effectiveness.

INTRODUCTION

The Integration of digital technologies like extension Massive Open Online Courses (MOOCS) (National Institute of Agricultural Extension Management, 2024), mobile applications, Artificial Intelligence (AI), gamification, augmented and virtual reality has transformed extension education and professional training (Roy et al., 2025). This digital transition complements in-person outreach and skill development activities (Ziaulhaq Haqyar et al., 2025) by enhancing flexibility, scalability, and inclusivity for geographically dispersed agricultural practitioners and extension personnel (Gao et al., 2024). Extension education increasingly occurs in asynchronous, self-paced formats, and learners face distinct

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engagement challenges such as limited real time interaction, learner isolation (Xue et al., 2025) motivational and self-regulation difficulties that impede effective learning and knowledge application (Malavika et al., 2025). As the digital learning environments become more adaptive and personalized through AI (Gupta & Anusha, 2020), conventional engagement metrics are insufficient to capture complex multidimensional patterns of engagement in hybrid and fully digital contexts.

Existing classroom-based engagement instruments (Kahu et al., 2018) and voluntary MOOC scales (Deng et al., 2020) have become outdated amid AI driven adaptive systems that deliver personalized learning pathways and real time feedback. These tools lack psychometric sensitivity for assessing engagement among workplace and remote extension learners balancing demanding occupational workloads (Gupta & Vatta, 2025). Although learning analytics, effectively track usage patterns and behavioural engagement through activity logs, clickstreams, and learning durations, fall short in capturing emotional, cognitive and psychological engagement dimensions that impact course completion rates and learning outcomes (Wong & Liem, 2022). These gaps reveal critical need for a psychometrically robust, context specific, multidimensional engagement scale (Greenhow et al., 2022).

Addressing this gap, this study develops and validates Digital Learning Engagement Scale (DLES) for digital extension education and workplace upskilling.

Grounded in modern engagement theory (Halverson & Graham, 2019) and foundational engagement frameworks (Appleton et al., 2006; Fredricks et al., 2004), Digital Learning Engagement (DLE) is conceptualized as a multidimensional construct comprising four distinct dimensions. Behavioural Learning Engagement (BLE) reflects active participation, effective time management, commitment and persistence. Emotional learning engagement (ELE) encompasses affective attachment to learning, including motivation, sense of belonging, and alignment with professional goals and organizational mission. Cognitive learning engagement (CLE) represents strategic mental effort in planning, monitoring, and evaluating learning tasks reflecting deep intellectual effort and reflective thinking. Psychological learning engagement (PLE) distinguished as separate dimension in extension and workplace contexts, constitutes motivational and social-psychological influences including supervisor and peer support, perceived learning benefits, and emotional factors that extend beyond individual emotion and cognition.

The DLES is developed through rigorous, multistage psychometric process, including systematic item generation with expert content validation for relevance and clarity, Exploratory Factor Analysis (EFA) to identify latent factorial structure; Confirmatory Factor Analysis (CFA) to verify model fit; and assessments of reliability, convergent and discriminant validity to establish scale robustness. DLES acts as a diagnostic tool for extension institutions, organizations, educators, trainers, and researchers to identify engagement barriers, measure engagement, refine adaptive learning pathways and implement targeted interventions to enhance motivation, participation, retention and learning outcomes.

METHODOLOGY

A cross-sectional survey design was employed to enable efficient large sample data collection and split sample validation (EFA and CFA) avoiding confounding effects of repeated measurements. After pilot testing the instrument with 100 respondents to refine the instrument, the final questionnaire was distributed to digital learning platform users in India, through online Google forms and offline questionnaires, yielding 461 valid responses. All respondents provided informed consent and participated voluntarily with guaranteed anonymity. Demographic information includes gender, age, education, and income for sample description and subgroup exploration.

An initial pool of 38 items (BLE - 6 items, ELE - 8 items, CLE -13 items, PLE - 11 items) were generated drawing from literature review, existing scales and theoretical frameworks. The items comprised elements of behavioural, emotional, cognitive, and psychological dimensions and learning interventions such as gamification, micro learning, and AI personalization. Items were validated by panel of eight experts for relevance, clarity, and adequacy. Sixteen items that are redundant, overly context specific and reverse worded were removed after content validity. Data integrity was checked through means, standard deviations, skewness and kurtosis. Missing data is handled with listwise deletion. Total sample was randomly split into two independent subsets for EFA (n = 227) and CFA (n = 234).

To examine the factor structure, EFA using Principal Axis Factoring (PAF) with oblimin rotation was selected, as engagement subdimensions are theoretically correlated and self-report data often deviates from normality. PAF suits scale development over Principal Component analysis (PCA) to extract latent constructs via shared variance (excluding unique/ error variance) permitting correlated factors for realistic psychological modelling (Fabrigar et al., 1999). Sampling adequacy and sphericity were supported by Kaiser Meyer Olkin (KMO) and Bartlett's test. Factor retention followed eigenvalue > 1.0 and scree plot inspection. Items were retained if the factor loading was ≥ .50 with minimal cross-loadings resulting in a four-factor structure consistent with theoretical subdimensions BLE, ELE, CLE, and PLE. CFA was conducted to validate the proposed four-factor model using Maximum Likelihood estimation. Model fit was assessed through chi square ratio (χ^2/df), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) using goodness of fit thresholds (CFI/TLI ≥ .90; RMSEA/SRMR ≤ .08, preferably ≤ .06). 18 items with factor loadings greater than 0.70 and statistically significant were retained.

Reliability was evaluated using Cronbach alpha, Composite Reliability (CR) and corrected item-total correlations, indicating internal consistency. Convergent validity was established through Average Variance Extracted (AVE) exceeding 0.50, CR above 0 .80 and significant factor loadings. For transparency regarding scale length, average inter-item correlation (r) (back-calculated from α and k) and Spearman–Brown projections, illustrating reliability changes for k±1 items are done. Fornell–Larcker and Heterotrait Monotrait ratio were used to assess Discriminant validity. This rigorous

methodology ensures psychometric robustness of DLES. The scale development and validation process following structured multistage approach is depicted in Figure 1.

RESULTS

Demographic characteristics and mean scores of digital learning engagement dimensions

Table 1 presents the demographic profile and engagement scores of four hundred and sixty-one participants within DLES. The sample predominantly consisted of males (65.1%) and millennials/Generation Y (81.6%). The age distribution is substantially skewed, reflecting real-world dominance of millennials among digital learners in workplace learning and extension education contexts. Mean scores across all engagement dimensions ranged from 3.77 to 4.19, indicating moderate to high engagement. Spearman's correlation between gender and engagement ($\rho = 0.025$), age and engagement ($\rho = -0.032$) were low, indicating no association. In contrast modest correlations of engagement with education ($\rho = 0.081$) and income ($\rho = 0.023$). The respondents with higher academic degrees, such as PhDs, reported greater engagement across the four dimensions. This can be most likely due to their enhanced meta cognitive capacity, better self-regulatory learning capacities, increased awareness of learning opportunities related to career development, and less difficulty in adapting to technology. Income correlations ranged from $\rho = 0.021$ to 0.028. 6-10 lakh annual income cohorts have higher engagement compared to lower income brackets driven by resource availability for sustained learning without competing financial pressures. Behavioural learning engagement has greater variability (SD = 0.89). Cognitive learning engagement exhibited higher consistency across subgroups (Mean = 4.19, SD = 0.72). These findings suggest that the DLES effectively differentiates engagement levels across demographic subgroups, highlighting opportunities for targeted workforce development interventions.

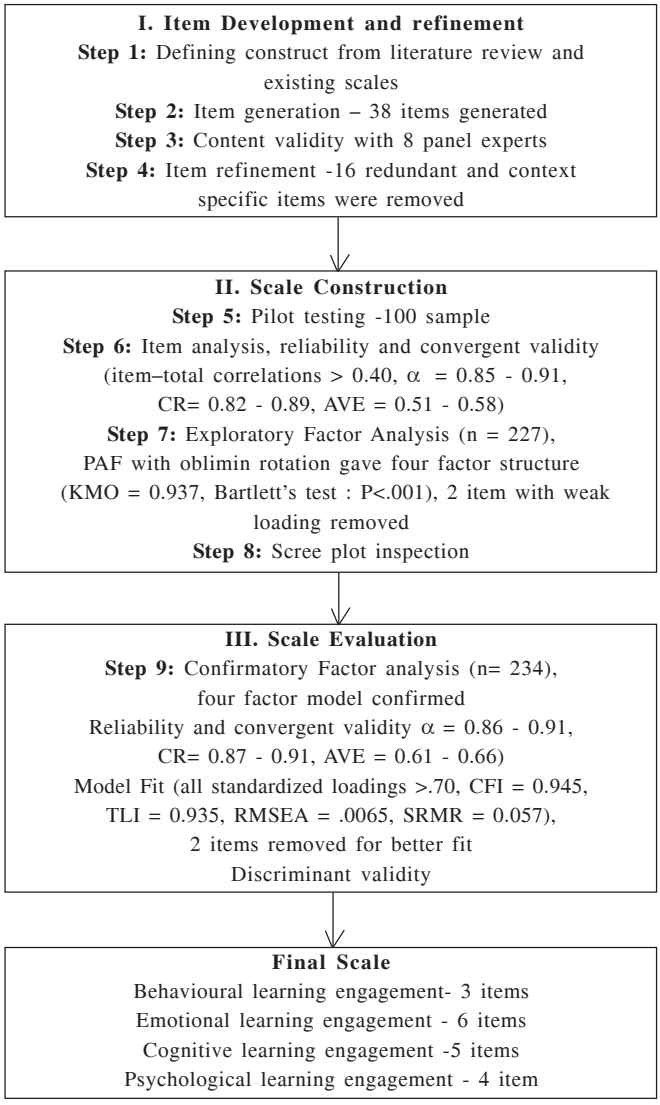

Figure 1. Sequential Scale Development and Validation Process of DLES

Item analysis, reliability and convergent validity

Table 2 presents reliability and convergent validity for each subscale of digital learning engagement. All corrected item–total correlations exceeded 0.40, supporting the item adequacy. The DLE scale demonstrated excellent internal consistency (Cronbach's α = 0.91), with subscales Cronbach's alphas ranging from 0.85 to 0.91, exceeding the established threshold of 0.70 for scale reliability. The ELE exhibited highest reliability ($\alpha = 0.91$), followed by the CLE ($\alpha = 0.87$), PLE ($\alpha = 0.85$), and BLE ($\alpha = 0.85$). Mean inter-item correlations ($r \approx .61 – .68$) indicated an appropriate conceptual focus within each subscale, reflecting related yet distinct facets of engagement without redundancy. Composite reliability coefficients (CR= 0.82 -0.89) and average variance extracted (AVE = 0.51 – 0.58) met and exceeded established psychometric benchmarks of CR $\geq$ 0.70 and AVE $\geq$ 0.50, confirming internal consistency and convergent validity.

Exploratory factor analysis

To examine the multidimensional latent structure of digital learning engagement, exploratory factor analysis was conducted. Sampling adequacy was tested using Kaiser-Meyer Olkin (KMO). The KMO value of 0.937, exceeded 0.60 threshold indicating good inter-item correlation for meaningful factor extraction. Bartlett's test of sphericity achieved statistical significance ($p < .001$), indicating correlation sufficiency among variables and suitability of data for factor analysis. Principal Axis Factoring (PAF) with oblimin rotation ($\delta = 0$) is chosen for factor extraction as it aligns with the conceptual expectation that sub dimensions of digital learning engagement are interrelated. PAF extracted four factors with eigenvalues > 1.0, collectively explaining 66.93 % of the total variance. Each factor aligned with the theoretical frameworks of the behavioural (BLE), emotional (ELE), cognitive (CLE), and psychological (PLE) engagement dimensions collectively represents the multifaceted nature of engagement in a digital learning environment. Table 3 presents detailed results of the pattern-matrix, and Figure 2 displays the scree plot of eigenvalues, showing a clear elbow after the fourth factor, confirming four-factor solution.

The sharp inflection after the fourth factor supports the four-factor model. EFA results confirmed that the DLE scale captures four coherent latent dimensions, explaining 66.93 % of the variance,

Table 1. Demographic characteristics, mean scores of digital learning engagement dimensions

Variable	n(%)	BLE (ρ) Mean±SD	ELE (ρ) Mean± SD	CLE (ρ) Mean ±SD	PLE (ρ) Mean ±SD	Total DLE (ρ) Mean ±SD
Gender		0.028	0.039	0.024	0.017	0.025
Male	300 (65.1)	3.91±0.85	4.06±0.79	4.18±0.71	4.05±0.82	4.05±0.67
Female	161 (34.9)	3.92±0.97	4.12±0.79	4.20±0.75	4.09±0.79	4.08±0.71
Age group		-0.035	-0.034	0.009	0.018	-0.032
Gen X	48 (10.4)	3.78±0.92	4.01±0.72	4.10±0.70	4.04±0.74	3.98±0.66
Gen Y	376 (81.6)	3.93±0.91	4.08±0.82	4.21±0.74	4.07±0.84	4.07±0.71
Gen Z	37 (8.0)	3.97±0.59	4.13±0.57	4.11±0.50	3.99±0.62	4.05±0.48
Education		0.071	0.066	0.06	0.054	0.081
Graduate	240 (52.1)	3.88±0.86	4.05±0.74	4.17±0.69	4.05±0.74	4.04±0.62
Post-Graduate	189 (41.0)	3.95±0.91	4.11±0.83	4.20±0.75	4.08±0.87	4.09±0.73
PhD	32 (6.9)	4.02±1.01	4.12±0.90	4.28±0.77	4.05±1.01	4.12±0.86
Annual Income (Rs. LPA)		0.028	0.028	0.027	0.021	0.023
0–3	91 (19.7)	3.95±0.84	4.09±0.76	4.24±0.64	4.07±0.86	4.08±0.67
3–6	94 (20.4)	3.77±0.92	4.04±0.74	4.05±0.80	3.88±0.89	3.94±0.69
6–10	117 (25.4)	4.00±0.92	4.09±0.86	4.24±0.73	4.18±0.74	4.13±0.71
> 10	159 (34.5)	3.93±0.88	4.10±0.79	4.21±0.71	4.08±0.78	4.08±0.67

Note (S): ρ = Spearman's rho correlation coefficient. All correlations are not significant (p > .05). BLE = Behavioural Learning Engagement, ELE = Emotional Learning Engagement, CLE = Cognitive Learning engagement, PLE = Psychological Learning Engagement, DLE = Digital Learning Engagement.

Table 2. Item analysis, reliability, and convergent-validity summary

Dimension	Number Items	Item-Total r Range	α	CR	AVE	r (Inter-item)	α if Item deleted (min–max)
BLE	4	0.59 – 0.73	0.88	0.85	0.54	0.62	0.85 – 0.89
ELE	8	0.66 – 0.80	0.91	0.89	0.58	0.68	0.89 – 0.92
CLE	5	0.66 – 0.73	0.87	0.82	0.53	0.65	0.84 – 0.89
PLE	5	0.53 – 0.74	0.85	0.84	0.51	0.61	0.82 – 0.87

aligning with the theoretical conceptualization of DLE. BLE 1and PLE 5 were removed due to weak loadings. due All items loaded saliently on their intended constructs, with minimal cross-loadings, validating the theoretical separation of the behavioural, emotional, cognitive, and psychological facets of DLE. These findings provide an empirical foundation for subsequent CFA and structural model validation.

Confirmatory Factor Analysis (CFA)

To validate the factor structure derived from the EFA, confirmatory factor analysis was performed on an independent sample (n = 234) to verify model's stability and fit. Maximum Likelihood estimation with oblique (correlated) factors is used. The four-factor DLES measurement model achieved a strong global fit and validity across indices. ELE 1 and ELE 7 with standard loadings (<0.60) and conceptual overlaps with psychological items were removed to improve model parsimony and psychometric strength of the ELE subscale. All standardized loadings exceeded 0.70 ($p < .001$), with clear indicator reliability and moderate inter-factor correlations consistent with related but distinct dimensions. The goodness-of-fit statistics indicated an excellent model fit. Chi-square ratio $\chi^2/df = 1.34$ is below the cutoff of 2.0, indicating an excellent fit. The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI = 0.935) both surpassed the acceptable cutoff of 0.90. The root mean square error of approximation (RMSEA =0.065) and the standardized root mean square residual (SRMR = 0.057) were below their recommended cutoffs (RMSEA < 0.06 and SRMR < 0.08), suggesting a low discrepancy between the proposed model and observed data.

Discriminant Validity

Upon establishing convergent validity and model fit, discriminant validity was assessed through Fornell–Larker criterion and the Heterotrait–Monotrait (HTMT) ratio. As shown in Table 5, the square root of AVE of all four dimensions BLE, ELE, CLE, and PLE exceeded its correlations with other constructs, confirming that each construct shares more variance with its own indicators than with others. The HTMT ratio was used to further validate the empirical distinctiveness of each dimension. HTMT values ranged from 0.81 to 0.88 all well below the threshold of 0.90 (Henseler et al., 2015), indicating that the four engagement factors were reliably separable within the measurement model. The slightly higher HTMT value between ELE and PLE is theoretically expected due to their shared motivational elements. Results from both discriminant validity tests confirm that the four dimensions behavioural, emotional, cognitive, and psychological are conceptually related in theory, yet distinct facets of engagement in practice, supporting the multidimensional structure of DLE.

Table 3. Exploratory Factor Analysis Results

Dimension/ Subscale	Factor loading	Eigen value	% Variance	Cumulative %
Behavioural Learning Engagement		8.930	44.902	44.902
BLE1	0.592			
BLE2	0.632			
BLE3	0.734			
BLE4	0.696			
Emotional Learning Engagement		2.057	10.342	55.244
ELE1	0.660			
ELE2	0.798			
ELE3	0.741			
ELE4	0.790			
ELE5	0.777			
ELE6	0.739			
ELE7	0.663			
ELE8	0.713			
Cognitive Learning Engagement		1.310	6.588	61.832
CLE1	0.661			
CLE2	0.680			
CLE3	0.693			
CLE4	0.733			
CLE5	0.714			
Psychological Learning Engagement		1.014	5.096	66.928
PLE1	0.718			
PLE2	0.660			
PLE3	0.739			
PLE4	0.726			
PLE5	0.527			

Note (s): The rotation converged in 11 iterations. Only primary loadings ≥ .50 are reported for clarity purposes.

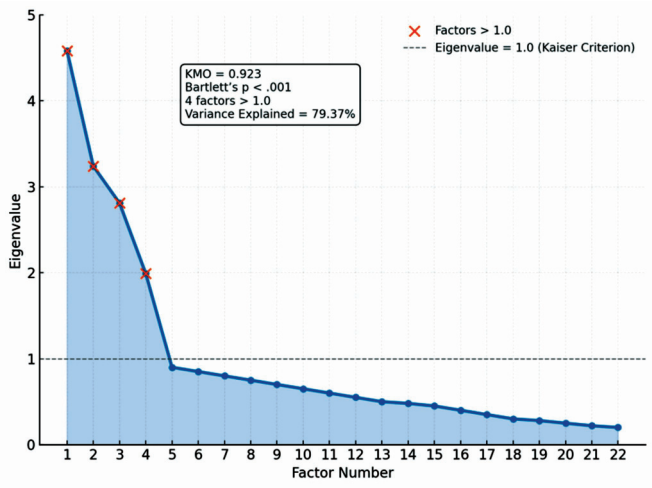

Figure 2. Scree Plot of Eigenvalues for DLE Scale

Table 5. Model fit indices summary

Fit Index	Recommended	Obtained	Interpretation
χ^2/df	<3.00	1.34	Excellent fit
CFI	≥ 0.90	0.945	Good fit
TLI	≥ 0.90	0.935	Good fit
RMSEA	≤ 0.06	0.065	Good fit
SRMR	≤ 0.08	0.057	Good fit

Table 6. Fornell–Larcker criterion results for discriminant validity

Dimension	√AVE	BLE	ELE	CLE	PLE
BLE	0.752	—	*0.79*	*0.73*	*0.76*
ELE	0.812	0.79	—	*0.77*	*0.82*
CLE	0.732	0.73	0.77	—	*0.74*
PLE	0.793	0.76	0.82	0.74	—

DISCUSSION

The digital learning engagement scale (DLES) is the first validated instrument designed for asynchronous, AI-augmented workplace and extension learning environments. Unlike prior scales developed for face-to-face classrooms (Kahu et al., 2018), voluntary MOOCS (Deng et al., 2020), DLES treats psychological engagement as distinct dimension rather than merging with emotional factors. DLES items were developed considering realities of occupational constraints, contemporary challenges such as limited peer interaction, real time facilitation, learner isolation and algorithmic personalization that are absent in previous instruments.

Results affirm a stable four-factor structure, indicating engagement's distinct yet interrelated sub dimensions in digital contexts. The developed scale exhibits robust psychometrics including high internal consistency, strong validity, and good model fit positioning DLES as a theoretically grounded tool for measuring engagement.

Demographic findings revealed significant shift in engagement determinants. Negligible correlations between age, gender and DLE scores indicate that modern learning platforms with user friendly interactive interfaces, with personalized content have effectively mitigated technology adoption challenges and use (Du Plooy et al., 2024). These findings emphasize the shift from technology barriers to psychological and motivational barriers like disengagement, learner isolation, and information overload (Feroz et al., 2022). Higher educational levels like post-graduation and PhD are linked to increased engagement due to psychological factors like self-regulation, intrinsic motivation and goal orientation.

The findings indicate that digital learning engagement is much more than participation, cognitive strategies, and emotional commitment. Behavioural engagement measured by proactive

Table 4. Confirmatory factor analysis – convergent validity, reliability

Dimension	Items (k)	Loading Range	AVE	CR	α	Inter-Factor (Range) r
BLE	3	0.79–0.82	0.66	0.87	0.86	0.58–0.65
ELE	6	0.78–0.87	0.61	0.91	0.91	0.62–0.71
CLE	5	0.79–0.86	0.63	0.89	0.90	0.64–0.72
PLE	4	0.76–0.82	0.62	0.88	0.88	0.59–0.70
Overall DLE	18	0.76–0.87	0.62	0.93	0.93	-

Note(s): k = No. of items, AVE = Average Variance Extracted, CR = Composite Reliability, α = Cronbach alpha, r = latent factor correlations.

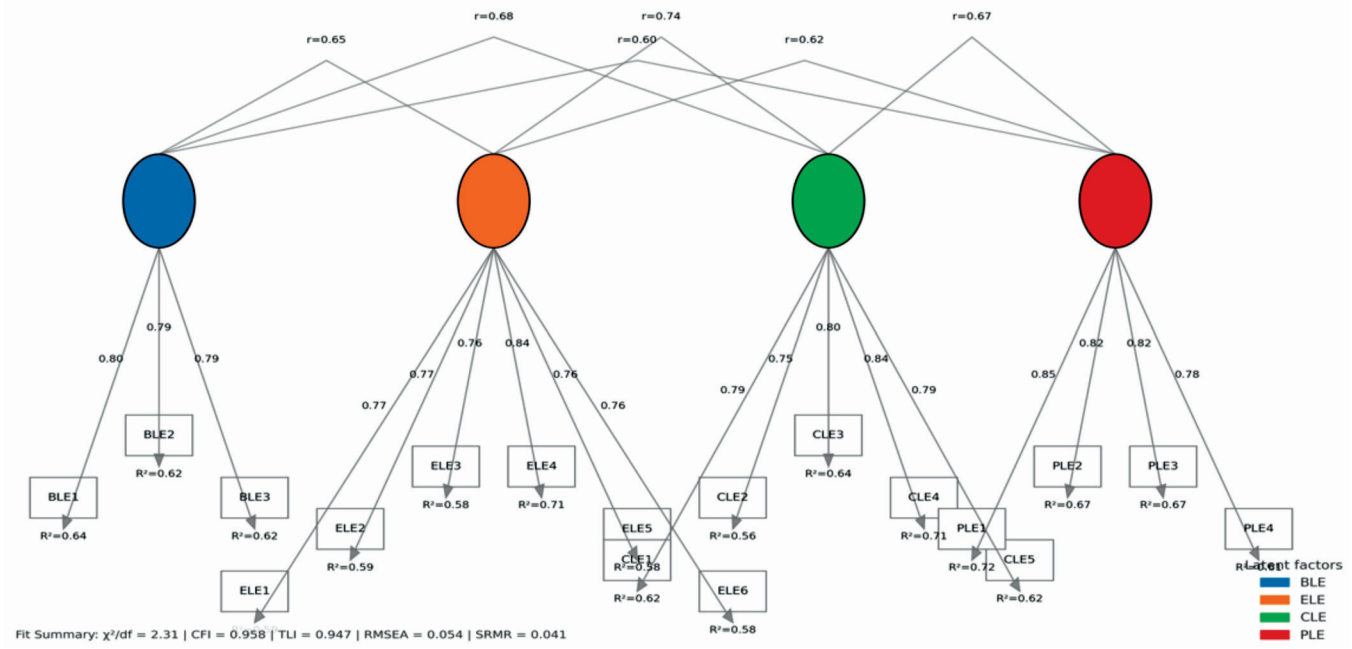

Figure 3. Standardized estimates and R^2 values of digital learning engagement

actions such as course completion, interaction in discussion forums aligns with technology driven asynchronous workplace learning. Emotional engagement as a critical indicator explains the affective experiences of learners, such as satisfaction, enthusiasm, and positive feelings in the learning process, maintaining motivation (Parekkadan House & Roy, 2025). Cognitive engagement is reflected through mental effort, persistence, and deep processing strategies resonating with self-regulated learning models (Das & Jha, 2025). Psychological engagement as a unique construct highlights social and psychological factors that motivate and influence engagement beyond cognitive efforts.

Following the best practices in scale development, this study performed both exploratory analysis and confirmatory factor analysis on independent samples to identify and validate the latent factor structure of digital learning engagement. Principal axis factoring with oblimin rotation, uncovered four distinct factors explaining major proportion of variance and consistent with theoretical framework. This enhances generalizability and reliability of the instrument minimizing overfit or underfit concerns in scale development. Reliability analysis further demonstrated that removal of any single item would have negligible effect on total consistency, highlighting robustness and precision of DLES. Convergent and discriminant validity results show that each sub dimension measures unique yet related aspects of digital learning engagement.

Although DLES demonstrated strong psychometrics, limitations include non-probability sampling, self-report biases, cross-sectional design within Indian professional contexts, limiting generalizability. Criterion validity could not be established due to absence of benchmarks for digital engagement. Future research should test predictive validity against outcomes like learning performance and retention, examine nomological networks, and adopt longitudinal designs to track engagement trajectories and validate DLES across diverse cultures, sectors and educational contexts. The DLES advances engagement measurement by introducing a context specific instrument tailored for adult professional learners. By emphasizing psychological resources and self-regulation abilities, the scale addresses the unique motivational profile of autonomous learners in professional learning. This scale serves as a diagnostic tool for identifying engagement gaps and predicting learner disengagement, enabling timely interventions. The DLES is theoretically grounded and empirically tested, thus adding literature on contemporary engagement research in complex digital learning environments.

CONCLUSION

The study successfully developed an eighteen item, multidimensional Digital Learning Engagement Scale (DLES) comprising behavioural, emotional, cognitive, and psychological engagement dimensions critical for professional digital learning. DLES with robust psychometric properties filled significant gaps by focusing on asynchronous and AI augmented learning contexts. DLES has beneficial implications for distance education and organizational learning to monitor and enhance learning engagement, personalizing instructional design, and support activities through targeted interventions. DLES engagement metrics insights support in improving course relevance, completion rates across diverse professional contexts. Future studies should validate and refine DLES across various sectors and extend the scale's generalizability, and utility.

DECLARATIONS

Ethics approval and informed consent: All respondents provided informed consent and participated voluntarily with guaranteed anonymity

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 Tool

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Scale to Measure Farmers' Attitude towards ICT-Based Agro-Advisory Services

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HIGHLIGHT

- The Attitude Scale with 48 items was developed with 0.86 reliability coefficient value.
- Captured six dimensions: usefulness, trust, accessibility, personalization, adoption, and general attitude.
- Demonstrated high reliability and strong content validity.
- The items were selected on the basis of Relevancy Percentage, Relevancy Weightage and Mean Relevancy Score (MRS) for all statements.

ARTICLE INFO

Keywords: ICT based Agro-advisory services, Attitude, Farmers' perception, Digital agricultural extension, Perceived usefulness.

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ABSTRACT

In recent years, rapid advancements in Information and Communication Technologies (ICT) have transformed agricultural extension by enabling timely, accurate, and farmer-specific agro-advisories. Farmers' attitudes play a crucial role in determining the acceptance, sustained use, and practical application of such services. Therefore, a study was undertaken in 2025 to develop and standardise an attitude scale for farmers toward ICT-based agro-advisory services. An initial pool of 110 statements was generated through literature review, farmer interactions, and expert consultations. After item screening and statistical analysis, 48 statements were finalised under six dimensions: Perceived Usefulness, Trust and Credibility, Accessibility and Convenience, Responsiveness and Personalisation, Adoption Behaviour, and General Attitude. Content validity was assessed through expert evaluation, wherein Item-level CVI values ranged from 0.80 to 0.95, and the Scale-level CVI/Average (S-CVI/Ave) was 0.91, reflecting excellent relevance. A multistage sampling procedure followed by Probability Proportional to Size (PPS) sampling was used to ensure proportional representation of farmers across selected villages. Reliability testing confirmed strong internal consistency, with Cronbach's alpha 0.86 and Split-Half reliability (Spearman-Brown coefficient) 0.89. The validated scale can serve as a useful tool for researchers and extension stakeholders to assess farmer readiness and design more user-centric ICT advisory systems.

INTRODUCTION

Rapid advances in information and communication technologies (ICT) have transformed how agricultural knowledge is created, packaged and delivered to farmers (Singh et al., 2025a). ICT-based agro-advisory services ranging from SMS alerts and call-centres to mobile apps, interactive voice response (IVR), and video-mediated extension promise timely, localized and scalable advisory support that can improve decision-making, productivity and resilience for smallholder farmers (Paliwal & Kumari, 2023). Despite these potential benefits, the effectiveness of ICT interventions depends critically on farmers' attitudes toward the technology and the service models used; attitude shapes uptake, sustained use and the translation of information into practice (Singh et al., 2023; Singh et

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al., 2024a; Khan et al., 2024). Extant literature has examined multiple dimensions of farmer engagement with ICT-based advisories. Some studies report generally positive perceptions of timeliness and usefulness, while others highlight barriers such as limited digital literacy, relevance of content, trust in source and socio-economic constraints that mediate attitudes and behaviour (Paliwal et al., 2025). For example, mobile advisory evaluations have shown improvements in information access but mixed levels of adoption of recommended practices, pointing to the role of attitudes, perceived usefulness and ease of use as mediators. Similarly, video-based and multimedia approaches have demonstrated promise for knowledge transfer but require supportive infrastructure and user confidence (Kumar et al., 2015; Kassem et al., 2021). Research from varied contexts underscores the need for careful measurement of attitude as a construct distinct from knowledge and access. Region-specific surveys and program evaluations (e.g., of Kisan Call Centres, Kisan Mobile Advisory Services, and KVK/extension-led ICT initiatives) indicate heterogeneity in farmer attitudes influenced by age, education, farm size, prior experience with technology, perceived credibility of advisory sources and socio-institutional support (Slathia et al., 2012; Singh et al., 2024b). A focused study published in the Indian Journal of Extension Education reported that while a majority expressed favourable opinions toward digital agricultural communication, mean attitude scores differed across stakeholder groups, suggesting that a single-size-fits-all assessment may obscure important variation (Koshy et al., 2012). Despite an expanding empirical base, gaps remain in standardizing measures for "attitude toward ICT-based agro-advisory services." Many evaluations rely on ad hoc Likert scales or single-item indicators that confound attitude with satisfaction or behavioural intent. The literature review and bibliometric analyses of ICT in extension further call for theoretically grounded, psychometrically validated instruments that capture cognitive (beliefs about usefulness and credibility), affective (liking, comfort) and behavioural-intent dimensions of attitude, while accounting for contextual moderators (infrastructure, social norms, institutional linkages). Such standardization would facilitate cross-study comparisons, meta-analysis and more precise program design (Mukherjee et al., 2025; Barman et al., 2025). This paper, therefore proposes to develop and validate a standardized research instrument to measure farmers' attitudes toward ICT-based agro-advisory services. Building on prior empirical findings and theoretical models (e.g., Technology Acceptance frameworks), the study will (1) operationalize attitude in multi-dimensional terms, (2) pilot and assess reliability and validity across a stratified sample of farmers, and (3) examine how attitude correlates with socio-demographic factors and service uptake. By providing a rigorously tested measure and situating it alongside evidence from different journaled studies and sectoral reports, the research aims to strengthen evidence-based design and evaluation of ICT-enabled advisories for smallholder agriculture (Abate et al., 2023).

METHODOLOGY

The study was conducted in 2025 to develop and standardize a scale measuring farmers' attitudes toward ICT-based agro-advisory services. A mixed-methods research design involving qualitative item generation and quantitative psychometric validation was employed to ensure both content relevance and statistical rigour. Initially, a comprehensive pool of 110 attitude statements was developed based on an extensive review of national and international literature and through consultations with scientists, extension professionals, ICT experts, government officials, NGOs, and progressive farmers. The items covered 11 theoretically grounded dimensions, including Accessibility, Content Relevance, Ease of Use, Credibility, Decision-making Usefulness, Cost-effectiveness, User Support, Feedback Provision, Trust and Privacy, Socio-cultural Compatibility, and Overall Satisfaction. Item wording followed the criteria suggested by Likert (1932) and Edwards (1957) to ensure clarity, evaluative orientation, and simplicity. The draft scale was reviewed by 90 experts in agricultural extension and ICT-based advisory applications. Out of these, 60 experts responded, and their suggestions were incorporated to refine dimensional adequacy, content accuracy, and language suitability. Quantitative content validity was established using Lawshe's Content Validity Ratio (CVR) and the Content Validity Index (CVI).

$$\text{S-CVI/Ave} = \frac{\Sigma \text{I-CVI}}{\text{Total Items}}$$

Item-level CVI (I-CVI) ranged from 0.80 to 0.95 and the Scale-level CVI/Average (S-CVI/Ave) was 0.91, indicating excellent relevance of items. For empirical validation and item analysis, respondents were selected using a multistage sampling procedure followed by Probability Proportional to Size (PPS) sampling to ensure proportional representation of farmers across selected villages. A total of 60 farmers who had been using ICT-based agro-advisory services for at least one year were selected. A five-point Likert continuum ranging from Strongly Agree (5) to Strongly Disagree (1) was used to record responses. Item analysis utilized Edwards' (1957) Critical Ratio method by categorizing respondents into upper and lower 25% groups. Items with a t-value ≥ 1.75 (Bird, 1940), item–total correlation ≥ 0.30, and mean relevance score ≥ 3 were retained. After sequential screening, a total of 48 statements showing strong discrimination ability were included in the final standardized scale. Reliability testing confirmed strong internal consistency with Cronbach's alpha = 0.86, while structural reliability established through a split-half method yielded a Spearman–Brown coefficient = 0.89. The methodological novelty of the scale lies in integrating traditional psychometric testing with emerging ICT-centric behavioural constructs such as digital trust, responsiveness, and privacy perception. Thus, the developed scale is a statistically sound and contemporary assessment tool to measure farmers' attitudinal readiness toward ICT-enabled agro-advisory service ecosystems.

RESULTS

The t-test–based item analysis confirmed that the selected statements were effective in discriminating between respondents with high and low attitudes toward ICT-based agro-advisory services. Out of the initially drafted statements, 48 items yielded t-values above the acceptable threshold of 1.75 (Bird, 1940), indicating that each item significantly contributed to distinguishing

Table 1.

S.No.	Item Statements	t-value
A.	Perceived Usefulness (Cognitive)	
1.	The platform helps me make better agro-advisory decisions	2.83
2.	I find the digital advisory platform to be highly efficient	1.95
3.	It provides valuable insights for my investment strategies	3.42
4.	It helps me save time in managing my agro-advisory	2.95
5.	The platform improves the quality of my agro-advisory planning	3.33
6.	It allows for more informed decision-making	2.93
7.	It assists me in identifying good investment opportunities	3.39
8.	The recommendations from the platform are practical and beneficial	2.46
B.	Trust and Credibility (Affective)	
9.	The platform's reputation influences my trust in it	2.73
10.	The transparency of the platform builds my trust	2.94
C.	Accessibility and Convenience (Cognitive + Affective)	
11.	The platform is easy to navigate	3.01
12.	I can access the platform anytime, anywhere	1.89
13.	It is convenient for managing my agro-advisory on the go	2.68
14.	I find it simple to perform tasks on the platform	3.01
15.	The platform integrates well with my lifestyle	2.77
16.	I feel less stressed using this platform than others	2.32
17.	I appreciate the platform's user-friendly design	4.05
18.	The speed of access makes it more usable for me	3.77
19.	I enjoy using the platform regularly	2.79
20.	It provides a seamless experience across devices	2.94
21.	I rarely encounter technical issues when using it	3.35
D.	Responsiveness and Personalization (Cognitive)	
22.	The platform tailor's advice based on my preferences	2.69
23.	I receive timely responses to my inquiries	3.11
24.	The agro-advisory service recommendations are relevant to me	2.73
25.	The platform understands my unique agro-advisory goals	2.13
26.	It uses my data to personalize content effectively	3.04
27.	I get alerts that are meaningful to me	2.67
28.	It continuously learns from my behaviour	2.22
29.	The advice reflects my agro-advisory history	1.89
30.	It updates me with relevant market insights	2.80
31.	The chatbot/virtual assistant is responsive and helpful	3.41
32.	It offers personalized reports and dashboards	1.94
E.	Adoption Behaviour (Cognitive)	
33.	I intend to continue using this platform	2.72
34.	I frequently log into the platform	3.69
35.	I have recommended this platform to others	3.01
36.	I check the platform at least once a week	1.99
37.	I have shared my positive experience on social media	2.87
38.	I am likely to use advanced features in the future	1.79
F.	Attitude Towards Digital Advisory Platforms(Optional Dimension)	
39.	I have a positive attitude toward digital agriculture advisors	2.93
40.	I believe digital advisory platforms are the future of agriculture	1.95
41.	I enjoy exploring new agro-advisory technologies	3.14
42.	I feel optimistic about using technology in agriculture	2.11
43.	I view these platforms as innovative and modern	2.74
44.	I see digital platforms as a cost-effective solution	3.01
45.	I think digital advisory tools are empowering	2.69
46.	I consider them a legitimate alternative to traditional advice	2.19
47.	I feel confident in their ability to scale with my needs	3.51
48.	I see them as a smart choice for agro-advisory service independence	2.92

attitude levels among farmers. These retained items represented six major dimensions: Perceived Usefulness, Trust and Credibility, Accessibility and Convenience, Responsiveness and Personalization, Adoption Behaviour, and Overall Attitude toward ICT platforms. Perceived usefulness and trust-related statements exhibited the highest discriminatory power, suggesting that these constructs most strongly explain variations in farmers' attitudes.

Validity and reliability testing

Reliability analysis ensured the psychometric strength of the developed instrument. Using the split-half method, the 48 items were divided into odd–even subsets and administered to 60 farmers familiar with ICT advisories. The Pearson product–moment correlation coefficient of 0.82 demonstrated strong inter-item association. The Spearman–Brown reliability estimate of 0.89 further confirmed high stability, consistent with reliability standards in attitude scale research (Shitu et al., 2018; Shelar et al., 2022; Gupta et al., 2022; Vavilala et al., 2024; Singh et al., 2025b). Additionally, the Cronbach's alpha value of 0.86 indicated excellent internal consistency, exceeding the recommended 0.70 threshold for scale acceptance. Content validity was established through expert judgment and theoretical grounding. Sixty domain experts specializing in extension science, ICT applications, and field advisory services reviewed the item pool for relevance, clarity, and dimensional coverage. Their evaluation confirmed that the statements adequately represented the multidimensional construct of farmers' attitudes toward ICT-enabled advisory services. Inputs from experts also ensured contextual alignment with contemporary digital agricultural extension practices.

DISCUSSION

The findings highlighted that the systematically developed scale effectively captured farmers' attitudes toward ICT-based advisory platforms across six major dimensions. Items with high t-values emphasised perceived usefulness and ease of access, indicating that farmers strongly valued ICT services which improved decision-making, saved time, and integrated smoothly into their daily routines. Similar results were reported by Khan (2024), who underscored those timely and credible ICT advisories significantly shaped farmers' trust and adoption levels. High mean scores on the trust and credibility dimension suggested that farmers' willingness to rely on ICT advisories was strongly influenced by perceptions of transparency, reputation, and reliability of the service provider a finding consistent with the observations of Koshy and Kumar (2016), who found that farmer confidence in Kisan Call Centres depended largely on trust in the authenticity of information provided. The responsiveness and personalization dimension exhibited moderate-to-high discriminating power, indicating that farmers appreciated ICT services offering timely responses, customised recommendations, and relevant alerts. Studies by Abate et al. (2023) and Mukherjee et al. (2025) corroborated that personalization in ICT-enabled services enhanced farmer engagement and adoption. Results for adoption behaviour suggested that farmers who perceived ICT services as user-friendly and beneficial were more likely to continue usage, recommend the platforms to peers, and explore advanced features. Finally, the overall high reliability and internal consistency of the developed scale supported its suitability as a standardised instrument for assessing farmers' attitudes toward ICT-based advisory services. As such, the scale can guide policymakers, extension agencies, and service providers in designing more farmer-centric ICT platforms, thereby enhancing adoption and impact.

CONCLUSION

The study developed and validated a standardized attitude scale to measure farmers' perceptions of ICT-based agro-advisory services. The final instrument, comprising 48 items across six major dimensions—Perceived Usefulness, Trust and Credibility, Accessibility and Convenience, Responsiveness and Personalization, Adoption Behaviour, and General Attitude—demonstrated strong reliability (Cronbach's alpha = 0.86) and internal consistency, as well as high content validity verified by domain experts. Results indicate that farmers value timely, relevant, and user-friendly ICT services, with trust and personalization being key determinants of adoption. The scale provides a robust tool for assessing attitudes, enabling policymakers, extension agencies, and service providers to better understand farmer needs, enhance service design, and promote wider adoption of ICT-based advisory platforms. By offering a theoretically grounded and empirically tested measure, this study contributes to evidence-based planning and evaluation of digital agricultural extension interventions.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought during the course of the data collection from the 60 experts who responded, and their suggestions were incorporated to refine dimensional adequacy, content accuracy, and language suitability regarding the study.

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

The authors 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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Design and Validation of a Scale to Assess Dairy Farmers' Attitudes toward Climate-Resilient Dairy Farming

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HIGHLIGHTS

- A scale assessing dairy farmers' attitudes toward climate-resilient dairy farming was developed using the Likert summated rating scale method.
- Out of 50 initial statements, 27 were retained after the relevancy test, with an overall mean relevancy score of 3.191.
- The final scale, comprising 23 items with t-values of 1.75 or higher, showed a reliability coefficient of 0.86.
- The results of content validity and internal consistency reliability analyses indicated that the scale is both valid and reliable.

ARTICLE INFO

Keywords: Attitudes, Climate resilient, Content validity, Cronbach's alpha, Dairy farmers, Guttman split-half coefficient, Likert scale, Spearman-brown coefficient.

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ABSTRACT

The study, carried out in 2025, aimed to develop a tool for assessing dairy farmers' attitudes toward climate-resilient dairy farming practices. For this purpose, an attitude scale was created using a Likert-type scale development method. Initially, 50 statements were compiled (both positive and negative) together and later improved in accordance with Edward's fourteen principles for constructing scales. The overall mean relevancy score obtained was 3.191. In a non-sampling area, a pilot study involving 60 farmers was undertaken, after which 27 statements were kept for subsequent analysis. Subsequently, after calculating the t-values for all statements, 23 had t-values of 1.75 or higher. A Cronbach's alpha of 0.732 indicated the scale's internal consistency, and the scale's content validity was determined based on the experts' evaluation. This completed scale is suitable for measuring the attitude of dairy farmers toward climate-responsive dairy practices in the current research setting, and with proper contextual adjustments, it can be used in other regions as well.

INTRODUCTION

Climate change is a global phenomenon with region-specific and localized effects. In India, livestock serves as a major source of livelihood, particularly for small and marginal dairy farmers who possess limited resources and a few animals. However, livestock are highly sensitive to climatic variations and simultaneously contribute to greenhouse gas emissions. Among the major economic impacts of climate-induced stress, the decline in milk yield is particularly significant. Upadhayay et al. (2007) projected that rising temperatures could reduce India's overall milk production by more than 15 million tonnes. Climatic factors such as heat waves, floods, and droughts adversely affect livestock health, productivity, and reproduction (Reddy et al., 2023). Consequently, variations in rainfall patterns and increased ambient temperature led to feed and water scarcity, deterioration of animal health and decline in milk productivity (Reddy et al., 2023). Furthermore, reproductive and productive performances of dairy animals are negatively affected under climatic stress conditions (Bossche & Coetzer, 2008).

Dairy farming remains an essential livelihood for rural households, offering steady income and employment opportunities

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(Reddy et al., 2023). Growing consumer demand for milk and milk-based products has further strengthened its economic significance (Mohapatra et al., 2012). However, the sustainability of this sector is increasingly threatened by climate variability and extreme weather events. These conditions force dairy animals to divert energy toward thermoregulation, limiting their production potential even within normal temperature ranges (Banerjee et al., 2023). The rising frequency of heatwaves and erratic rainfall patterns has intensified these challenges, leading to considerable declines in milk production and significant income losses for farmers (Reddy et al., 2024).

Uttar Pradesh, the largest milk-producing state in India, relies heavily on mixed crop–livestock systems, where dairy farming provides crucial supplementary income to resource-poor households (Yadav et al., 2022). Yet climate-related uncertainties have already caused substantial losses, and these are projected to increase in the coming years. Studies indicate that dairy cattle in the state may experience up to a 30% decline in milk yield due to heat stress, accompanied by higher mortality rates resulting from increased disease susceptibility (Sukumaran & Y C, 2025). Heat stress–related losses in the Northern Plains may reach INR 12.44 billion annually, underscoring the severe economic burden on dairy farmers (Choudhary & Sirohi, 2022). This vulnerability is compounded by the relatively low productivity of indigenous cattle breeds under sub-optimal conditions, compared to the higher yields observed in buffaloes under improved management systems (Singh & Ukey, 2024). These impacts highlight the urgent need for climate-resilient dairy strategies in regions highly vulnerable to climatic shifts (Pandey et al., 2022; Banerjee et al., 2023).

Effectively addressing these challenges requires promoting the adoption of climate-responsive practices. Understanding farmers' knowledge, attitudes and perceptions is critical for strengthening their intention to adopt such measures (Ghanghas et al., 2015; Bharat et al., 2021). The widely used Likert technique provides a reliable method for assessing these attitudes (Özsayýn, 2023). Hence, a region-specific Likert-type scale is essential for accurately measuring attitudes toward climate-resilient dairy farming (Kumar, 2023; Seji et al., 2023).

METHODOLOGY

An attempt was undertaken to evaluate how dairy farmers perceive climate-resilient dairy farming practices. The Likert's Summated Rating Scale technique was employed for the construction of the attitude scale, as it effectively captures individual or subject-centred differences among respondents regarding specific aspects (Ramya et al., 2019). The methodological framework suggested by Shitu et al. (2018), Reddy et al. (2023), Chandra et al. (2024), and Singh et al. (2025) was followed for scale development. Initially, a pool of 50 attitude statements related to climate-resilient dairy farming practices was generated through a review of literature, consultation with experts, and field observations. These statements were then evaluated against 14 criteria for attitude statement construction as proposed by Edwards (1957) and Wing (1932). After scrutiny, 23 statements were found relevant to the objectives of the study and were retained for further analysis. The selected statements were arranged in a five-point continuum, ranging from strongly agree to strongly disagree, and compiled into a preliminary questionnaire. To obtain expert validation, the questionnaire was sent to 100 professionals possessing specialized knowledge in animal husbandry, dairy science, and extension education. Based on the experts' feedback, a pilot study was conducted with 60 randomly selected dairy farmers from non-sampling villages, namely Sheer Goverdhanpur and Narottampur, located around Varanasi city (Uttar Pradesh). During item analysis, the t-values were calculated for each statement, and those with a t-value equal to or greater than 1.75 were retained following the procedure outlined by Edwards (1957). Consequently, 27 statements were eliminated, and 23 statements were finally included in the attitude scale used for the study.

$$RW = \frac{MR+R+SWR+LR+NR}{MPS}$$

$$MRS = \frac{MR+R+SWR+LR+NR}{n}$$

Whereas, MR = Most relevant (5), R= Relevant (4), SWR = Some What Relevant (3), LR= Less Relevant (2), NR= Not Relevant (1), MPS= Maximum Possible Score (40×5 = 200), n=Number of judges (40)

$$OMRS = \frac{MR+R+SWR+LR+NR}{\text{Number of Judges} \times \text{Number of statements}}$$

$$t = \frac{\bar{X}H - \bar{X}L}{\sqrt{\frac{\Sigma(X_H - \bar{X}_H)^2 + \Sigma(X_L - \bar{X}_L)^2}{n(n-1)}}}$$

Whereas,

$$\Sigma(X_H - \overline{X}_H)^2 = \Sigma(X_H)^2 - \frac{(\Sigma X_H)^2}{n} \text{ and } \Sigma(X_L - \overline{X}_L)^2 = \Sigma(X_L)2 - \frac{(\Sigma X_L)^2}{n}$$

$\overline{X}_H$ = Mean score of given statements in the high group,

$\overline{X}_L$ = Mean score of given statements in the low group,

$\Sigma(X_H)^2$ = Sum of squares of individual scores on a given statement for the high group,

$\Sigma(X_L)^2$ = Sum of squares of individual scores on a given statement for the low group,

ΣX_H = Summation of scores on a given statement for the high group,

ΣX_L = Summation of scores on a given statement for the low group,

Items were selected on criterion; Relevancy Weightage (RW) > 0.80, Mean Relevancy Score (MRS) > Overall Mean Relevancy Score (OMRS), *i.e.,* 3.191

A constructed scale was developed with the help of 40 experts belonging to the field of animal husbandry and dairy professionals. They reviewed all of the revised statements and gave their expertise on the scrutinize of the final statements. There are 23 items considered to assess the attitude towards climate-resilient dairy farming practices. The Cronbach's alpha coefficient was determined using an SPSS tool. The scale was administered to 60 dairy farmers of non–sampling areas. The scale reliability was assessed using the split-half method. The scale was divided into two sets on the basis of odd and even numbers of items with the help of the following formula.

$$R = \frac{2r}{1+r}$$

Whereas, R = reliability coefficient of the whole scale
r = Estimated correlation between two (sets) halves

RESULTS

Table 1 presents the t-values for the selected items, encompassing statements related to climate-resilient dairy farming practices. For scale standardization, reliability was measured using the split-half approach (Spearman-Brown coefficient), Pearson correlation, and Cronbach's alpha, and content validity was determined through expert evaluation.

Assessment of the scale's validity and reliability

The internal consistency reliability of the Dairy Farmers' Attitudes toward Climate-Resilient Dairy Farming Scale was checked using a number of reliability coefficients by using SPSS 22. The 23 items were divided into two sets, one with 12 items and the other with 11, for using the split half method (Combination presented at the bottom of Table 2). Although Cronbach's alpha for the two split halves of the attitude scale was moderate (Part 1 = .531; Part 2 = .501), this does not indicate poor reliability of the overall instrument. In split-half analysis, each half contains fewer items, and Cronbach's alpha is highly sensitive to the number of items in a scale. Shorter scales inherently produce lower alpha values even when the items are internally consistent (Vaske et al., 2017). For the full 23 item scale, Cronbach's alpha was .732, suggesting acceptable internal consistency for measuring dairy farmers' attitudes toward climate resilient dairy farming. The correlation between the two halves was .762, showing a strong relationship between them. After applying the Spearman–Brown formula, the reliability estimate rose to .865 (for both equal and unequal length), which reflects excellent split half reliability. The Guttman Split Half coefficient was very similar at .861, further supporting the strength of the measure. Overall, these results show that the scale is reliably measuring the intended attitudes and is suitable for use in this context.

A scale is considered valid if it precisely reflects the construct it is intended to evaluate. Content validity was established by gathering statements from existing literature and consulting experts in animal husbandry with extensive experience in the field, and sending them to the experts for obtaining their agreement about the

Table 2. Reliability Coefficients of the Attitude Scale

S.No.		Reliability Statistics		
1.	Cronbach's Alpha	Part 1	Value	.531
			N of Items	12[a]
		Part 2	Value	.501
			N of Items	11[b]
		Total N of Items		23
		For Whole Scale		.732
2.	Correlation Between Forms			.762
3.	Spearman-Brown Coefficient	Equal Length		.865
		Unequal Length		.865
4.	Guttman Split-Half Coefficient			.861

a. The items are: 1., 3., 5., 7., 9., 11., 13., 15., 17., 19., 21., 23.
b. The items are: 2., 4., 6., 8., 10., 12., 14., 16., 18., 20., 22.

Table 1. Final selected items of the attitude scale

S.No.	Statements	t-value
1	Proper feed management helps reduce nutrient loss and enhances sustainability.	2.484
2	Indigenous breeds utilize local feed more efficiently under harsh conditions.	2.127
3	Precision feeding helps deliver the right nutrients at the right time.	2.970
4	High-quality forage, especially with legumes, improves digestion and reduces emissions.	2.653
5	Use of sprinklers or ventilation systems helps reduce heat stress.	2.782
6	Indigenous cattle breeds are better suited to hot and humid conditions.	3.238
7	Crossbred cattle cannot survive extreme climate conditions.	3.627
8	Indigenous breeds adapt well to drought and feed scarcity.	2.809
9	Proper manure management reduces emissions and improves soil health.	2.249
10	Water conservation techniques like rainwater harvesting are important.	2.632
11	Community-based resources like fodder banks help during climate shocks.	3.094
12	Climate change increases the risk of livestock diseases.	2.670
13	Heat stress reduces semen quality in breeding bulls.	2.688
14	Regular vaccination and sanitation help prevent disease outbreaks.	2.849
15	Climate-resilient dairy practices are necessary for sustainable farming.	2.962
16	I am open to adopting new technologies that improve climate resilience.	2.925
17	Combining scientific methods with local knowledge improves farm resilience.	3.029
18	Cross-breeding can improve both productivity and climate tolerance.	3.171
19	Heat stress decreases both the quantity and quality of milk.	1.890
20	Lack of timely climate updates makes dairy planning difficult.	2.119
21	Government incentives can motivate farmers to adopt resilient practices.	3.183
22	Insurance can reduce climate-induced financial losses in livestock.	2.755
23	Preserving indigenous breeds ensures future sustainability in dairying.	2.981

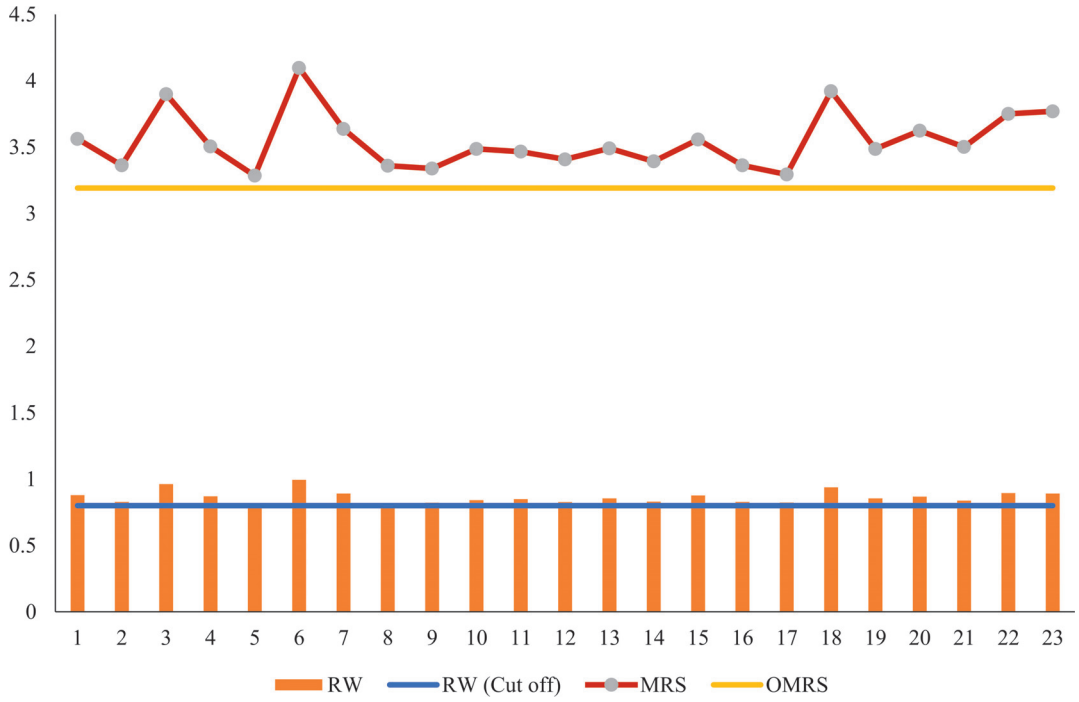

Figure 1. Relevancy measures of the attitude scale against cut-off values

relevance of the items to represent the intended universe of the construct. The three indices, namely Relevancy Weightage (RW), Mean Relevancy Score (MRS), and Overall Mean Relevancy Score (OMRS), were utilized to ensure the relevance of each item based on expert judgement (Figure 1). This step was carried out before checking the reliability of the scale using respondents from a non-sampling area.

DISCUSSION

The focus of this study was to evaluate the validity and reliability of the instrument used for the data collection. To ensure the reliability of our measuring instrument, we employed the Cronbach alpha coefficient, a well-known indicator of internal consistency. Reinforcing confidence in the scale's reliability (Cronbach, 1951), a Cronbach alpha value of 0.732 reflected a satisfactory reliability of the scale. It indicates the reliability of the scale item that is used to measure the same construct across different respondents. Additionally, Additional analyses were carried out to confirm the scale's reliability, following methods employed by other researchers (Kumar et al., 2015; Ramya et al., 2019; Gupta et al., 2022; Gupta et al., 2023; Reddy et al., 2023; Chandra et al., 2024; Singh et al., 2025). A Spearman-Brown coefficient of 0.865 indicated the split-half reliability of the scale. Furthermore, the Pearson correlation coefficient among all scale items was 0.762, further confirming the strong internal consistency of the scale. Content validity ensures the reliability of items that accurately represent the construct being measured, and therefore it is crucial to measure.

CONCLUSION

In this study, the developed attitude scales provide robust tools for thoroughly assessing dairy farmers' attitudes toward climate-resilient dairy farming practices. It will be used by policymakers, researchers, and stakeholders as an effective intervention tool. Furthermore, climate change presents a serious threat to the sustainability of dairy farming, highlighting the necessity for farmers to adapt their practices to evolving environmental conditions. By assessing farmers' attitudes toward these practices, policymakers can create intervention tools that work more efficiently and effectively. These interventions will benefit farmers directly while also enhancing the overall sustainability and resilience of the dairy farming sector

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the experts possessing specialized knowledge in animal husbandry, dairy science, and extension education to obtain validation. Based on the experts' feedback, a pilot study was conducted with 60 randomly selected dairy farmers from non-sampling villages.

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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Development and Validation of AgTech-Enabled Market Access Scale for Hi-Tech Agriculture

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HIGHLIGHTS

- A total of nine dimensions covering both traditional market access and emerging AgTech-driven aspects were identified for AgTech-enabled market access in hi-tech crop cultivation.
- The scale has high conformity (mean = 13.64), strong relevancy ratings (>3.0), high internal consistency (Cronbach' alpha value = 0.97), and significant dimensional distinctiveness (ANOVA, F = 3.301; p < 0.01

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ABSTRACT

Digital technologies and institutional innovations are increasingly shaping agricultural market access alongside traditional infrastructure. This study, conducted in 2025, developed and validated a multidimensional scale to systematically measure farmers' perceptions of AgTech-enabled market access in hi-tech cultivation. The validated scale consisted of 56 items across nine dimensions: transportation infrastructure, distance to market, market information access, digital market platforms, agri-input accessibility, market institutions, storage and logistics, intermediaries, and frequency of market visits. Empirical validation demonstrated high conformity (mean = 13.64), strong relevancy ratings (>3.0), high internal consistency (Cronbach' alpha value = 0.97), and significant dimensional distinctiveness (ANOVA, F = 3.301; p < 0.01). The mean value of Simpson's Index of Diversity was found to be 0.834, indicating the diverse nature of the scale items across the nine dimensions. The scale provides a robust and reliable instrument for researchers, policymakers, and extension professionals to assess AgTech-enabled market access, identify barriers, and design evidence-based interventions for strengthening hi-tech agriculture.

INTRODUCTION

Global agriculture is rapidly transforming through digitalization, automation, and data intelligence. Hi-tech agriculture integrates advanced technologies such as artificial intelligence (AI), robotics, sensors, Internet of Things (IoT), drones, and biotechnology to boost productivity, sustainability, and profitability (Bocean, 2024; Das et al., 2025). This transformation, driven by technology-enabled systems, plays a crucial role in enhancing market integration by connecting producers with buyers in real time. Traditionally, market access has been defined by spatial and infrastructural factors such as distance, transport, and reliance on intermediaries (Wang et al., 2025). However, farmers also face broader barriers, including information gaps, low bargaining power, poor logistics, and weak institutional linkages, which limit market efficiency and inclusiveness (Otekunrin, 2019; Barbier, 2023; Gurmu et al., 2024; Dey & Singh, 2025). In the AgTech era, market access now includes both physical and digital connectivity, which present previously unheard-of chances to revolutionize conventional farming methods (Chandra et al., 2024). Tools like real-time price information, e-

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NAM, blockchain traceability, and FPO-enabled trade networks have transformed how farmers access markets and ensure transparency (World Bank, 2019; Abiri et al., 2023; GOI, 2025). However, small and marginal farmers often face barriers such as cost, connectivity, digital literacy, and gender disparities, making AgTech both a market equalizer and divider (Choruma et al., 2024).

Despite the expanding body of research on agricultural digitalisation, there remains a major gap: the lack of a validated tool to systematically measure AgTech-enabled market access. Most studies focus on individual technologies rather than the integrated market access experience in the digital era (Jadhav, 2024; Janvry & Sadoulet, 2020). This limits comparative research, policy evaluation, and impact assessment across contexts. A scientifically validated measurement instrument is essential for quantifying latent constructs like farmers' perceived market accessibility. Therefore, the development of an AgTech-Enabled Market Access Scale (AEMAS) is both timely and necessary it allows for a standardized, quantifiable, and empirically valid assessment of farmers' perceptions toward market access in the digital agriculture ecosystem. AgTech-enabled market access includes physical, digital, and institutional domains, which together shape farmers' efficiency, profitability, and competitiveness. A validated scale capturing these dimensions enables systematic measurement and comparison, supporting evidence-based interventions for inclusive market integration.

Existing literature highlights gaps, including the lack of a framework integrating physical and digital market access and no validated scale to measure farmers' perceptions of AgTech-enabled markets. Accordingly, this study addresses two research questions: What are the core dimensions characterizing AgTech-enabled market access among hi-tech farmers, and how can these dimensions be systematically operationalized into a valid and reliable measurement scale? To this end, the proposed AEMAS is guided by two hypotheses: H_1–market access is a multidimensional construct encompassing physical, digital, and institutional domains, forming the conceptual basis of the scale; H_2–farmers' socio-economic characteristics significantly influence their perceived market access, supporting the scale's relevance and predictive capability. Developing a validated AEMAS addresses a key methodological and policy gap by quantifying farmers' market integration.

METHODOLOGY

A systematic procedure was employed to develop a scale for measuring AgTech-enabled market access in hi-tech agriculture, grounded in recognized methodologies for attitude and perception scale development (Edwards & Kilpatrick, 1948; Supe & Singh, 1976). The process comprised sequential stages to safeguard theoretical rigor and ensure empirical validity. Initially, a comprehensive pool of potential statements was generated, sourced from an extensive literature review and consultations with specialists in agricultural marketing, extension, and agri-business. These statements were intended to reflect diverse dimensions of market access and were provisionally associated with nine key conceptual domains, including transportation infrastructure, distance to market, market information access, digital market platforms, agri-input market accessibility, access to market institutions, storage and logistics, market intermediaries, and frequency of market visits.

Content validation formed the next stage and entailed expert consultations through Focus Group Discussions (FGDs). The primary objectives in this stage were to review each item for clarity, avoid duplication, and confirm representativeness and relevance. This thoroughly refined the item pool, ensuring statements were both precise and contextually appropriate. The third phase applied Edwards and Kilpatrick's (1948) informal criteria for attitude statements, emphasizing the exclusion of double-barreled items, universal qualifiers, and factual or binary forms. Focus was placed on clarity, singularity of idea, balance, precision, and discriminatory power. Each statement underwent systematic evaluation against 14 such criteria, with conformity scores guiding retention or modification.

Subsequently, a relevancy check was conducted, wherein experts rated the items using a four-point scale, ranging from "not relevant" to "highly relevant," further enhancing content validity and allowing for language refinement as required. Importantly, classification of items into the nine conceptual dimensions was reserved for the final stage, thereby minimizing the risk of classification bias. In the final stage, validated statements were systematically categorized under the nine dimensions, capturing both conventional aspects of market access and AgTech-driven components such as digital platforms and information flow. The diversity and representation across dimensions were evaluated using Simpson's Index of Diversity, calculated with the following formula:

$D = \Sigma(pi^2)$, where pi = Mean$i$ / Total mean

D = Simpson's Index, 1-D = Index of Diversity

One-way ANOVA was utilized to test for distinctiveness among items across dimensions. This comprehensive process resulted in a theoretically rigorous and empirically robust scale for evaluating AgTech-enabled market access in hi-tech agriculture.

RESULTS

Item Refinement and Finalisation

The scale development process produced a validated set of 56 statements, distributed across nine dimensions of AgTech-enabled market access. Initially, 110 items were generated; 52 were eliminated through expert review for duplication, ambiguity, or irrelevance of the content (Shitu et al., 2018; Gupta et al., 2022; Meethal & Thomas, 2024a; Kademani et al., 2025). Further application of Edwards and Kilpatrick's (1948) criteria ensured only statements meeting minimum conformity were retained, in line with established social science methodologies (Supe & Singh, 1976; Likert, 1932). The final 56 statements encompass both traditional (e.g., transportation, distance, intermediaries, institutions) and AgTech-driven (e.g., digital platforms, input access, market information) market access factors as shown in Table 1. This dual emphasis strengthens the instrument's ability to capture the evolving nature of agricultural markets in the digital era.

Conformity and Relevance Scores

The average conformity score for retained items was 13.64, indicating strong adherence to Edwards and Kilpatrick's criteria also eliminated ambiguous or irrelevant statements (Meethal & Thomas, 2024b). Most statements also scored above 3.0 on expert ratings

Table 1. Selected statements with conformity and mean score of AgTech enabled market access scale

S.No.	Statements	Conformity Score	Mean Score
I	Transportation Infrastructure		
1	The road to the nearest market is well-maintained with good quality.	14	3.397
2	The condition of rural roads enables the timely transportation of agricultural produce.	14	3.324
3	I face delays in transporting produce due to poor road infrastructure.	14	3.044
4	Seasonal changes (like rains) do not severely affect my road access to markets.	14	2.794
5	Transportation vehicles can access my farm without difficulty throughout the year.	14	3.162
6	My farm is connected to a paved road that allows vehicle access in most seasons.	13	3.103
7	The availability of local transport services supports my marketing activities.	14	3.162
8	I can access nearby towns using affordable transport options.	13	3.338
II	Distance to Market		
9	Market is within a convenient travel distance from my farm.	14	3.118
10	Distance does not significantly affect my frequency of visits to market.	14	2.794
11	I avoid some markets due to long travel distances.	14	3.044
12	I am satisfied with how quickly I can reach the main market from my farm.	13	3.221
13	The proximity to markets allows me to sell perishable items efficiently.	14	3.471
14	I can access more than one market within a short distance from my farm.	14	3.162
III	Market Information Access		
15	I receive real-time price updates through AgTech tools or mobile apps.	14	3.324
16	The absence of timely market information leads to poor sales decisions.	14	3.250
17	I use AgTech apps to access information about crop demand and supply.	13	3.059
18	I consider market demand and price trends when planning my crops.	13	3.206
19	The information I receive about markets helps me make better selling decisions.	14	3.176
20	I regularly use government or private SMS/IVRS for market updates.	14	3.015
21	I trust the accuracy of market information I receive through digital means.	13	2.809
IV	Digital Market Platforms		
22	I regularly use digital marketing platforms to sell my produce.	12	2.956
23	I feel digital platforms improve my market access and reduce dependence on middlemen.	13	3.250
24	I find registration in digital market platforms (eNAM, FPO, Kisan app) useful for selling my produce.	12	3.103
25	I find digital channels reliable for receiving payments after online sales	13	3.162
26	I face difficulty navigating digital market platforms.	14	3.368
27	Digital marketing tools have improved my access to distant buyers.	14	3.235
V	Agri-input Market Accessibility		
28	I receive timely information about input availability through AgTech tools.	14	3.088
29	Distance or availability does not hinder my access to essential inputs.	14	2.912
30	I have easy access to shops or cooperatives for buying quality agricultural inputs.	14	2.882
31	I find it easy to access shops that sell certified seeds, fertilizers, and inputs.	12	2.941
32	I receive updates on input availability through apps or helplines.	14	2.882
33	Delays in accessing quality inputs affect my crop planning.	14	2.897
34	Input dealers are located within a convenient distance from my farm.	14	2.882
35	I face no difficulty in obtaining credit or invoices from input providers.	14	2.691
VI	Access to Market Institutions		
36	I have access to regulated markets such as APMC or eNAM.	14	3.029
37	I am aware of the rules, pricing, and grading system in formal markets.	12	3.118
38	I find formal market procedures complex and time-consuming.	13	3.265
39	Farmer Producer Organizations (FPOs) help me with market linkages.	14	3.147
40	I prefer using government procurement schemes for selling my produce.	12	3.044
VII	Storage & Logistics		
41	I have access to cold storage or warehouses for short-term produce storage.	14	3.015
42	Lack of storage facilities forces me to sell produce immediately.	14	3.441
43	Transport logistics (vehicles, agents) are available when needed.	14	3.265
44	I use AgTech platforms to book logistics or manage supply chains.	14	3.015
45	Poor storage infrastructure increases my post-harvest losses.	14	3.206

Table 1 contd...

S.No.	Statements	Conformity Score	Mean Score
VIII	Market Intermediaries		
46	I rely on middlemen for selling my produce.	14	3.103
47	I sell my produce directly to traders or commission agents.	14	3.191
48	I rely on middlemen because they offer timely payment and pickup.	13	3.162
49	Middlemen reduce my profit margins significantly.	14	3.206
50	I prefer using digital tools to bypass intermediaries.	14	3.368
51	I have bargaining power over the prices offered by intermediaries.	14	3.088
IX	Frequency of Market Visits		
52	I visit the market more than once a week during the harvest period.	14	2.956
53	I make fewer market visits due to availability of digital sale channels.	14	3.015
54	High transportation cost reduces my frequency of market visits.	14	3.088
55	Regular market visits help me build relationships with buyers.	14	3.206
56	I coordinate marketing decisions based on scheduled market days.	14	3.176

for relevance, supporting both content and face validity. This reflects items' conceptual soundness, clarity, relevance to the construct measured and ensuring that the instrument is scientifically robust and practically meaningful (DeVellis, 2017).

Reliability of the Scale

Reliability refers to the consistency and stability of a measurement instrument (Raj & Thomas, 2022). A reliable scale consistently yields similar results when measuring the same construct under comparable conditions. In this study, reliability was assessed using Cronbach's Alpha, a widely recognized statistical measure for evaluating internal consistency in multi-item scales (Ray & Mondal, 2011; Collins, 1996). Cronbach's alpha was calculated for the 56-item AgTech-enabled Market Access Scale based on responses from 68 experts, using the formula:

$$\alpha = (N / (N - 1)) \times [1 - (\Sigma\sigma_i^2 / \sigma T^2)]$$
$$\alpha = (56 / (56 - 1)) \times [1 - (53.66 / 1040.52)] = 0.9657$$

Where, N = Number of items in the scale = 56, σ_i^2 = Variance of each individual item (i = 1 to N)
$\Sigma\sigma_i^2$ = Sum of the variances of all items = 53.66, σT^2 = Variance of the total score (sum of all items for each respondent) =1040.52

The computed Cronbach's alpha value of 0.97 demonstrates excellent internal consistency, confirming that the scale items are coherent and reliable for assessing AgTech-enabled market access in hi-tech agriculture. Additionally, dimension-wise Cronbach's alpha values ranged from 0.72 to 0.87, further indicating high internal consistency within each dimension, as presented in Table 2. While these high values confirm the constructs' coherence, they may also suggest redundancy, implying that item reduction could be considered in future refinements.

Validity of Scale

Validity reflects how accurately an instrument measures the intended construct, making it essential for drawing meaningful, relevant, and practical conclusions in studies of AgTech-enabled market access (Singh, 2019). The distribution of 56 statements across nine dimensions demonstrates that the scale effectively captures the complex and multifaceted nature of market access in hi-tech agriculture. Some dimensions, such as transportation infrastructure and agri-input market accessibility, include more items, while dimensions like access to institutions and frequency of market visits have fewer items. This distribution is both intentional and methodologically sound, as items were classified into dimensions only after the elimination process to prevent bias during selection.

Dimensional Representation

To assess the representativeness of each dimension, Simpson's Index of Diversity (1–D) was calculated, yielding values from 0.800

Table 2. Dimension-wise reliability, Simpson'D and Simpson's Index of Diversity (1 - D)

Dimension	No. of Items	Cronbach's Alpha (α)	Simpson'D	Simpson's Index of Diversity (1 – D)
Transportation Infrastructure	8	0.8576	0.1249	0.875
Distance to Market	6	0.7191	0.1670	0.833
Market Information Access	7	0.8514	0.1429	0.857
Digital Market Platforms	6	0.8745	0.1665	0.834
Agri-input Accessibility	8	0.8742	0.1247	0.875
Market Institutions	5	0.8574	0.1998	0.800
Storage & Logistics	5	0.7958	0.2000	0.800
Market Intermediaries	6	0.8305	0.1664	0.834
Frequency of Market Visits	5	0.7574	0.1998	0.800
				Mean = 0.834

Table 3. Summary of ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.586	8.000	0.073	3.301	0.006	2.194
Within Groups	0.844	38.000	0.022			
Total	1.430	46.000				

to 0.875 and an overall mean of 0.834, as shown in Table 2. These consistently high values indicate that the scale maintains strong dimensional diversity and avoids over-concentration in any single category. Such diversity is crucial, ensuring that the scale holistically assesses market access without disproportionate emphasis on particular components.

Distinctiveness Across Dimensions

A one-way ANOVA conducted on the mean scores across dimensions revealed significant variation ($F = 3.301$; $p < 0.01$).

Maximum mean score – F crit = 3.471-2.194 = 1.277

It is evident that no mean score across dimensions falls below this threshold. This suggests that the mean scores for all dimensions are comparable. The calculated F-statistic exceeding the F-critical value confirms a statistically significant difference among the dimensions (Kim, 2014). This finding provides strong evidence that the dimensions are not redundant but represent distinct constructs within the broader concept of market access. These results align with previous research emphasizing the increasing complexity of agricultural market systems, where traditional and digital elements coexist and collectively influence farmers' market access and decision-making processes (Choruma et al., 2024).

DISCUSSION

The scale was developed and validated to measure AgTech-enabled market access in hi-tech agriculture, following established procedures in social science research. The final instrument consists of 56 statements spanning nine dimensions, ensuring coverage of both traditional market access factors and new AgTech-driven components. By incorporating input from subject matter experts and adhering to rigorous criteria for item construction, the scale achieves both content and conceptual validity. High conformity and relevance scores indicate that the retained items are clear, unbiased, and directly related to the construct being measured. Reliability analysis yielded a strong overall Cronbach's alpha of 0.97, with dimension-wise coefficients between 0.72 and 0.87. These values confirm that the scale and its dimensions consistently assess coherent aspects of market access, though future refinement may address potential item redundancy.

Dimensional validity was supported by the distribution of statements and Simpson's Index of Diversity values, which ranged from 0.800 to 0.875. This demonstrates a balanced representation across all dimensions, minimizing over-concentration and ensuring that the scale holistically evaluates market access. Results from the one-way ANOVA revealed significant differences among dimensions, as indicated by an F-statistic greater than the critical value. This establishes that each dimension captures a distinct facet of market access, rather than duplicating information. Such differentiation is essential for understanding how both traditional and digital factors affect farmers' ability to access markets.

Overall, the AgTech-enabled market access scale offers a scientifically robust tool for research and extension work. It provides reliable and comprehensive measurement of market access in hi-tech agriculture, supporting future studies and policy interventions targeting both technological advancements and persistent structural barriers. The validated AgTech-enabled Market Access Scale offers multiple contributions for researcher, policymakers and extension systems to do research and practice. It provides a standardized, multidimensional scale to identify bottlenecks in AgTech adoption and supports the design of targeted capacity-building programs that address both traditional and digital challenges.

CONCLUSION

A systematic scale development procedure led to the construction of a validated 56-item AgTech-enabled Market Access Scale covering nine dimensions of hi-tech agriculture. The iterative refinement through expert consultation and relevancy testing ensured methodological rigour and content validity. Statistical checks, including conformity scores, relevancy ratings, and ANOVA, confirmed both robustness and dimensional distinctiveness. The scale empirically integrates traditional aspects of market access with emerging digital and institutional factors, providing a reliable tool for assessing farmers' perceptions. It holds practical value for researchers, policymakers, and extension systems in measuring adoption barriers, designing interventions, and strengthening market linkages in the AgTech era.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the experts possessing specialized knowledge in animal husbandry, dairy science, and extension education to obtain validation. Based on the experts' feedback, a pilot study was conducted with 60 randomly selected dairy farmers from non-sampling villages.

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 Tool

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Construction and Validation of a Knowledge Test on Pesticide Safety for Vegetable Growers

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HIGHLIGHTS

- Eighty-two items were initially developed using extensive literature review and multidisciplinary expert inputs.
- Sixty experts evaluated item relevancy, refining the pool to 45 high-quality, validated items.
- Thirty-eight items met all psychometric criteria, including acceptable difficulty, discrimination, and point biserial values.
- The final knowledge test showed excellent reliability with Cronbach's alpha of 0.90.

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ABSTRACT

Vegetable farmers frequently utilize a diverse array of pesticides at varying doses to mitigate yield losses arising from insect pests, pathogens, and other biotic stresses. Although pesticide use has substantially contributed to enhanced crop productivity, a growing body of scientific evidence highlights that indiscriminate, excessive, or unsafe pesticide use can impose serious health hazards on applicators and consumers, while also generating adverse ecological consequences. In this context, the present study was conducted in 2025, developed and standardized a comprehensive knowledge test to assess vegetable growers' understanding of safety measures in pesticide application. An initial pool of 82 items was generated ensuring coverage of all critical dimensions of pesticide safety. Based on relevancy scores obtained from 60 experts, 45 items were shortlisted for further evaluation. Item analysis was performed using three statistical indices: difficulty index, discrimination index, and point biserial correlation. Following established psychometric criteria, 38 items were retained with difficulty values between 30–70, discrimination indices ranging from 0.30–0.80, and a minimum point biserial correlation of 0.15. The finalized test comprised 38 items and demonstrated high internal consistency, with a Cronbach's alpha coefficient of 0.90, confirming its reliability for assessing knowledge on pesticide safety.

INTRODUCTION

Pesticides have played a crucial role in enhancing crop productivity and strengthening India's food security (Arora, 2018; Kumar et al., 2025). In vegetable cultivation, insect pests and diseases continue to pose major constraints, often resulting in yield losses of 10–30 per cent (Roy et al., 2017). To mitigate these losses, most vegetable growers depend extensively on chemical pesticides. As a result, vegetable production has become one of the most pesticide-intensive agricultural activities, owing to the high vulnerability of vegetable crops to pest and disease infestations (Meenakshi & Saini, 2022; Singh et al., 2025; Singh et al., 2023a, Singh 2023b). Despite the availability of scientific recommendations, a considerable gap persists between recommended pesticide-use practices and those actually followed by vegetable growers. Indiscriminate, excessive, and unsafe pesticide application

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practices pose serious threats to human health, environmental integrity, and the sustainability of agricultural ecosystems (Nain & Singh, 2015; Mishra et al., 2021; Pathak et al., 2022). Although vegetable growers acknowledge the importance of pesticides for crop protection, their adherence to essential safety measures such as using personal protective equipment (PPE), ensuring safe storage, following correct disposal procedures for empty containers, and complying with label instructions remains inadequate (Hossain et al., 2024). Even trace levels of pesticide residues in vegetables have been linked to long-term health risks among consumers (Gupta et al., 2010). Studies across India highlight this paradox: while vegetable growers are aware of the potential hazards associated with pesticides, they often continue to engage in unsafe practices. For example, in Haryana, more than 77 percent of vegetable growers reported awareness of the harmful effects of pesticides, yet the majority could not interpret toxicity colour codes or follow label guidelines, leading to frequent incidents of acute poisoning (Meenakshi & Saini, 2022). These patterns underline the urgent need for interventions that address not only growers' knowledge but also their attitudes toward safe and responsible pesticide use. Integrated Pest Management (IPM) has been promoted as a sustainable alternative to indiscriminate pesticide reliance (Lal et al., 2024; Lal et al., 2025). Through national programs, Krishi Vigyan Kendra's (KVKs), and state extension agencies, IPM advocates the use of biological control agents, cultural practices, and judicious chemical application (Meenakshi & Saini, 2022). However, the effective adoption of IPM hinges largely on farmers' attitudes toward safety, precautionary measures, and long-term sustainability. Although awareness about IPM is gradually increasing, actual adoption remains limited, primarily due to entrenched attitudes favouring chemical pesticides (Gupta et al., 2020). Given these challenges, systematically assessing vegetable growers' knowledge level toward pesticide safety particularly in relation to IPM practices is essential for designing behaviour-oriented interventions. While several Knowledge, Attitude, and Practice (KAP) studies have examined pesticide use among Indian farmers, there remains a notable lack of standardized tools tailored specifically to measure knowledge level toward pesticide safety in vegetable cultivation. A rigorously developed and validated knowledge test is needed to capture the multidimensional aspects of pesticide safety, including handling, storage, application methods, post-application precautions, container disposal practices, health and environmental safeguards, and compliance with regulatory norms.

METHODOLOGY

Items related to safety measures in pesticide application were systematically developed, refined, and standardized through sequential stages comprising item generation, expert validation, and statistical screening. Initially, a pool of 82 statements was generated from secondary sources, including scientific journals, extension manuals, research reports, and other relevant literature. Expert consultations from the disciplines of Plant Pathology, Entomology, and Agricultural Extension were further utilized to enhance comprehensiveness and conceptual clarity. The preliminary items were subjected to relevancy judgment by 60 experts. Each statement was rated on a three-point continuum Most Relevant (3), Relevant (2), and Not Relevant (1). Relevancy Weightage (RW) and Mean Relevancy Score (MRS) were computed using:

$$RW = \frac{MR + R + LR}{MPS}, MRS = \frac{MR + R + LR}{n}$$

Where, MR = Most Relevant, R = Relevant, LR = Least Relevant, MPS = Maximum Possible Score (60 × 3 = 180), and n = number of judges. The Overall Mean Relevancy Score (OMRS) was 2.35. Items with RW > 0.80 and MRS ≥ OMRS were retained, resulting in 45 qualified statements.

Item analysis

These 45 items were administered to 30 non-sample respondents. Total scores were arranged in descending order and classified into six equal groups: G1 to G6. For item analysis, only the extreme groups G1, G2, G5, and G6 were considered. Difficulty Index (P) was computed as:

$$P = \frac{\text{Number of correct responses}}{\text{Total respondents}} \times 100$$

Items with P between 30 and 70 were retained to avoid extremely easy or difficult questions.

Discrimination Index (E1/3), reflecting the item's ability to differentiate between high and low scorers, was calculated using:

$$E1/3 = \frac{(S1 + S2) - (S5 + S6)}{N/3}$$

Where, S1, S2, S5, and S6 denote frequencies of correct responses in respective groups. Items with discrimination values ranging from 0.20 to 0.80 were selected. Internal validity of each item was further examined using point biserial correlation:

$$r_{pbis} = \frac{(M_P - M_Q)}{SD} \sqrt{PQ}$$

Where, MP and MQ represent mean scores of respondents answering correctly and incorrectly; P and Q denote proportions of correct and incorrect responses. Items significant at 1% and 5% levels were retained.

After applying all screening criteria, 38 items were selected for the final knowledge test. Reliability was assessed using Cronbach's alpha in SPSS (Version 27), yielding a coefficient of 0.90, confirming excellent internal consistency and robustness of the instrument.

RESULTS

Reliability analysis

The internal consistency of the knowledge test was assessed using Cronbach's alpha. The computed reliability coefficient was 0.90, which falls within the "excellent" category. This indicates that the items function cohesively to measure a single underlying construct knowledge on safety measures in pesticide application. Such a high level of internal consistency suggests that the instrument is stable, dependable, and suitable for use in further empirical assessments.

Validity analysis

Content validity

The content validity of the test was ensured through a rigorous multi-stage development process. A comprehensive pool of 82 items was derived from scientific literature, extension manuals, expert consultation, and field-level experience. Sixty experts evaluated each item on relevancy, and items with RW > 0.80 and MRS ≥ OMRS (2.35) were retained. This ensured that the retained items represented the full conceptual domain of pesticide safety, establishing strong content adequacy.

Construct validity

Construct validity was examined using Point Biserial Correlation (rpbis). Items with significant correlations at the 1% and 5% levels were retained, indicating that each of these items was appropriately aligned with the underlying construct and effectively discriminated between knowledgeable and less-knowledgeable respondents. The majority of retained items had rpbis > 0.25, which is considered satisfactory for educational and psychometric testing.

Relevancy assessment

Table 1 presents the results of relevancy analysis. Out of 82 initially generated items, 45 items met the requisites of RW and MRS for inclusion in the preliminary test. These items demonstrated strong content representation of pesticide safety knowledge.

Item analysis

The 45 selected items were administered to 30 non-sample vegetable growers for statistical screening. Difficulty Index (DI), Discrimination Power (DP), and Point Biserial Correlation (PBS/ rpbis) were computed. The item analysis revealed that the retained statements met all standard psychometric criteria. Most items fell within the acceptable difficulty range (0.30–0.70), indicating neither excessive ease nor undue difficulty. The discrimination indices (0.20–0.80) confirmed strong ability of the items to differentiate between high- and low-knowledge respondents. Additionally, all selected items achieved the minimum point biserial correlation (≥0.15, preferably >0.20), demonstrating satisfactory internal consistency and strong item total relationships. Analysis revealed

Table 1. Relevancy test scores of item selection

Item No	Items	RW	MRS	OMRS
1.	Are you able to recognize the symptoms of disease infestation, Insect attack, nematode attack or nutritional deficiency?	0.96	2.88	2.35
2.	A face mask is not required while mixing pesticides	0.69	2.08	
3.	Do you apply pesticides based on the specific pest identified?	0.91	2.72	
4.	Can you distinguish/identify the beneficial insects?	0.82	2.45	
5.	It is safe to use the same gloves for pesticide application and other farm activities.	0.64	1.93	
6.	Do you know the color code of pesticide?	0.84	2.53	
7.	I think written materials are the best way to educate farmers about pesticide safety.	0.64	1.93	
8.	Pesticide safety training continuous process, not a one-time event.	0.63	1.90	
9.	Do you identify symptoms of little leaf of brinjal?	0.81	2.42	
10.	Do you have know bio-pesticides (eg. *Trichoderma,* NSKE etc.)	0.82	2.47	
11.	Do you know the best time of pesticide spray? (Yes/No)	0.84	2.52	
12.	It is legal to apply pesticides in a manner specified on the label.	0.72	2.15	
13.	Do you identify symptoms of fruit borer, late blight of tomato?	0.90	2.70	
14.	I think pesticides applied by certified applicators	0.73	2.18	
15.	I think record-keeping of pesticide application is not necessary.	0.77	2.30	
16.	Do you know Diamond Back Moth of cabbage can be managed by growing Chinese cabbage or Indian mustard?	0.81	2.43	
17.	It is legal to use pesticides that have not been approved by the government.	0.74	2.22	
18.	I monitor the health of myself and workers regularly for symptoms of pesticide exposure	0.74	2.23	
19.	Do you know the best time of pesticide spray?	0.81	2.43	
20.	Do you know about pheromone trap (yellow, blue sticky trap etc.)	0.85	2.55	
21.	Do you know upward curling of chilly is due to?	0.80	2.40	
22.	I know drinking milk can neutralize ingested pesticides.	0.77	2.32	
23.	Do you know downward curling of chilly is due to?	0.69	2.08	
24.	I know pesticides can cause allergic reactions in some individuals.	0.74	2.22	
25.	Inhalation is the route of exposure to pesticides.	0.75	2.25	
26.	Do you know marigold is good trap crop in tomato for the control of tomato fruit borer?	0.84	2.52	
27.	It is safe to spray pesticides during rainy weather.	0.73	2.18	
28.	Do you know Cueleue is good trap for fruit fly of cucurbits?	0.85	2.55	
29.	Buffer zones around water bodies help prevent pesticide contamination	0.67	2.02	
30.	Do you know about universal antidote? (eg. charcoal, tannic acid, magnesium oxide etc.?	0.80	2.40	
31.	Do you know the waiting period of any pesticides?	0.91	2.72	
32.	Applying more pesticide than recommended will increase its effectiveness	0.68	2.03	
33.	Do you know the mode of action of pesticides?	0.84	2.52	

Table 1 contd...

Item No	Items	RW	MRS	OMRS
34.	Using pesticides does not affect non-target species.	0.63	1.90	
35.	Crop rotation can reduce the need for pesticide use.	0.79	2.38	
36.	Do you know at which stage paraquat herbicide is typically applied?	0.87	2.62	
37.	The application rate of pesticides is same for all types of crops.	0.71	2.13	
38.	It is important to calibrate spraying equipment before each use.	0.68	2.05	
39.	Do you know the most serious disease of brinjal?	0.87	2.62	
40.	Do you know the, which fungicide is the most effective for the control of Phomopsis blight of brinjal?	0.81	2.42	
41.	Are you aware of banned pesticides?	0.82	2.47	
42.	Pesticide spills should be cleaned immediately using any available cloth.	0.67	2.00	
43.	Whitefly is a serious pest of which vegetable?	0.85	2.55	
44.	Do you know the Critical weed-free period in tomato?	0.82	2.47	
45.	Do you know which type of nozzle is used for managing insect and disease in agriculture?	0.83	2.50	
46.	Eye exposure to pesticides, rinse the eyes with clean water for at least 15 minutes.	0.74	2.22	
47.	I take regular training on safe use of pesticide	0.76	2.27	
48.	Do you know Metribuzin 70% WP (Bayer sensor) is used in potato for? A. Insect pests such as cutworms; B. Fungal diseases such as late blight C. Broad-leaf weeds and some grasses; D. Nematode infestation	0.89	2.68	
49.	Do you know the Critical Weed free period in cabbage?	0.90	2.70	
50.	Pesticide safety training continuous process, not a one-time event.	0.67	2.00	
51.	Do you know the which one of the following-coloured pesticide has least toxicity? A. Green; B. Blue; C. Yellow; D. Red	0.80	2.40	
52.	Knowledge of local pest species and their biology is crucial for effective pesticide use.	0.74	2.22	
53.	Do you know the which one of the following-coloured pesticide has maximum toxicity? A. Green; B. Blue; C. Yellow; D. Red	0.89	2.68	
54.	Do you know *Trichoderma viride* used as? A. Seed treatment; B. Soil treatment	0.86	2.57	
55.	It is unnecessary to seek medical attention if the symptoms of pesticide exposure are mild.	0.73	2.20	
56.	Pesticide exposure incidents should be documented and reported.	0.68	2.05	
57.	Do you know the recommended dose of *Trichoderma viride* 1.0% WP for Seed Treatment in cauliflower?	0.87	2.60	
58.	Do you know that incorrect pesticide use can contaminate water sources?	0.69	2.07	
59.	Do you know that pesticides can cause both acute and chronic health effects?	0.69	2.08	
60.	Do you know that Pheromone trap can control insect-pest?	0.85	2.55	
61.	Do you know Coragen® MaX pesticide is used for the control of which pests?	0.91	2.73	
62.	Do you know that emergency contact numbers should be available during pesticide use?	0.69	2.07	
63.	Do you know that label instructions must be strictly followed when mixing pesticides?	0.84	2.52	
64.	Do you know that immediate medical help is needed if pesticide poisoning is suspected?	0.79	2.37	
65.	Do you know the trade name of Halosulfuron Methyl 75% WG is?	0.79	2.38	
66.	Do you know that wearing gloves is necessary when handling pesticides?	0.68	2.05	
67.	Do you know the trade name of Emamectin Benzoate 5% SG is?	0.78	2.35	
68.	Do you know that pesticides must be kept out of reach of children and pets?	0.74	2.23	
69.	Do you know which insecticide is used in control of Whitefly, Thrips, Aphids, Caterpillar and Leaf miner in bitter gourd and watermelon?	0.64	1.93	
70.	Do you know the recommended dose of Cyantraniliprole 10.26% OD in bitter gourd for insects' control?	0.79	2.38	
71.	Do you know that spraying equipment must be cleaned after each use?	0.81	2.43	
72.	Do you know that children and pregnant women are more vulnerable to pesticide poisoning?	0.80	2.40	
73.	Do you know the trade name of Mandipropamid 23.4% SC is?	0.77	2.30	
74.	Do you know the recommended dose of *Ampelomyces quisqualis* 2.0% WP for powdery mildew disease of cucumber?	0.75	2.25	
75.	Do you know that long-term pesticide exposure may lead to cancer?	0.84	2.52	
76.	Do you know the recommended dose of *Trichoderma viride* 1.0% WP for Seedling Root dip Treatment in cabbage?	0.68	2.05	
77.	Do you know the trade name of Imidacloprid 17.8 SL	0.76	2.27	
78.	Do you know that symptoms like headache, dizziness, and nausea indicate pesticide poisoning?	0.83	2.50	
79.	Do you know that Integrated Pest Management (IPM) helps reduce dependency on pesticides?	0.90	2.70	
80.	Do you know that leftover pesticides should not be disposed of in rivers or streams?	0.87	2.62	
81.	Did you know that pesticides should always be stored in a cool, dry place and kept strictly out of the reach of children and pets for safety?	0.88	2.65	
82.	Do you know the mode of action of Imidacloprid 17.8 SL or Thiamethoxam 25% WG?	0.77	2.32	

Table 2. Item difficulty, discrimination and point biserial correlation scores of items for item analysis

S.No.	Items	P	E1/3	rpbis
1	Can pesticides cause both acute (short-term) and chronic (long-term) health effects? (Yes/No)	0.70	-0.13	-0.13
2	Should pesticides always be stored in their original containers with the labels intact? (Yes/No)	0.63	0.13	0.01
3	Do you keep records of pesticide use, including the date, type, and quantity applied? (Yes/No)	0.60	0	0.02
4	Is reading the pesticide label alone sufficient to fully understand proper pesticide application and safety measures? (Yes/No)	0.60	0.25	0.13
5	Should an emergency contact number be kept readily available in case of pesticide exposure? (Yes/No)	0.60	0.13	0.10
6	Are you able to recognize the symptoms of disease infestation, Insect attack, nematode attack or nutritional deficiency? (Yes/No)	0.60	0.50	0.47*
7	Can you distinguish/identify the beneficial insects? (Yes/No)	0.50	0.38	0.27*
8	Do you know the color code of pesticide? (Yes/No)	0.63	0.50	0.38*
9	Do you know the which one of the following-coloured pesticide has least toxicity? A. Green B. Blue C. Yellow D. Red	0.60	0.38	0.35*
10	Do you know the which one of the following-coloured pesticide has maximum toxicity? A. Green B. Blue C. Yellow D. Red	0.60	0.63	0.53*
11	Do you identify symptoms of fruit borer, late blight of tomato? (Yes/No)	0.63	0.25	0.27*
12	Do you know that long-term pesticide exposure may lead to cancer? (Yes/No)	0.57	0.50	0.48*
13	Do you know Diamond Back Moth of cabbage can be managed by growing Chinese cabbage or Indian mustard? (Yes/No)	0.63	0.75	0.50*
14	Do you know the best time of pesticide spray? (Yes/No)	0.57	0.75	0.52*
15	Do you know about pheromone trap (yellow, blue sticky trap etc.) (Yes/No)	0.50	0.63	0.37*
16	Do you know upward curling of chilly is due to? A. Thrips B. Yellow mites C. Whitefly D. Caterpillars	0.57	0.75	0.55*
17	Do you know downward curling of chilly is due to? A. Thrips B. Yellow mites C. Whitefly D. Caterpillars	0.57	0.75	0.58*
18	Do you know marigold is good trap crop in tomato for the control of tomato fruit borer? (Yes/No)	0.60	0.63	0.47*
19	Do you know Cueleue is good trap for fruit fly of cucurbits? (Yes/No)	0.63	0.50	0.38*
20	Do you know about universal antidote? (eg. charcoal, tannic acid, magnesium oxide etc.? (Yes/No)	0.60	0.38	0.35*
21	Do you know the waiting period of any pesticides? (Yes/No)	0.60	0.63	0.53
22	Do you know the mode of action of any pesticides (like-systematic, contact? (Yes/No)	0.63	0.25	0.27*
23	Do you know at which stage paraquat herbicide is typically applied? A. Post-emergence of weeds; B. Pre-plant application before crop emergence C. After crop emergence; D. Both a and b	0.57	0.50	0.48*
24	Do you know the most serious disease of brinjal? A. Leaf spot; B. Phomopsis Blight; C. Alternaria Leaf Spots; D. Fruit Rot	0.63	0.75	0.50*
25	Do you know the, which fungicide is the most effective for the control of Phomopsis blight of brinjal? (Yes/No)	0.57	0.75	0.52*
26	Do you know which of the following insecticide are banned now? A. Endosulfan; B. Benomyl; C. Carbendazim; D. Delegate	0.50	0.63	0.37*
27	Do you know Metribuzin 70% WP (Bayer sensor) is used in potato for? A. Insect pests such as cutworms; B. Fungal diseases such as late blight C. Broad-leaf weeds and some grasses; D. Nematode infestation	0.57	0.75	0.55*
28	Do you know the Critical Weed free period in cabbage?	0.57	0.75	0.58*
29	Do you identify symptoms of little leaf of brinjal? (Yes/No)	0.60	0.63	0.47*
30	Do you have know bio-pesticides (eg. *Trichoderma,* NSKE etc.) (Yes/No)	0.60	0.38	0.35*
31	Do you know *Trichoderma viride* used for? A. Seed treatment B. Soil treatment	0.60	0.63	0.53*
32	Do you know the recommended dose of *Trichoderma viride* 1.0% WP for Seed Treatment in cauliflower? A. 3 g/kg seed; B. 2 g/kg seed; C. 4 g/kg seed; D. 5 g/kg seed	0.63	0.25	0.27*
33	Do you know that Pheromone trap can control insect-pest? A. Brinjal shoot & fruit borer; B. Tomato fruit borer; C. Bhindi shoot & fruit borer; D. All of these	0.57	0.50	0.48*
34	DO you know which type of nozzle is used for managing insect and disease in agriculture? A. Hollow cone B. Flat fan C. Solid cone nozzle D. All can be used	0.63	0.75	0.50*
35	Did you know that pesticides should always be stored in a cool, dry place and kept strictly out of the reach of children and pets for safety? (Yes/No)	0.57	0.75	0.52*
36	Do you know that label instructions must be strictly followed when mixing pesticides? (Yes/No)	0.50	0.63	0.37*
37	Do you know that spraying equipment must be cleaned after each use? (Yes/No)	0.57	0.75	0.55*
38	Do you know that children and pregnant women are more vulnerable to pesticide poisoning? (Yes/No)	0.57	0.75	0.58*
39	Do you know that symptoms like headache, dizziness, and nausea indicate pesticide poisoning? (Yes/No)	0.60	0.63	0.47*

Table 2 contd...

S.No.	Items	P	E1/3	rpbis
40	Do you know that Integrated Pest Management (IPM) helps reduce dependency on pesticides? (Yes/No)	0.60	0.13	0.02
41	Do you know that leftover pesticides should not be disposed of in rivers or streams? (Yes/No)	0.60	0.88	0.59*
42	Do you know that leftover pesticides should not be disposed of in rivers or streams? (Yes/No)	0.50	0.63	0.40*
43	Do pesticide safety workshops help in increasing awareness about reducing the risk of pesticide-related accidents? (Yes/No)	0.53	0.13	0.10
44	Do you practice proper handwashing with soap and water immediately after completing pesticide application? (Yes/No)	0.53	0.38	0.26*
45	Is knowledge of basic first aid procedures important for pesticide users to respond quickly and safely in case of pesticide exposure or poisoning? (Yes/No)	0.57	0.75	0.65*

P= Item difficulty index, E1/3= Item discrimination index, rpbis =point biserial correlation, *Selected items

that 38 items met all three criteria. Items exhibiting extremely low discrimination, high difficulty extremes, or negative rpbis were removed. Items with particularly strong rpbis values were marked with "*", indicating high internal validity.Thus, the final standardized knowledge test consisted of 38 items suitable for assessing the knowledge level of vegetable growers on safe pesticide application practices.

DISCUSSION

The present study aimed to develop a statistically sound and content-rich instrument to measure the knowledge of vegetable growers regarding pesticide safety. The results indicate that the methodological rigor employed spanning item construction, expert validation, and psychometric testing was effective in generating a robust and reliable instrument.

The high Cronbach's alpha coefficient (0.90) aligns with the findings of Priyadarshini et al. (2021), who reported similar reliability (0.904), reaffirming that knowledge tests developed through structured multi-stage processes can achieve strong internal consistency. The involvement of experts from multiple disciplines further enhanced content validity, ensuring that the instrument covered all critical dimensions of pesticide safety such as identification of pests, toxicity classification, protective equipment, safe storage, first-aid measures, and environmental precautions.

The discrimination index values observed in this study reflect the instrument's ability to distinguish between well-informed and poorly informed respondents (Loukham & Bandyopadhyay, 2014; Kumar et al., 2016; Muyal et al., 2022; Vijayan et al., 2022; Vijayan et al., 2023). Additionally, the point biserial correlation values (>0.25 for most items) confirm strong construct validity, indicating that individual items contributed meaningfully to the overall knowledge measurement.

The retention of 38 high-quality items from an initial pool of 82 demonstrates the necessity of rigorous filtration in test development. Such refinement minimizes redundancy, enhances precision, and ensures that the final tool is not only comprehensive but also efficient for field administration.

Overall, the study successfully developed a standardized, reliable, and valid knowledge test for assessing safety-related awareness among vegetable growers. The final test can serve as a scientific tool for researchers, extension personnel, policymakers, and training institutions to evaluate and improve pesticide safety literacy, ultimately contributing to safer agricultural practices and reduced pesticide-related health risks.

CONCLUSION

Despite the essential role of pesticides in safeguarding vegetable crops, widespread gaps persist between recommended safety practices and farmers' actual behaviour, posing substantial risks to human health, ecosystems, and food safety. Through a rigorous multi-stage development process including expert validation, difficulty and discrimination testing, and psychometric evaluation the study successfully standardized a 38-item knowledge test with excellent reliability (Cronbach's $\alpha = 0.90$) and strong evidence of content and construct validity (Cronbach, 1951). The instrument effectively captures multidimensional aspects of pesticide safety, ranging from pest identification and toxicity interpretation to storage, handling, application practices, first aid, and environmental safeguards. This validated tool offers significant utility for researchers, extension systems, and policymakers in designing targeted interventions aimed at strengthening safe pesticide use. Ultimately, its application can contribute to reducing pesticide-related hazards and promoting sustainable vegetable production systems.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the judges of the statements/ items 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 Note

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Perceptions on the Selection of Seed Varieties for Paddy Farming in Palakkad: A Qualitative Inquiry

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HIGHLIGHTS

- The present research has used a qualitative approach to identify the pattern of selection of seed varieties of paddy.
- It was found that the selection between traditional and hybrid paddy seed varieties has a crucial role in the enhancement of productivity.
- It was found that the choice between traditional and hybrid seeds is mainly based on climatic conditions, yield potential and input cost.

ARTICLE INFO

Keywords: Paddy cultivation, Seed varieties, Traditional seeds, Hybrid seeds.

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ABSTRACT

Paddy is an important item of food and a source of livelihood in Palakkad district of Kerala. However, it was observed that the productivity of paddy cultivation has been declining in Palakkad. Earlier research has identified some of the causes of the decline in the productivity of paddy. But the decision on the selection of seed varieties of paddy remains under-investigated in a qualitative manner. Considering this context, the present research attempted to analyse the selection-decision of seed varieties of paddy in Palakkad. To meet this goal, the present research has used a qualitative approach. The primary information was collected through in-depth interviews and focus group discussions with respondents in 2025. These responses were analysed by word-cloud analytics. Based on the analysis, it was found that farmers used the traditional seed varieties of paddy in the 'dry season' and hybrid varieties in the 'wet season'. The major factors that influenced their seed selection were climate conditions, satisfaction from farming, size of the holding, availability of irrigation facilities, input costs, yield capacity, market for paddy and nature of Government support. Based on these findings, the present research argues that novel paddy varieties of seeds should be developed to suit the region-specific climate and socio-economic conditions of paddy farmers in Palakkad.

INTRODUCTION

Kerala has a unique geographic and climatic situation, ranging from high rainfall zones to rain shadow regions as compared to other major states in India. Based on the climatic and food habits of the people, paddy has been the major food crop in Kerala. It occupies 7.1 per cent of the total cropped area. However, the production and productivity of the paddy have been declining in Kerala. For instance, the productivity of paddy amounts to 2790 kilograms/hectare in Kerala. Punjab has the highest yield (3952 kilogram/hectare) among major states in India. In Kerala, districts such as Palakkad, Alappuzha, Thrissur, and Kottayam together account for 81.2 per cent of the total rice production. They account for 41 per cent, 16 per cent, 14 per cent, and 9 per cent in the total rice production, respectively (Kerala Economic Review, 2024).

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There are various causes in the decline of productivity of paddy production such as sup-optimum size of paddy fields, inadequate access to credit to farmers, lack of scientific knowledge to farmers, poor technological capacity, competition from other crops, shifting of paddy field into real estate, lack of scientific knowledge on farming, lack of crop-specific government initiatives and wrong selection of paddy varieties for cultivation (Sabu & Roy, 2024; Kerala Economic Review, 2024).

Selection of paddy varieties for cultivation depends on various socio-economic, cultural, technological, economic and institutional factors. The attributes such as maturity period, yield potential, tolerance to stress, grain quality and size of the grain is crucial (Mehar et al., 2017). Generally, paddy-seed varieties may be divided into traditional and hybrid seeds. In addition to these biological classifications, cooking quality and stress tolerance of seed varieties are also pivotal. Moreover, the gender of the farmer and region-specific factors would also influence their decisions of choice (Addison et al., 2014; Mehar et al., 2017; Sharma et al., 2025). From these observations from the previous literature, it may be found that there are a variety of factors that influenced the decision on the selection of seeds and the productivity of paddy cultivation.

Based on the productivity decline and problems of paddy farmers, the Government of India (GoI) and the Government of Kerala (GoK) initiated various steps. Various schemes involve producing and distributing certified seeds. For instance, the 'Registered Seed Growers Programme (RSGP)' and 'Rice Development Scheme' were introduced to help farmers (Kerala Economic Review, 2024). But the impact of these initiatives and the seed selection pattern of paddy is seldom analysed.

Although there is ample earlier research in this area, they seldom examined the choice pattern and impact of the selection of varieties of paddy seeds in Kerala. In this context, the present research attempted to examine the selection of paddy seed varieties in Palakkad. In addition, it analysed the impact of the selection of traditional and hybrid seeds in a qualitative manner. This novel area and approach will fill the existing research gap. Furthermore, it has contributed to the existing literature by suggesting measures to improve the choice of paddy seed varieties to improve productivity.

METHODOLOGY

The present research attempts to accomplish the research goals through a qualitative survey in Palakkad. The present research has used probability stratified sampling method to identify the respondents. Firstly, the present research divided the sample district into Block Panchayats. Population was collected from the records of Krishi Bhavans, farmer organisations, Local Self-Governments (LSGs) and village offices. From each Block Panchayath, the total number of paddy farmers was collected. Successively, farmers were stratified with respect to their characteristics. These characteristics are: (i) experience of farmers; (ii) season of cultivation; (iii) size of holding of farmers; (iv) gender of farmers; (v) age group of farmers and (vi) educational qualification of farmers. Farmers were stratified with respect to their socio-economic and agricultural characteristics. Subsequently, farmers were selected randomly from each stratum (Hounyo & Lahiri, 2023). Subsequently, semi-structured schedule and notes for focus group discussions were prepared. The semi-structured schedule contained four sections. They were: (i) socio-economic characteristics of paddy farmers in Palakkad district; (ii) nature of section of paddy varieties of seeds; (iii) causes of selection pattern of paddy varieties of seeds and (iv) constraints in the selection pattern of paddy varieties of seeds. The themes were finalized with respect to the review of previous theoretical and empirical literature and the pilot survey. Each theme categorized into sub-themes for clarity. The standardisation of the research instrument was done through following steps: (i) a clear-definition of research objectives; (ii) definition of themes; (iii) clarity on each sub-theme; (iv) framing of items; (vi) development of items and (vii) ensured validity and consistency.

Based on the stratification, this study purposively selected 80 paddy farmers to collect primary information. The number of farmers was selected with respect to the stratification of framer groups. The categories are: (i) size of paddy fields of farmers; (ii) gender of the farmers and (iii) age group of the farmers. Respondents were finalized with respect to their convenience and appointment. Qualitative data was gathered through in-depth interviews and discussions. It allowed them to share and discuss their views openly. At the same time, interviews and discussions were followed a structured format to collect the information based on research goals (Sekhri, 2025). Each interview was lasted approximately 30 to 45 minutes in their regional language.

Subsequently, collected information were categorised and transcripts prepared. The audio recordings were transcribed into text, using a software called 'automated transcription software'. After initial verbatim transcription, transcripts were reviewed and cross checked with the recording for accuracy. Subsequently, transcripts were marked through different inks and pasted slips for each theme. Secondly, initial codes were prepared. Successively, codes were modified repeatedly and broader themes developed. Subsequently, sub-themes were developed for each main theme (Braun & Clarke, 2006; Silverman & Patterson, 2021; Sekhri et al., 2025).

Word cloud analytics was applied to systematically analyse the transcripts. The verbatim quotes collected from the primary survey were compiled and cleaned to remove redundancies and irrelevant words. The analysis was performed using the Python programming language (Word Cloud and matplotlib libraries), which enabled the generation of word clouds that visually display the most frequently used terms. In this visualization, the size of each word corresponds to its relative frequency in the text corpus, making it easier to identify dominant concepts and issues (Heimerl et al., 2014; Jaidka et al., 2020). Furthermore, keywords such as traditional, hybrid, cost, climate, government support and impact were weighted to highlight their significance in the context of farmers' perceptions. This method was provided a quick, rigorous, and replicable way of identifying dominant themes in the data (DePaolo & Wilkinson, 2014).

RESULTS

The findings of this research are exhibited in Figures 1-4. The causes for the selection of 'hybrid' and 'traditional' varieties of paddy are interwoven and exhibited in these four figures. It is evident that most of the farmers were cultivated the traditional

varieties of paddy seeds in Palakkad district in Kerala. At the same time, their preference were mainly due to the 'climate'. There are various factors that influenced the decision-making process regarding the selection of paddy seed varieties in Palakkad. They are: (i) satisfaction from paddy farming; (ii) societal practices of paddy cultivation; (iii) eco-friendly practices of paddy farming; (iv) yield capacity of hybrid and traditional seeds; (v) economies of scale; (vi) input cost; (vii) fertilizers and pesticides application on hybrid and traditional varieties of seeds; (viii) paddy farming and total farm income (ix) differences of productivity of traditional and hybrid seeds; (x) level of government support; (xi) profit prospects from paddy farming and (xii) debt level of paddy farmers. It may be inferred that 'climate' is one of the major factors that influenced the selection of paddy varieties of seeds for farming. If the climatic conditions were more favourable, they would have cultivated 'hybrid varieties' of seeds in Palakkad district in Kerala. Farmers expressed that they wish to cultivate 'hybrid varieties' of paddy both in 'dry' and 'wet' seasons. Howevevr the irrigation facilities were not always conducive to all farmers to cultivate hybrid varieties of paddy.

Therefore, they switched their options and cultivate traditional varieties in 'dry' season and hybrid varieties of seeds in 'wet' season. Farmers also emphasized that government support is necessary to manage the challenges like flood and water scarcity.

Secondly, 'environmental protection' is a concern raised by farmers cultivating traditional seeds of paddy. Farmers presumed that 'traditional seeds' requires low level of fertilizers and pesticides as compared to farming of 'hybrid seeds' in the district. Furthermore, 'satisfaction from paddy farming' is a crucial factor in determining the selection of seeds for paddy farming. Some farmers expressed that they got satisfaction from the cultivation of 'traditional' varieties of seeds. Few farmers expressed that they got satisfaction from the cultivation of 'hybrid' seeds of paddy. 'Farm income' is a crucial factor in determining the selection of seed varieties of paddy of farmers.

Majority of the farmers prefer to cultivate the hybrid varieties of seeds if they are not constrained to climate conditions.

They believed that hybrid varieties can enhance the productivity of paddy and thereby total farm income. Productivity and input costs are interwoven and it will affect the profit from paddy farming.

Figure 1. Selection of paddy seed varieties of paddy farmers in dry season in Palakkad
Source: Compiled by authors from qualitative data

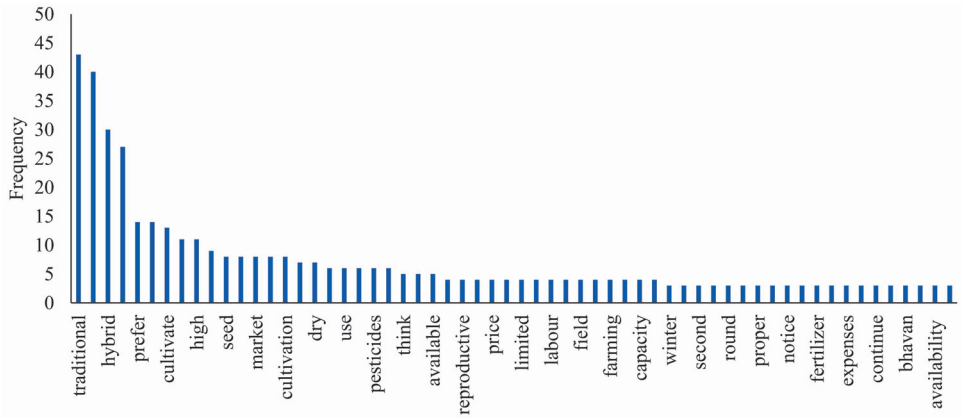

Figure 2. Frequency of selection of seed varieties of paddy farmers in dry season
Source: Compiled by authors from qualitative data

Figure 3. Selection decision of seed varieties of paddy in the wet-season in Palakkad
Source: Compiled by authors from qualitative data

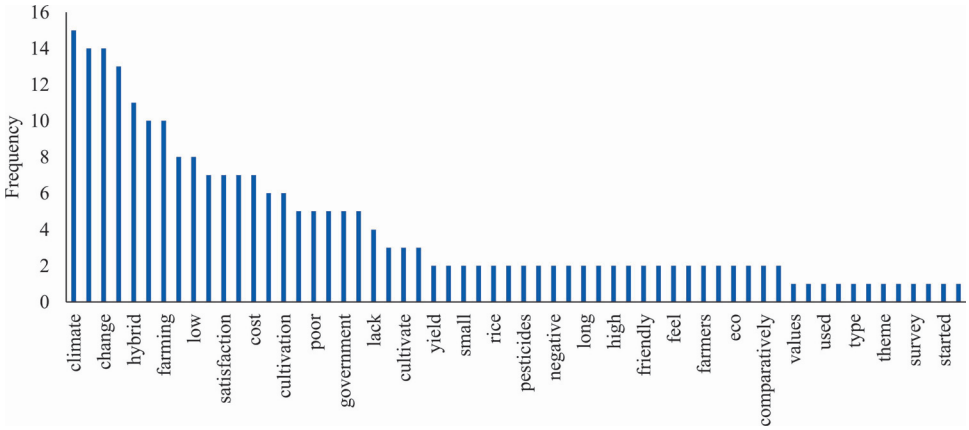

Figure 4. Decision on seed varieties of paddy in wet season in Palakkad
Source: Compiled by authors from qualitative data

'Economies of scale' was helpful in the large-scale farmers to reduce their cost of operations. At the same time, small scale farmers revealed that their input costs are high and cost of operations.

DISCUSSION

The present research enquired the perceptions on the major selection criteria of farmers on varieties of paddy seeds for farming in Palakkad. A qualitative research approach was followed for the collection and analysis of data. Analysis revealed that there are mixed factors that which determined the selection of seed varieties of paddy. 'Climate' is one of the major factors that which determined the selection of varieties of paddy. Generally, farmers selected 'hybrid seeds' of paddy in 'wet' season while traditional varieties applied in 'summer' season. Furthermore, farmers decided to cultivate both traditional and hybrid varieties of seeds during the 'winter' season that which exhibited a mixed pattern. Apart from 'climate', there are various factors that which determined the selection of varieties of seeds. They are: (i) size of the paddy field; (ii) profit for paddy; (iii) satisfaction of farming in a region; (iv) fertilizer and pesticides availability and its cost; (v) yield potential of seeds; (vi) seed and labour and (vii) government support for farming.

These findings seem to be directly and indirectly mentioned in the earlier literature on the various dimensions of paddy farming. For instance, earlier literature indicated that 'supportive climatic' are necessary to execute any paddy farming plan. Perceptions on 'climate change' was a crucial factor in determining the paddy farming. Adoption of 'climate smart agriculture' seem to be one of the critical factors to improve the climate resilience of farmers (Pradhan et al., 2025). Furthermore, cultivation of 'hybrid seeds' require optimum application of fertilisers, pesticides and water as compared to 'traditional' varieties of seeds. Previous findings indicate that traditional varieties have more salinity and flood tolerance capacities as compared to hybrid varieties of seeds. Climate and irrigation facilities are seemed to be closely linked to paddy farming (Sowmya & Padannakkad, 2016; Koppa & Amarnath, 2021; Shafeeqa et al., 2022; Ashokkumar et al., 2023; Vivekanandhan et al., 2024)

Secondly, the present research found that 'size of the landholdings' is one of the most prominent factors that which influenced the selection of paddy seeds. Large scale farms along with adequate irrigation facilities prefer to cultivate hybrid varieties of seeds irrespective of seasons. On the contrary, 'small-scale farms 'prefer to cultivate traditional varieties of paddy especially in 'dry'

season. This finding seems to be indirectly validated by the earlier literature on decision of choice in farming (Bannor et al., 2020; Krishnankutty et al., 2021; Prasad et al., 2022).

Thirdly, the present research inferred that 'profit' is a crucial factor in determining the decision of the selection of paddy seeds. Profit is mainly determined by the market demand. Market demand is often related to cooking quality, grain quality and biochemical qualities. Previous literature indicated that 'boldness of the grain' one of the major factors in determining the demand of rice varieties (Mehar et al., 2017; Suma et al., 2018). Apart from these factors, there are some micro-factors such as yield and resistance capacity of seeds also influenced the decision-making process. Previous literature was mentioned that yield-capacity of seeds is an important trait for the preference of cultivation (Mehar, 2017; Sharma et al., 2025).

Finally, present research revealed that some farmers are attached to traditional varieties of paddy seeds with respect to cultural factor like satisfaction from farming. Earlier literature suggested that protection of traditional varieties is essential. It hints that traditional varieties of seeds are tools for generic revisions, seed development and ecological conservation (Thomas, 2011; Ahaljith, 2019; Bannor et al., 2020; Prasad et al., 2022).

CONCLUSION

The research attempted to identify the criterion for the selection of paddy varieties of seeds in Palakkad district of Kerala. Findings indicate that majority of the farmers prefer traditional varieties of paddy in 'dry' season. At the same time, farmers prefer hybrid varieties of paddy seeds in 'wet' season. Apart from climatic and irrigation facilities, factors that which influenced the selection of paddy seeds were size of the landholdings, financing options, market demand, knowledge and attitude of the farmers, yield capacity, pest and disease resistance of seed, cultural heredity and level of government support. Based on these findings, this research suggests that Krishibahanvans can initiate 'paddy-specific' awareness programmes on choices of seeds. Furthermore, support to optimise irrigation facilities for farmers will be helpful to enhance their ambit of choices. Development of novel paddy-varieties of seeds to suit the region-specific climate and socio-economic conditions of paddy farmers is also essential.

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 Note

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Factors Influencing Farmers' Adaptive Capacity to Climate Change

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HIGHLIGHTS

- The variables education, scientific orientation, social participation showed a strong positive correlation towards the adaptive capacity.
- The determinants contributing 65% variance towards adaptive capacity were economic motivation, age, education, social participation, annual income, risk preference, and farming experience.
- Integrating climate literacy into local training and extension programs, encouraging farmer groups and community networks to promote peer learning was recommended.

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ABSTRACT

The study was carried out in the Kendrapara district of Odisha to assess the adaptive capacity of farmers to climate change with a view to analysing the socio-economic, communication and psychological profile attributes in the year 2024. India's agrarian economy is at risk from both gradual climatic shifts and sudden extreme weather events, emphasising the need for adaptation and resilience-building strategies. Both purposive and random sampling techniques were followed for the selection of the district, blocks, villages, and respondents, and primary data were collected from 120 respondents through a pre-tested structured interview schedule developed. Five dimensions, namely social capital, physical capital, economic capital, human capital and management capital, were considered to assess the adaptive capacity. (71.6%) of the respondents had a medium level of adaptive capacity, followed by low level (16.67%) and high level (11.67%). Among the independent variables taken, education, scientific orientation, and social participation showed a strong positive correlation with the adaptive capacity. 65% variance towards adaptive capacity was economic motivation, age, education, social participation, annual income, risk preference, farming experience, information source utilisation, extension participation, and scientific orientation.

INTRODUCTION

Climate change, as defined by the United Nations Framework Convention on Climate Change (UNFCCC), refers to alterations in the global climate system resulting from human activities that have modified the atmospheric composition. Climate change is a major global concern due to its potentially profound impacts on human societies (UNFCCC, 2009). Numerous studies have indicated that climate change, if left unaddressed, poses a substantial threat to agricultural productivity and food security. Research suggests that while climate change generally has a negative impact on agriculture, the implementation of suitable adaptation measures can help minimise these effects (Bahinipati & Venkatachalam, 2016) and the knowledge help in combating it (Ghanghas et al., 2015). India, with its vast geographical diversity and dependence on climate-sensitive sectors like agriculture, water, forestry, and fisheries, is particularly vulnerable to the impacts of climate change. Over recent decades, the country has witnessed a rise in average temperatures, erratic rainfall patterns, increased frequency of extreme weather events such as heatwaves, floods, cyclones, and droughts, all of which have

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serious implications for livelihoods, food security, and the overall economy (MoEFCC, 2023). These changes have already affected agricultural productivity, particularly in rainfed areas, which comprise nearly 60% of India's net sown area. Crops such as wheat, rice, and maize have shown signs of yield reduction in several regions due to increased temperature and water stress (ICAR, 2021). In India, agriculture is still considered as an integral part of the economy as it makes up around 22% of the GDP, provides 58% of employment, fulfills the food and nutritional needs of the nation, produces raw materials, and contributes to around 14% of the exports (Swain, 2014) as per the projected climate change scenarios. Odisha is among the most climate-vulnerable states in India, facing increasing risks from cyclones, coastal erosion, sea level rise, floods, and droughts due to climate change. Among the key determinants of how effectively the farming community responds to these challenges is their adaptive capacity—a concept that refers to the ability of individuals or systems to adjust to potential damage, take advantage of opportunities, or respond to consequences (IPCC, 2014). Adaptive capacity is not uniform across regions or farming communities; it is shaped by a complex interplay of factors such as access to information, technology, education, extension services, institutional support, income level, landholding size, social networks, and perception of climate risk. Farmers with higher adaptive capacity are better equipped to modify agricultural practices, adopt resilient technologies, diversify income sources, and engage with climate-smart interventions. Understanding these disparities is crucial for equitable adaptation planning. Therefore, understanding the determinants of adaptive capacity and identifying region-specific gaps is essential for designing inclusive, effective, and targeted adaptation strategies. By assessing socio-economic attributes, level of adaptive capacity and access to different dimensions of adaptive capacity, this research seeks to provide insights that can inform policy recommendations for enhancing resilience and sustainability in India's agrarian economy.

METHODOLOGY

The study was conducted in Kendrapara district of Odisha, a coastal region situated in the eastern part Odisha. The district is known for its agrarian economy, with a majority of the population dependent on agriculture and allied activities for their livelihood. Kendrapara district was selected purposively, and three blocks namely Kendrapara, Derabish, and Rajnagar were chosen for the investigation randomly. From each block, two villages were selected randomly, namely Pandiri and Kantabada from Kendrapada block, Gulasingh and Basupur from Derabish block, and Jarimula and Nagada from Rajnagar block, resulting in a total of six villages. From each selected village, 20 farmers were chosen as respondents using a simple random sampling method, making a total of 120 respondents for the present study. An interview schedule was carefully developed to collect data after proper pre-testing with 5% of the non-respondents in alignment with the objectives of the study. It included detailed sections covering the socio-economic profile of the respondents, communicational profile, psychological profile which were likely to influence the level of adaptive capacity of farmers towards climate change. The total score of an individual was computed and the respondents were categorized into 3 groups by computing the mean and standard deviation. The three groups are- low (< Mean - SD), medium (Between Mean ± SD) and high (>Mean ± SD). From the past studies and literature, 5 dimensions were taken into consideration for measurement of adaptive capacity i.e., social capital, physical capital, economic capital, human capital and management capital which were believed to influence the adaptive capacity. In terms of climate change impacts, adaptive capacity is often defined as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2007). The 5 dimensions are operationalised as follows. Social capital includes networks, group memberships, and trust in relationships, essential for achieving livelihood objectives (Chepkoech et al., 2020). Physical capital represents the basic infrastructural facilities and tools required for carrying out agricultural activities (Nawrotzki et al., 2012). The availability and accessibility of financial resources that contribute to the wealth essential for agricultural activities are referred to as economic capital (Williges et al., 2017). Human capital refers to the knowledge, skills, working capacity, and good health condition that are required to meet livelihood objectives (DFID, 1999). Management capital comprises of the knowledge, skills, and decision-making competencies that enable farmers to effectively plan, implement, and adapt their agricultural practices in response to climate variability and other challenges. Under each dimension of adaptive capacity, 12 statements were taken for response from the respondents in Likert 5-point continuum i.e., strongly disagree, disagree, undecided, agree and strongly agree making it a total of 60. On the basis of mean and S.D, the respondents were divided in to three (High, Medium and Low) categories of their level of adaptive capacity. Data were analysed with the help of Pearson's correlation and regression analysis.

RESULTS

Adaptive capacity of farmers

Adaptive capacity is defined as a latent property of an individual, community, or social-ecological system, which is activated in response to a crisis or opportunity (Engle, 2011). After calculating the mean and S.D the respondents were categorized as low, medium and high. Majority 71.6% of the farmers had a medium level of adaptive capacity whereas, 16.67% and 11.67% of the respondents had low and high level of adaptive capacity towards climate change.

Level of adaptive capacity and relationship with the selected independent variables

Correlation analysis was carried out to determine the association between the selected independent variables and the

Table 1. Distribution of respondents according to their level of adaptive capacity

Category of Adaptive Capacity	Percentage	Mean	SD
Low (<176.02)	16.67	199.68	23.66
Medium (176.02-223.34)	71.66		
High (> 223.34)	11.67		
Total	100.000		

Table 2. Correlation analysis of selected independent variables with the adaptive capacity of the farmers to climate change

Independent variables	Correlation Coefficient (r)
Age (X_1)	-.156
Education (X_2)	.365**
Family type (X_3)	.246*
Family size (X_4)	.116
Farming experience (X_5)	.261*
Ownership of land (X_6)	.153
Land holding (X_7)	.018
Occupation (X_8)	.152
Annual income (X_9)	.255*
Information source utilization (X_{10})	.198*
Social participation (X_{11})	.329**
Extension participation (X_{12})	.194*
Risk preference (X_{13})	.203*
Scientific orientation (X_{14})	.277**
Economic motivation (X_{15})	-.114

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

adaptive capacity of farmers towards climate change. Table 2 presents the correlation analysis between selected independent variables and the adaptive capacity of farmers in response to climate change. Among all the socio-economic factors analyzed, education (X_2) exhibited the strongest positive and highly significant correlation with adaptive capacity. Similarly, social participation (X_{11}) and scientific orientation (X_{14}) also showed a strong and significant influence on adaptive capacity. On the contrary, age (X_1) and economic motivation (X_{15}) were found to have negative correlations with adaptive capacity, though these were not statistically significant. Additionally, variables such as family size (X_4), ownership of land (X_6), area of land (X_7), and occupation (X_8) did not show any significant correlation. Overall, the analysis highlights the critical role of education, experience, social connectivity, scientific mindset, and income level in shaping the adaptive capacity of farmers facing the challenges of climate change.

Table 3. Multiple regression analysis of selected independent variables with the adaptive capacity of the farmers to climate change

Variables	Beta	t	Sig	R square
Age (X_1)	-.332	-2.871	.005	0.650
Education (X_2)	-.242	-2.113	.037	
Family type (X_3)	-.303	-3.046	.003	
Family size (X_4)	.005	.055	.956	
Farming experience (X_5)	.055	3.266	.001	
Ownership of land (X_6)	.189	2.062	.042	
Land holding (X_7)	-.148	-1.530	.129	
Occupation (X_8)	.126	1.208	.230	
Annual income (X_9)	.071	2.711	.014	
Information source utilization (X_{10})	-.048	-2.354	.026	
Social participation (X_{11})	.238	2.674	.009	
Extension participation (X_{12})	.243	2.456	.016	
Risk preference (X_{13})	.179	2.107	.037	
Scientific orientation (X_{14})	-.097	-2.549	.031	
Economic motivation (X_{15})	-.223	-2.373	.019	

Multiple regression analysis between socio economic variables with adaptive capacity of the farmers to climate change

A multiple regression analysis was conducted to determine the influence of selected socio-economic variables on the adaptive capacity of farmers to climate change. The results, as presented in the above table revealed several significant predictors of adaptive capacity.

The model was statistically significant with an R value of 0.806, indicating a strong correlation between the independent variables and the dependent variable (adaptive capacity). The R^2 value of 0.650 suggests that approximately 65% of the variance in adaptive capacity can be explained by the set of independent variables included in the model. The adjusted R^2 value of 0.601 further confirms the model's robustness, accounting for the number of predictors used. Age (X_1) had a significant negative influence whereas, education (X_2) had a positive and significant influence on adaptive capacity. Family Type (X_3) was negatively associated with adaptive capacity. Farming Experience (X_5), ownership of land (X_6), and annual income (X_9) all had positive and significant effects. Participation in extension activities (X_{12}), social participation (X_{11}), and risk preference (X_{13}) also significantly contributed to farmers' adaptive behavior. Interestingly, scientific orientation (X_{14}), Information sources utilization (X_{10}) and economic motivation (X_{15}) had significant negative influences. Other variables like family size (X_4), occupation (X_8), and area of land (X_7) were not statistically significant, suggesting limited or no direct influence on adaptive capacity in the study context

DISCUSSION

The results revealed that education exhibiting the strongest positive and highly significant correlation with adaptive capacity suggested, farmers with higher educational attainment are more likely to adopt adaptive strategies to cope with the adverse effects of climate change. Higher levels of education increase farming households' adaptive capacity (Elahi et al., 2015). Similarly, social participation and scientific orientation also showed a strong and significant influence on adaptive capacity, indicating the importance of social networks and a progressive mindset in climate resilience. The findings also indicated that experienced farmers with greater economic stability, access to information, involvement in extension programs, and a higher risk-bearing capacity are more likely to adopt effective climate adaptation strategies. Risk taking is a significant factor in the adoption of Climate Smart Agriculture (Jatav, 2024). Improving farmers' knowledge and enhancing their economic capacity could substantially increase CSA adoption, thereby strengthening climate resilience (Mishra et al, 2025). Farmers must adopt PCAPs in order to capitalize on their promise for sustainable food production with a reduced environmental effect (Shitu & Nain, 2025). Additionally, variables such as family size, ownership of land, area of land, and occupation did not show any significant correlation, suggesting their limited direct influence on adaptive behaviour in this study context. Overall, the analysis highlights the critical role of education, experience, social connectivity, scientific mindset, and income level in shaping the adaptive capacity of farmers facing the challenges of climate change.

Byrne (2014) in his study on household adaptive capacity revealed that at household or community level, adaptive capacity is strongly influenced by factors such as the knowledge base, which enables anticipation of environmental change and identification of new or revised livelihood opportunities. The model was statistically significant with an R value of 0.806, indicating a strong correlation between the independent variables and the dependent variable (adaptive capacity). Age having a significant negative influence suggesting that younger farmers tend to be more adaptive. Family type was negatively associated with adaptive capacity, implying that certain family structures may hinder adaptability. Scientific orientation and economic motivation had significant negative influences, suggesting a complex relationship where economic or scientific drivers alone may not always foster adaptiveness. Information source showed a negative influence, which may indicate an issue with the quality or relevance of information accessed. The majority of the paddy farmers had experienced the effects of climate change, especially irregular rainfall and temperature fluctuations. However, few farmers remain unaware of adaptation measures due to limited access to information and a lack of communication with the extension agency (Pradhan et al., 2025). Socio-demographic variables such as gender, age, education, income, and ethnicity significantly influence individuals' awareness, attitudes, risk perceptions, and knowledge regarding climate change according to Masud et al. (2017). The intensity and probability of adoption of climate smart agriculture practices (CSAPs) were affected by numerous factors, such as demographic characteristics, access to market, farm plot features, climate risks, socio-economic, access to extension services and training (Aryal et al., 2018).

CONCLUSION

Farmers largely exhibited medium levels of information use, social participation, risk preference, scientific orientation, and economic motivation. Participation in peer learning, self help groups, and extension activities such as Field Days and Krishi Melas played a vital role in enhancing awareness and preparedness. Their adaptive capacity was shaped by strong community ties, practical knowledge, and a long-term perspective rooted in sustainability. Statistical analyses confirmed that education, farming experience, land ownership and annual income significantly and positively influenced adaptive capacity. Factors such as age, family type, scientific orientation, and economic motivation had negative associations with the adaptive capacity of farmers. The findings underscore the need for multi-dimensional strategy to strengthen farmers' adaptive capacity, integrating targeted education, responsive extension systems, institutional facilitation, and community-based knowledge-sharing. Building climate resilience ultimately depends on empowering farmers with the right tools, information, and supportive policies to make informed and forward-looking decisions in an increasingly unpredictable climate.

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 Note

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Farmer Preparedness and Constraints for Agribusiness Opportunities at Vizhinjam International Seaport, Kerala

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HIGHLIGHTS

- Institutional and policy barriers were the most critical constraints limiting farmer preparedness.
- Market fragmentation and weak collectives restricted integration with port-led agribusiness.
- Digital divide and low awareness of export standards reduced export readiness.
- Strengthening FPOs, ICT-enabled extension, and farmer-centric schemes is essential.

ARTICLE INFO

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ABSTRACT

The study was conducted during 2024-25 in Thiruvananthapuram district, Kerala, to assess farmer preparedness and constraints in leveraging agribusiness opportunities associated with the Vizhinjam International Seaport. The principal objective was to identify and prioritize constraints affecting farmer participation in port-led agribusiness. A total of 100 farmers were selected using purposive and random sampling techniques. Data were collected through a structured interview schedule, focus group discussions, and expert consultations. The Garrett Ranking Technique was applied to rank the identified constraints. The results revealed that institutional and policy barriers such as frequent policy shifts and inadequate extension–export support were ranked as the most severe. Market fragmentation, weak farmer collectives, land fragmentation, labour scarcity, and digital gaps also limited preparedness. Farm-level and compliance-related challenges, including stagnant productivity and certification costs, were reported but considered relatively less critical. It was concluded that systemic and governance issues outweigh farm-level problems in determining export readiness. The study highlights the need for policy stability, farmer-centric export schemes, strengthened FPOs, ICT-enabled extension, and targeted capacity building to ensure inclusive integration of smallholders into global value chains through Vizhinjam Seaport.

INTRODUCTION

Agriculture remains the backbone of India's economy, providing livelihoods for nearly half of the workforce while contributing about 18% to the national GDP (Government of India, 2023). With globalization, the competitiveness of agricultural exports is influenced not only by production but also by logistics efficiency, port connectivity, and compliance with international standards (UNCTAD, 2023; World Bank, 2023). Seaports reduce transaction costs, improve time efficiency, and strengthen access to global markets, thereby serving as critical nodes in international value chains (Notteboom & Rodrigue, 2005).

Kerala holds a distinctive place in India's agricultural landscape. Even with land fragmentation, Kerala leads in exporting

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high-value agricultural and marine commodities such as spices, coconut and seafood, aided by established export channels via Cochin Port. (NABARD, 2019; Spices Board of India, 2023). The state's long history of maritime trade reinforces its comparative advantage in port-linked agribusiness. However, fragmented holdings, high labour costs, and inadequate infrastructure continue to restrict the participation of smallholders in global export markets (Manoj & Joseph, 2016).

The Vizhinjam International Seaport, located in Thiruvananthapuram district, is India's first deep-water transshipment hub. Strategically positioned just 10 nautical miles from the busy East–West shipping lanes, it is expected to reduce shipping costs, improve turnaround time, and strengthen India's position in global maritime trade (Government of Kerala, 2020). For Kerala's farmers, Vizhinjam presents a significant opportunity to link their high-value crops with international markets, thereby transforming regional agribusiness.

Yet, infrastructure development alone does not ensure farmer integration into export-led trade. Smallholders continue to face multiple barriers to preparedness. These include limited awareness of international quality and safety standards (Henson & Jaffee, 2008), weak collectivization and bargaining power (Trebbin, 2014), high compliance and certification costs (Navya et al., 2022), and structural issues such as fragmented landholdings (Aswani & Varghese, 2023). Farmer preparedness is a multidimensional concept encompassing awareness of export opportunities, adoption of export-oriented practices, attitudes towards trade, access to information and resources, and institutional support systems (Rogers, 2003; Reardon et al., 2009; Malik et al., 2023). Unless these dimensions are adequately addressed, the benefits of Vizhinjam Seaport are likely to bypass smallholders, reinforcing the dominance of larger agribusiness players.

In this context, it becomes necessary to assess the extent of farmer preparedness and identify the constraints that restrict their ability to leverage the agribusiness potential of Vizhinjam International Seaport. The present study was undertaken during 2024–25 in Thiruvananthapuram district with the objective of prioritizing these constraints and generating insights for policy and extension interventions to strengthen smallholder participation in port-led agribusiness growth.

METHODOLOGY

The study was conducted during 2024–25 in Thiruvananthapuram district of Kerala, purposively selected as it hosts the Vizhinjam International Seaport. A multi-stage random sampling technique was adopted to select respondents. Five agricultural blocks–Nedumangad, Parassala, Athiyannur, Vellanad, and Nemom–were identified, and from each block, one panchayat was chosen based on the production of agricultural commodities. Subsequently, twenty farmers were selected from each panchayat, constituting a total sample of 100 respondents.

Primary data were collected using a structured interview schedule, supported by in-depth interviews, focus group discussions, and direct field observations. The schedule was developed based on the study objectives, relevant literature, and expert consultations, and comprised sections on farmers' awareness, institutional and infrastructural support, market access, technological readiness, and economic constraints. The tool was pre-tested in a non-sample panchayat (Kanjiramkulam) with fifteen farmers to assess clarity, content validity, and reliability. Based on the feedback, ambiguous or redundant items were revised or removed. Secondary data were sourced from institutional reports such as NABARD (2019), Spices Board of India (2023), and the Department of Ports, Government of Kerala (2020), along with relevant research publications and government documents. Data analysis involved descriptive statistics such as frequency and percentage to describe respondent profiles and interpret results, while the Garrett Ranking Technique was used to prioritize the constraints faced by farmers in leveraging agribusiness opportunities associated with the Vizhinjam International Seaport.

The constraints faced by farmers in leveraging agribusiness opportunities were identified and prioritized using the Garrett Ranking Technique (Garrett & Woodworth, 1969). Respondents were asked to rank the selected constraints according to their perception of severity. The percentage position for each rank was calculated using the formula:

$$\text{Per cent position} = \frac{100(R_{ij}-0.5)}{N_j}$$

Where, R_{ij} is the rank for i^{th} constraint experienced by the j^{th} individual, N_j is the number of constraints ranked by the j^{th} individual

The calculated percentage positions were then converted into scores using the Garrett conversion table. The individual scores for each constraint were aggregated across respondents and divided by the total number of farmers to obtain the mean scores. The constraints were finally ranked in descending order of mean values, which facilitated the identification of the most critical factors affecting farmer preparedness for seaport-linked agribusiness opportunities. All collected data were compiled, coded, and analyzed using appropriate statistical tools. The analysis ensured both accuracy and validity, enabling meaningful interpretation of the results in alignment with the objectives of the study.

RESULTS

To provide a structured perspective, the fifteen identified constraints were categorized in Institutional and Policy Constraints (1-6), Market and Structural Constraints (7-9), Technological and Information Constraints (10-11), Digital divide and poor access to export-market information (12) and Farm-Level and Economic Constraints (13-15).

This classification enables clearer interpretation, showing that institutional and policy-related factors predominate in constraining farmer preparedness, while market, technological, and farm-level issues further compound the challenges to export readiness.

The study attempted to identify and prioritize the constraints faced by farmers in leveraging agribusiness opportunities in the wake of Vizhinjam International Seaport. Using the Garrett Ranking Technique, 15 constraints were ranked based on the mean scores obtained from farmer responses. The results are presented in Table 1. A higher mean score indicates a more severe constraint as perceived by the respondents.

Table 1. Constraints faced by farmers in leveraging agribusiness opportunities

Rank	Constraint Statement	Mean Score
1	Frequent changes in state government cause shifting priorities, inconsistent support, and poor follow-through on export promotion and rural infrastructure.	52.61
2	Institutional gaps in extension and export support result in inadequate guidance on procedures, market linkages, and compliance with international standards.	51.72
3	Market fragmentation and weak farmer collectives limit aggregation, bargaining power, and coordinated access to port-based exports.	50.75
4	Highly fragmented landholdings restrict large-scale production, mechanization, and supply consistency required for export markets.	49.66
5	Scarcity of farm labour has driven wages up, sharply increasing cultivation and post-harvest costs.	49.20
6	Information gaps and a rural digital divide delay access to export market data, e-platforms, and real-time price intelligence.	49.16
7	Limited awareness and preparedness for meeting export standards, certifications, and global buyer requirements.	48.70
8	Restrictive agricultural regulations and excessive government intervention reduce market flexibility and slow decision-making for export ventures.	47.98
9	Poor last-mile infrastructure and logistic bottlenecks between farms and the port reduce export efficiency and quality.	47.91
10	Smallholder farmers are often sidelined in policy-making, with port-linked infrastructure and schemes favouring larger, organized players.	46.70
11	Absence of farmer-centric schemes to integrate smallholders with Vizhinjam port-based trade and value chains.	46.43
12	Complex documentation, permits, and legal compliance for exports are difficult to navigate without costly middlemen or consultants.	45.97
13	Stagnant farm productivity due to policy emphasis on traditional crops, low irrigation efficiency, and slow adoption of agri-technologies.	44.23
14	High export compliance costs–small and marginal farmers struggle to afford certifications, quality assurance, traceability, and audits.	41.59
15	Lack of clear government policies focusing on farmer integration with port trade and value chains.	38.61

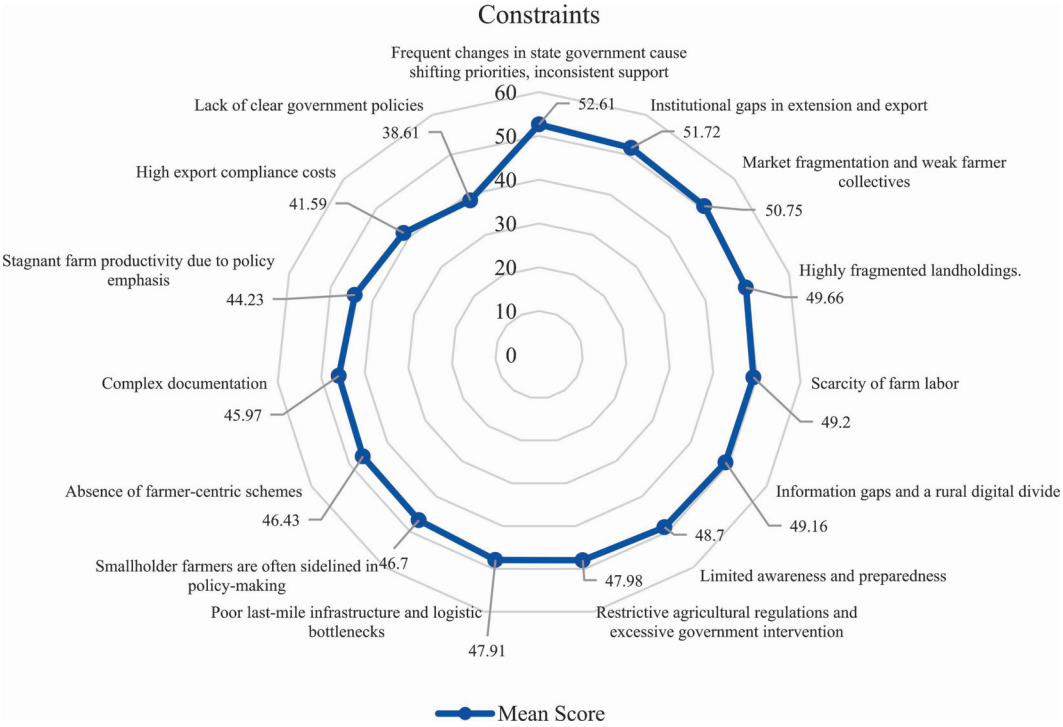

Figure 1. Mean Garrett scores of constraints faced by farmers in leveraging agribusiness opportunities (Radar Chart Placeholder).

The ranking highlights that institutional and governance-related barriers dominate farmer concerns. The most severe constraint (Rank 1) was frequent policy changes (Mean = 52.61), indicating that farmers are highly vulnerable to government instability and shifting priorities. This was closely followed by institutional gaps in extension and export support (Mean = 51.72), which shows that farmers lack clear, continuous guidance on export-oriented practices, certification, and market linkages. Together, these top two constraints emphasize that the readiness of farmers to exploit port-led agribusiness opportunities is strongly tied to policy consistency and extension effectiveness. The third-ranked constraint (Mean = 50.75), market fragmentation and weak farmer collectivization, demonstrates that smallholder farmers are unable to aggregate produce effectively for large-scale exports. This is a well-recognized

issue in Kerala's agriculture, where the predominance of marginal holdings limits economies of scale. Unless farmers are integrated into stronger Farmer Producer Organizations (FPOs) or cooperatives, their bargaining power will remain low.

Farm-level structural issues such as fragmented landholdings (Rank 4, Mean = 49.66) and labour scarcity (Rank 5, Mean = 49.20) further constrain export preparedness. Small farms limit mechanization and large-scale production, while rising wages inflate cultivation and post-harvest costs. Together, these highlight that the inherent smallholder nature of Kerala's agriculture acts as a major bottleneck in scaling up for international trade. Technological and knowledge-related gaps also emerged as significant mid-ranked constraints. The digital divide and lack of timely access to export market data (Rank 6, Mean = 49.16) and low awareness of export standards and certification requirements (Rank 7, Mean = 48.70) point to limited preparedness in terms of information flow and compliance. In the era of digital agriculture and global trade, these gaps place farmers at a competitive disadvantage.

Regulatory and infrastructural barriers featured in the middle of the ranking. Restrictive regulations (Rank 8), poor last-mile connectivity (Rank 9), and the absence of farmer-centric export schemes (Rank 11) indicate that institutional rigidity, weak infrastructure, and poor scheme design together reduce farmers' ability to capitalize on port-led opportunities. Documentation and legal compliance burdens (Rank 12, Mean = 45.97) further add to transaction costs, discouraging participation in export markets. Lower-ranked constraints included stagnant farm productivity (Rank 13) and high export compliance costs (Rank 14). Though ranked lower, these remain significant challenges, as low yields and unaffordable certification processes prevent farmers from competing with global suppliers. The least severe constraint (Rank 15, Mean = 38.61) was lack of long-term government policy on farmer integration. Although farmers perceived it as less immediate compared to day-to-day challenges, the absence of a strategic export vision risks marginalizing smallholders in the long run.

DISCUSSION

The Garrett analysis clearly shows that farmers' preparedness for seaport-linked agribusiness is influenced more by institutional and governance constraints than by farm-level issues. Frequent policy changes and discontinuity in export promotion emerge as the most critical barriers, which discourages smallholders from making long-term investments in agribusiness ventures. This finding agrees with earlier studies that highlight how policy instability reduces farmer confidence and weakens participation in commercial agriculture (Roy & Ghosh, 2022; Anamika et al., 2023; Kademani et al., 2024; Megha et al., 2025). The evidence confirms that infrastructure alone is insufficient to promote farmer integration with global markets unless supported by a stable policy environment. Institutional gaps in extension and export support further underline the lack of effective advisory systems to guide farmers in documentation, certification, and meeting international standards. This is consistent with the findings of Chandran and Podikunju (2021), who reported that inadequate extension services restricted vegetable growers in Kerala from adopting improved marketing practices. The absence of farmer-centric advisories points to the urgent need for reorienting extension systems toward export facilitation, certification literacy, and ICT-based support. Market and structural barriers also limit farmer preparedness. Weak farmer collectives (Rank 3) and fragmented landholdings (Rank 4) restrict aggregation and reduce bargaining power, thereby limiting participation in global value chains. These findings reinforce the conclusions of Trebbin (2014), who emphasized the role of farmer producer organizations (FPOs) in enhancing market access and export readiness. Labour scarcity and high wages, ranked fifth in severity, are symptomatic of Kerala's agrarian system and reduce farm-level competitiveness. This observation is in agreement with Aswani and Varghese (2023), who noted that dependence on hired labour and limited mechanization inflate production costs, making smallholder exports less competitive.

Preparedness gaps linked to digital exclusion and low awareness of export standards (Ranks 6 and 7) reflect broader international patterns. Kersting and Wollni (2012) and Fonseka et al. (2025) highlighted that inadequate knowledge of certification processes and high compliance costs constrain smallholders from meeting export quality standards, thereby limiting their integration into high-value markets and found that exclusion from ICT platforms and certification processes reduces the ability of smallholders to participate in high-value export chains. In the present study, farmers similarly identify lack of access to real-time information and inadequate knowledge of global standards as major barriers, which underscores the importance of digital extension approaches. Infrastructure and compliance-related barriers also remain important. Poor last-mile connectivity and logistic bottlenecks (Rank 9), complex documentation (Rank 12), high export compliance costs (Rank 14), and stagnant productivity (Rank 13) all limit export competitiveness. Comparable findings were reported in Assam and Tripura, where inadequate infrastructure and bureaucratic hurdles constrained farmer participation in markets (Das et al., 2014; Roy & Ghosh, 2022). These results suggest that logistical challenges are not unique to Kerala but represent a wider structural issue in Indian agriculture.

Overall, the results confirm that systemic and governance challenges dominate farmer concerns, while farm-level constraints, though present, are secondary. The evidence indicates that inclusive participation in seaport-led agribusiness requires policy stability, stronger FPOs, and reoriented extension systems that emphasize export preparedness. Investment in packhouses, cold chains, and logistics around Vizhinjam is equally critical to reduce costs and improve quality. By aligning these institutional, infrastructural, and extension efforts, Vizhinjam International Seaport can serve as a catalyst for farmer integration into global value chains.

CONCLUSION

The farmers' preparedness to leverage opportunities from the Vizhinjam International Seaport is constrained more by systemic and institutional barriers than by farm-level issues. Frequent policy shifts, inadequate advisory support, market fragmentation, weak collectives, labour scarcity, and the digital divide emerge as key obstacles. Farm-level concerns such as productivity and certification costs are important but secondary. The infrastructure development alone does not guarantee farmer participation in export-led agribusiness. Strengthening preparedness requires policy stability,

farmer-focused schemes, strong producer organizations, ICT-enabled extension, and targeted training to build export readiness. By reorienting extension services and fostering institutional convergence, farmers can be better integrated into port-led value chains. These interventions are essential for ensuring that smallholders equitably benefit from the seaport's role as a driver of agribusiness growth in Kerala.

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 Note

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Mapping Determinants of Beneficiary Knowledge in TSP: Evidence for Targeted Extension Strategies

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HIGHLIGHTS

- Educational attainment, social exposure, targeted training, and institutional engagement were key levers for improving the effectiveness of TSP outreach and beneficiary empowerment
- Education, cosmopoliteness, training participation, and extension contact expressed significant contribution towards knowledge

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ABSTRACT

The study was conducted in 2024 to map the determinants of the knowledge levels of tribal beneficiaries enrolled under the Tribal Sub Plan (TSP) programme. A sample of 240 tribal farmers was considered as respondents under multi-stage random sampling, followed by a personal interview with a structured questionnaire for executing the process of data collection. More than half of the factors expressed a significant relationship with the knowledge level of TSP programme. Factors like education, cosmopoliteness, training participation and extension contact were prominently contributing towards knowledge level, as these, along with other factors, in total managed to elucidate about fifty-six per cent of the variation caused in knowledge level.

INTRODUCTION

Odisha, as a state of agrarian economy, is distinguished by its tribal diversity, being home to 62 tribal communities that constitute 22.1% of the state's population and thus enjoys the title of the third largest Scheduled Tribe (ST) populous state of the country as per the 2011 census. Notably, 94.5% of this tribal population lives in close proximity to nature (Palo et al., 2020; Bahubalendra et al., 2025), who have been historically excluded from mainstream development. Tribals have remained significantly disadvantaged across all major socio-economic parameters, with persistent poverty, low education levels, and poor health outcomes despite some gradual improvements, which is quite evident from the studies conducted by various authors (Rath, 2018; Behera & Dassani, 2021; Takri & Sahoo, 2022; Padhan, 2022). Thus, in this respect, many of the institution-backed initiatives for the upliftment of the tribal population and thus, the Tribal Sub Plan programme is one of those ventures.

Tribal Sub Plan (TSP) was introduced in the Fifth Five-Year Plan (1974-1978) period as a strategic tool that would ensure that benefits and resources of the general development areas is evenly distributed to the States, Union Territories, and Central Ministries in proportion to the tribal population in terms of space and in terms of finances (Makwana, 2017; Rathour et al., 2022). The emergence of Integrated Tribal Development Projects (ITDP) to address disparities in development between tribal and non-tribal areas, with a concentrated emphasis on area-based development. The initiatives were created to reduce poverty, increase educational levels, and eliminate exploitation among the tribal families. The plan involved

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measures of income generation, infrastructure development, administrative need strengthening, as well as capacity building (Mathew, 2024). But the initiative is yet to produce the results as were optimistically dreamt of during its initial implementation, whereby majority of the tribals were still below in poverty line in Odisha (Sethi et al., 2021). So, there might be issues related to the comprehensibility of the programmes amongst the tribal people, which would be causing such inefficacies and failures.

This investigation attempts to map out determinants of the knowledge level of beneficiaries enlisted under the programme, whose results prove to be vital for tailoring future interventions and communication strategies to enhance the effectiveness of the programme, which would lead to overall transformation of the tribal populace towards progress and sustainability.

METHODOLOGY

The study was conducted in Kendujhar and Rayagada districts of Odisha under the Tribal Sub-Plan (TSP), representing tribal-dominated areas with diverse socio-economic conditions. A multistage purposive sampling procedure was followed for the selection of blocks, villages, and respondents, yielding a total sample size of 240. The questionnaire, formulated after literature review and expertise consultation, was pretested on the officials, supported with an explanation in the local Odia dialect, and feedback obtained served insights for finalising the interview schedule (Jayasingh & Mishra, 2024). Data collection occurred through interviews in their workplace from September 2024 to May 2025.

Knowledge level refers to the extent to which the tribal respondents have knowledge about the existence and functioning of TSP scheme in their native vicinity. A structured knowledge test was developed to assess key aspects of the Tribal Sub Plan (TSP) programme. Relevant items were identified through expert consultation and pre-testing to ensure content validity. The test was administered to tribal farmer beneficiaries using culturally appropriate formats and local language. Closed-ended questions, such as multiple-choice and true/false items, were employed to evaluate factual understanding. Responses were scored objectively, assigning one point per correct answer. Item difficulty and discrimination indices were analyzed for refinement. Total scores were computed to derive a knowledge index, and respondents were categorized into low, medium, and high knowledge levels using the half-standard deviation method. Ethical considerations, including informed consent and contextual sensitivity, were maintained throughout the process.

Factors relevant to the study were chosen based on a comprehensive literature review, followed by the advice of expert consultation. Then, a structured questionnaire was prepared with the help of scales taken up for the suitability to measure the concern factor as an independent variable, with a pre-testing exercise followed by modifications to make it adaptable for the concerned sample. Pearson's correlation analysis was carried out to encompass the relationship of the concerned factors with that of the knowledge level of tribal respondents regarding the TSP scheme. Multiple linear regression analysis was employed to determine the relative contribution of the selected factors and their combined effect on the training effectiveness.

RESULTS

Association of profile characteristics with the knowledge level

The results presented in Table 1 highlight the association between selected independent variables and the knowledge level of Tribal Sub Plan (TSP) beneficiaries. Several variables showed a statistically significant positive correlation with knowledge level, indicating their strong influence.

Table 1. Association of selected independent variables with the knowledge level of TSP beneficiaries

Variables	Correlation coefficient	*p*-value
Age	0.432**	0.000
Education	0.593**	0.000
Family Type	0.112NS	0.083
Family Size	0.072NS	0.266
House Type	0.091NS	0.159
Farm Holding Size	0.08NS	0.216
Occupation	0.138*	0.032
Annual Income	0.125NS	0.053
Farming Experience	-0.432**	0.000
Cosmopoliteness	0.118NS	0.068
Training Participation	0.397**	0.000
Source of Information	0.761**	0.000
Extension Contact	0.821**	0.000
Social Aptitude	0.632**	0.000
Scientific Orientation	0.601**	0.000
Economic Aptitude	0.594**	0.000

*=Significant at 5% level; **=Significant at 1 % level; NS=Non-significant.

Among the most influential factors, extension contact, education and source of information exhibit very high positive correlations, all significant at the one per cent level of significance. These findings suggest that beneficiaries who are more educated, socially connected, and have better access to information and extension services tend to possess higher knowledge about the TSP scheme. Other positively correlated and significant variables include age, training participation, social aptitude, scientific orientation and economic aptitude. These factors further reinforce the role of personal development, exposure, and cognitive traits in enhancing awareness of the scheme. Interestingly, farming experience shows a significant negative correlation, implying that more experienced farmers may have lower knowledge levels about the TSP scheme, possibly due to reliance on traditional practices or limited engagement with newer institutional mechanisms.

In contrast, variables such as family type, family size, house type, farm holding size, and annual income exhibited low correlation coefficients and non-significant t-values, indicating no meaningful association with knowledge level. Occupation showed statistically significant positive correlation at a five per cent level of significance, suggesting a considerable influence on knowledge level. Overall, the analysis underscores the importance of education, extension contact, cosmopoliteness, and access to information in shaping beneficiaries' understanding of the Tribal Sub Plan scheme, while demographic and economic variables appear less influential.

Contribution of profile characteristics towards the Knowledge level

The regression model as depicted in Table 2, yielded an R^2 value of 0.578, indicating that approximately 57.8 per cent of the variation in the knowledge level of Tribal Sub Plan (TSP) beneficiaries is explained by the combined influence of the selected independent variables. The adjusted R^2 value of 0.563 further reinforces the model's robustness by accounting for the number of predictors and penalising the inclusion of non-contributory variables. The minimal difference between R^2 and adjusted R^2 suggests that most of the predictors included in the model were relevant and contributed meaningfully to explaining the dependent variable. This balance between explanatory strength and model parsimony enhances the credibility of the significant findings and supports the reliability of the regression framework used in the study.

Table 2. Multiple linear regression analysis for the factors affecting the knowledge level of TSP beneficiaries

Variables	b-value	Std. error	t-value	*p*-value
Age	0.023	0.37	0.062^{NS}	0.951
Education	5.470	2.41	2.27*	0.024
Family Type	-4.720	2.76	-1.710^{NS}	0.089
Family Size	-1.680	1.06	-1.585^{NS}	0.114
House Type	1.970	1.39	1.417^{NS}	0.158
Farm Holding Size	2.280	1.64	1.390^{NS}	0.166
Occupation	6.630	3.79	1.749^{NS}	0.816
Annual Income	3.550	1.90	1.868^{NS}	0.063
Farming Experience	-15.080	9.02	-1.672^{NS}	0.095
Cosmopoliteness	6.826	4.45	1.534^{NS}	0.095
Training Participation	2.540	1.18	2.153*	0.032
Source of Information	6.840	5.38	1.271^{NS}	0.205
Extension Contact	5.180	1.68	3.083**	0.002
Social Aptitude	7.910	9.15	0.864^{NS}	0.388
Scientific Orientation	8.550	6.76	1.265^{NS}	0.207
Economic Aptitude	0.234	0.34	0.688^{NS}	0.492

*= Significant at 5% level; ** = Significant at 1 % level; ^{NS} = Non-significant. Dependent variable: Knowledge level of TSP beneficiaries, R^2= 0.578, adjusted-R^2= 0.563

Among these 16 variables fitted in the model, four variables emerged as statistically significant contributors. Education showed a positive and significant influence, suggesting that higher educational attainment enhances beneficiaries' awareness and understanding of the TSP scheme. Training participation was also significant, highlighting the role of structured learning experiences in improving scheme-related knowledge. Extension contact proved to be a highly significant factor, reinforcing the importance of regular interaction with extension personnel in disseminating information and encouraging engagement.

The remaining variables, namely age, family type, family size, house type, farm holding size, occupation, annual income, farming experience, source of information, social aptitude, scientific orientation, and economic aptitude were statistically non-significant, suggesting that their individual contributions to explaining variation in knowledge level were limited within this model. Overall, the findings underscore the critical role of education, training exposure, and extension contact in enhancing tribal farmers' understanding of the TSP scheme, offering valuable insights for designing targeted interventions and capacity-building strategies.

DISCUSSION

The distribution of tribal respondents' knowledge about the Tribal Sub Plan (TSP) scheme reveals a layered awareness profile. Majority of them possessed medium knowledge but a few expressed high levels of it, which pictures about the general familiarity of the scheme yet less number of them managed to grasp it deeply and thus capable of engaging meaningfully with the facets of the scheme. The existence of ones expressing low extent of knowledge highlights a significant gap amongst the beneficiaries who were unable to reap the benefits of the scheme as this segment may face barriers such as low literacy, poor outreach, or geographic isolation. Their limited awareness underscores the need for inclusive communication strategies and targeted interventions. In their study conducted in Tamil Nadu on the same context, Satish et al. (2024) concluded that more than 90 per cent of tribals lack knowledge about various tribal schemes thus highlighting a significant gap in awareness as well as professing for the need for inclusive communication strategies. These results do points towards the importance of continued efforts for increasing the knowledge level of tribals regarding TSP scheme whose sole purpose is achieving their upliftment.

The level of knowledge a tribal farmer possesses about the Tribal Sub Plan (TSP) Scheme is shaped by a constellation of socio-personal and psychological factors, each contributing in distinct ways to their awareness, understanding, and engagement with the scheme. Age plays a prominent role in shaping knowledge levels. Younger farmers are generally more open to new ideas and technologies, making them more receptive to development schemes like TSP. In contrast, older farmers may rely more on traditional practices and have limited exposure to formal information channels, which can hinder their awareness unless targeted outreach is provided. Jayathilake et al. (2019) concluded that older farmers had limited access to new information as compared to rural youth. Education level was a strong determinant of Tribal Sub Plan knowledge. Farmers with higher education were better equipped to comprehend policy guidelines, interpret written materials, and engage with digital platforms. This literacy advantage enables them to access and process scheme-related information more effectively. Nagesha et al. (2022) stated that education had been a significant determinant of farmer's knowledge about government schemes like PM-Fasal Bima Yojana. Occupation also influenced exposure to the scheme. Farmers engaged in diversified livelihoods such as poultry, dairy, or forest-based enterprises that often interact with multiple institutions and markets. These interactions increase their chances of learning about TSP benefits. Conversely, those practicing subsistence agriculture might have fewer institutional contacts, limiting their awareness (Hatai & Singh, 2019). Training participation had a direct and positive impact on tribals as the one who attend government or NGO-led training programs are often introduced to Tribal Sub Plan modules, eligibility criteria, and application procedures. These structured learning opportunities significantly boost their understanding of the scheme. Source of

information is another critical factor whereby farmers who rely on formal channels—such as extension agents, newspapers, radio, television, or mobile apps—tend to have more accurate and comprehensive knowledge of TSP programme. In contrast, those depending solely on informal sources like neighbors or local leaders may receive incomplete or distorted information. Authors like Krishnan (2023) and Ndimbwa et al. (2020) stated the domination of informal sources of communication by the local people, quite unlike this context. Extension contact is a powerful enabler of awareness. Regular interaction with extension personnel, including Krishi Vigyan Kendras, Integrated Tribal Development Project (ITDP) officers, and agricultural officers, provides farmers with updates, clarifications, and encouragement to participate in schemes like Tribal Sub Plan programme. Srivani et al. (2022) inferred that tribal farmers had considerate extent of extension contact as related to awareness of about Pradhan Mantri Van Dhan Vikas Yojana activities. Social aptitude, defined by a farmer's ability to engage in community activities and group discussions, fosters peer learning and collective awareness. Farmers with high social aptitude are more likely to learn about Tribal Sub Plan programme through community platforms and local leadership networks. Scientific orientation reflects a farmer's inclination toward evidence-based thinking and modern agricultural practices. Those with strong scientific orientation are more curious about structured schemes and are better positioned to understand the technical and procedural aspects of Tribal Sub Plan programme. Katole et al. (2017) also identified scientific orientation as key psychological factor influencing technological adoption. Finally, economic aptitude defined as the ability to plan, budget, and assess financial risks—enhances a farmer's capacity to evaluate the benefits of TSP. Economically adept farmers are more proactive in accessing subsidies, loans, and development programs, making them more likely to engage with the scheme (Gaurav & Singh, 2012). The negative relationship of farm experience of tribal respondents to that of knowledge level of Tribal Sub Plan program can be owed to the fact that experienced tribal farmers often rely on traditional practices, resist external interventions, and have limited exposure to institutional channels. These factors reduce their engagement with modern schemes like the Tribal Sub Plan, despite their deep agricultural knowledge and long-standing field experience.

The regression analysis revealed that out of the 16 variables examined, only four emerged as statistically significant contributors to the knowledge level of Tribal Sub Plan (TSP) beneficiaries, offering critical insights into the drivers of policy awareness. The education level of respondents demonstrated a positive and significant influence, underscoring the role of formal learning in enhancing comprehension and engagement with development schemes such as the Tribal Sub Plan programme. This finding aligns with broader evidence that literacy and schooling improve access to institutional resources and the ability to interpret policy information (Aryal et al., 2024). Training participation also proved significantly contributing towards knowledge of the Tribal Sub Plan programme's beneficiaries, highlighting the value of structured learning platforms in equipping beneficiaries with relevant insights and procedural clarity. Such programs not only build capacity but also foster confidence in navigating scheme benefits. Extension contact positively influences Tribal Sub Plan knowledge by facilitating regular interaction between beneficiaries and field-level personnel. These engagements provide timely information, clarify scheme procedures, address doubts, and build trust, thereby enhancing awareness, understanding, and active participation in the Tribal Sub Plan programme among tribal communities (Muttanna et al., 2019). Collectively, these findings emphasise that educational attainment, social exposure, targeted training, and institutional engagement are key levers for improving the effectiveness of TSP outreach and beneficiary empowerment.

CONCLUSION

The findings illuminate critical disparities in the knowledge levels of tribal beneficiaries regarding the Tribal Sub Plan (TSP) programme, with implications for both programme efficacy and policy design. The identification of education, cosmopoliteness, training participation, and extension contact as significant predictors reinforces the need for multi-pronged policy interventions. Strengthening these dimensions through localised training modules, mobile-based information systems, and culturally attuned extension strategies can bridge the awareness gap. For TSP to fulfill its transformative mandate, future efforts must prioritise inclusive knowledge dissemination, adaptive outreach, and sustained engagement with tribal communities, ensuring that policy intent translates into tangible empowerment. A proactive and innovative extension outreach technique is strongly recommended to traverse the gap in the knowledge levels of tribal people for the effectiveness of the flagship programme.

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 Note

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Prioritizing Backyard Poultry Bottlenecks Using Analytic Hierarchy Process in Punjab, India

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HIGHLIGHTS

- Analytic Hierarchy Process identified and prioritized critical bottlenecks constraining backyard poultry value chain.
- Production constraints ranked as the leading challenge with highest priority weight of 0.250.
- Limited access to market information highlighted as a significant marketing constraint (global priority score: 0.037).
- Predator attacks recognized as the most alarming threat to backyard poultry (global priority score: 0.079)

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ABSTRACT

Backyard poultry in rural India symbolizes both opportunity & adversity, offering livelihoods while battling chronic gaps in feed, healthcare & marketing. This study, conducted during 2022-2023, used the Analytic Hierarchy Process (AHP) to prioritize bottlenecks in the backyard poultry value chain. A total of 385 farmers from 11 districts of Punjab were purposively selected using the snowball sampling technique. The study revealed production constraints (priority weight: 0.250) as the leading challenge faced by respondents. Within input supply constraints, lack of access to credit and insurance support was ranked highest (global priority score: 0.109). High feed costs (0.065) and limited market information (0.037) were the most critical production and marketing challenges, respectively. Inadequate transportation (0.050) topped processing and transportation constraints. Predator attacks (0.079) were identified as the most alarming threat. The study highlights major bottlenecks requiring targeted interventions for sustainable rural poultry development.

INTRODUCTION

Backyard poultry farming, a dynamic and resilient sector, sustains millions of households worldwide, providing essential nutrition and income diversification. Its traditional small-scale structure efficiently supports expanding food needs, enhances rural incomes, and contributes to food security, livelihood creation, poverty alleviation, and sustainable ecological management (Aklilu et al., 2008). This decentralized model not only enhances food security but also empowers local communities by fostering self-reliance and economic independence. Despite its significance, challenges such as access to quality feed, healthcare services, and market opportunities persist (Jadoun, 2019; Patel et al., 2022), underscoring the need for innovative solutions to optimize productivity and sustainability. Embracing modern analytical frameworks like the Analytic Hierarchy Process (AHP) promises to unravel complexities and elevate backyard poultry farming to new heights of efficiency and resilience on a global scale.

Backyard poultry farming refers to the small-scale rearing of up to 100 birds, typically managed in outdoor or semi-free-range

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conditions with minimal inputs and limited biosecurity (Guèye, 2000). In rural India, this low-investment, high-return enterprise plays a crucial role in strengthening the socio-economic resilience of resource-poor families (Chakrabarti et al., 2014). Compared to commercial poultry, which has expanded by only 4.50 per cent over the last census, backyard poultry production has evidenced an incredible growth rate of 45.80 per cent (Livestock Census, 2019). Native poultry breeds like Kadaknath, Aseel, Nicobari, Danki, Tellicherry, and Haringhata Black are sturdy, good brooders, have good mothering abilities, adaptive in challenging climatic situations, and are resistant to many diseases. They can survive well on agriculture and domestic wastes by scavenging on the residual feed. Desi breeds of poultry are more heat-tolerant than exotic breeds (Kumar et al., 2017). Due to their rich flavour, health benefits, and low-fat content, as well as rising purchasing power and urban population, desi or indigenous poultry breeds that are raised in backyards are currently experiencing a substantial surge in demand for their meat and eggs in metropolitan areas.

As consumer preference shifts toward desi poultry raised under natural conditions, the backyard poultry sector is evolving into a high-potential enterprise, making value chain strengthening both timely and necessary. Despite its growing market demand and suitability for low-input rural households, the system continues to face multiple constraints related to feed supply, healthcare access, input distribution, and marketing channels. Although earlier studies have identified several of these challenges, most have relied on conventional ranking methods and lack an integrated prioritization of constraints across the entire value chain. This gap underscores the need for a more structured analytical approach capable of determining which issues require urgent intervention. Therefore, the present study employs the Analytic Hierarchy Process (AHP) to systematically identify and rank key bottlenecks in backyard poultry production and marketing, offering deeper insights into where strategic efforts should be focused to enhance efficiency, improve farmer welfare, and strengthen the long-term viability of this emerging rural enterprise.

METHODOLOGY

The present study was conducted from September 2022 to June 2023 in 11 districts of Punjab (Latitude 30°42 N, Longitude 75°52 E), covering approximately 50% of the state. Districts were selected purposively in proportion to their backyard poultry population as reported in the Livestock Census. However, since no district-wise sampling frame of backyard poultry keepers was available, individual respondents were identified using the snowball sampling technique. The sample size was calculated with the help of an online statistical calculator, according to which on supposing that from the population, 50% of the subjects have factor of interest & for estimating the probable proportion with 95% confidence and 5% precision (absolute), the size of sample should not be less than 385 (Dhand & Khatkar, 2014). From each district, 35 backyard poultry farmers (Broilers and layers) having more than 10 backyard poultry birds, willing to participate, of 20 years of age or more and well-versed with Punjabi language, were contacted to collect the information through a set of structured interview schedule. Thus, total 385 backyard poultry farmers were selected for the study.

The constraints analysis was performed by using Analytic Hierarchy Process (AHP) (Saaty, 1980) among backyard poultry farmers in the Punjab. AHP is a structured technique developed by Saaty (2008), for organizing and analysing the complex decision, based on mathematics and psychology. It aids the decision-maker to set priorities and make the best decision. AHP utilizes a pair-wise comparison method to know the overall priority of each factor considered by respondents; which, in turn, determines the constraints situation in backyard poultry farming value chain in India. The AHP helps to capture both subjective and objective aspects of a decision. Saaty (2008), proposed one nine-point scale to have a pair-wise comparison (Eq. 1) of different constraints criteria and factors. In this AHP, the verbal statements are converted into integers from one to nine, based on the intensity of importance of one over the other.

$$M = (a_{ij}) = \begin{array}{c} \\ D_1 \\ D_2 \\ \vdots \\ D_n \end{array} \begin{array}{c} \begin{array}{cccc} D_1 & D_2 & \dots & D_n \end{array} \\ \begin{pmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ .. & .. & .. & .. \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{pmatrix} \end{array}$$ M= Pair-wise comparison matrix

Eq. 1

Utilizing AHP in constraints analysis yields analytical priorities for the factors included in constraints analysis and makes them commensurable. AHP measures the relative importance of the constraint's factors. Making pairwise comparisons forces the decision–makers to think over the weights of the constraints factors and to analyse the situation more precisely and in more depth.

RESULTS

The bottlenecks in the backyard poultry value chain were assessed by five criteria i.e., Input Supply Constraints (ISC), Production Constraints (PC), Marketing Constraints (MC), Processing and Transportation Constraints (PTC), and Miscellaneous Constraints (MSC). AHP was used to assign a priority weight to each constraint's component in order to ascertain how strongly each constraint was perceived to be affecting the farmers. Statements used for constraints analysis are listed in Table 1.

Priority weights of overall constraints faced by backyard poultry value chain actors

A priority matrix was developed based on the cumulative individual priority rank of each factor after the criteria for each constraint analysis aspect had been determined. Each section of the constraint analysis was assigned a unique set of five criteria, after which the priority scores for each of the 10 groups of those criteria were calculated individually. Using Saaty's (1991) nine-point continuum priority scale, the aggregate individual priority score for each group of each criterion was determined. The individual priority matrix was utilized to calculate the consistency ratio using AHP. According to the AHP thumb rule, each factor's and criterion's consistency ratio value must be smaller than 0.1, indicating that all the factors and criteria used in the constraint analysis are valid at their respective points.

Table 1. Problem modelling for constraints analysis in backyard poultry farming value chain

Factors (F)	Input Supply Constraints (IC)	Production Constraints (PC)	Marketing Constraints (MC)	Processing & Transportation Constraints (PTC)	Miscellaneous Constraints (MSC)
F1	IC1: Lack of accessibility for improved germplasm	PC1: High cost of feed	MC1: Limited access to market information	PTC1: Lack of processing	MSC1: Attack by predators
F2	IC2: Non availability of day-old chicks round the year	PC2: Low production performance of native birds	MC2: Price fluctuation	PTC2: Lack of storage facility	MSC2: Mortality due to extreme weather conditions
F3	IC3: Lower accessibility to veterinary services	PC3: Lack of knowledge about scientific poultry farming practices	MC3: Weak market linkage	PTC3: Lack of value addition skills for meat and egg products	MSC3: High cost of private veterinary services
F4	IC4: Non availability of medicines and vaccines at right time	PC4: Low hatchability	MC4: Poor access to markets and distant markets	PTC4: Lack of proper transportation facilities to access veterinary services	MSC4: Lack of a practice to provide supplementary feed
F5	IC5: Lack of access to credit, subsidy, and insurance support	PC5: Mortality due to higher incidences of disease and outbreaks	MC5: Seasonality in supply and demand of eggs and meat	PTC5: Inadequate transportation from production areas to markets	MSC5: Theft cases

The priority weights (Table 2) of each factor were used to rank the constraints. Production constraints received a priority weight of 0.250, ranking it first. The subsequent ranking was assigned to input supply constraints (0.237). Corresponding to their respective priority weights, miscellaneous constraints (0.195), processing and transportation constraints (0.174), and marketing constraints (0.144), were ranked III, IV, and V, respectively. All the factors utilised for the constraints analysis were consistent at a consistency ratio of 0.061.

Input supply constraints faced by backyard poultry value chain actors

The most significant input supply constraint faced by respondents was the lack of access to credit, subsidy, and insurance (global priority score: 0.109). Limited accessibility to veterinary services (0.039) ranked next, followed by the untimely availability of medicines and vaccines (0.036) and restricted access to improved germplasm (0.027). The unavailability of day-old chicks throughout the year (0.025) was considered the least critical factor (Table 3).

Production and marketing constraints faced by backyard poultry value chain actors

As presented in Table 3, the strongest production constraint experienced by the respondents was the high cost of feed (global priority score: 0.065). Low hatchability (0.053) and insufficient knowledge of scientific poultry practices (0.047) ranked next, while the suboptimal performance of native birds (0.045) and mortality due to frequent disease outbreaks (0.040) also posed notable challenges. For marketing, limited access to market information (0.037) stood out as the primary hurdle, followed closely by seasonal fluctuations in the supply and demand of eggs and meat (0.035). Issues such as price instability (0.027) and weak market linkages (0.025) further constrained marketing efficiency, whereas poor access to distant markets (0.020) was considered less critical."

Processing, transportation and miscellaneous constraints faced by backyard poultry value chain actors

Table 3 revealed that inadequate transportation from production areas to markets (global priority score: 0.050) was the leading challenge in processing and transportation. Lack of storage facilities (0.048), lack of processing infrastructure (0.032), insufficient transport to access veterinary services (0.027), and limited skills for value addition (0.016) followed in significance. With a global priority scale value of 0.079, respondents rated attacks by predators as the greatest challenge, followed by mortality due to extreme weather conditions (0.034). High cost of private veterinary services (0.029) and insufficient practice of providing supplementary feed (0.028) also affected backyard poultry production, while theft (0.024) was considered the least significant factor.

Table 2. Priority weights of overall constraints faced by backyard poultry value chain actors

Factors	Priority Weights	λ (Max)	Consistency Index (CI)	Consistency Ratio (CR)	Rank
Input supply constraints	0.237	5.274	0.068	0.061	II
Production constraints	0.250				I
Marketing constraints	0.144				V
Processing and transportation constraints	0.174				IV
Miscellaneous constraints	0.195				III

Table 3. Local and global priorities of constraints among backyard poultry value chain actors

Factors	Scaling factors	Alternatives	Consistency Ratio (CR)	Priority of the within factors	Globally or overall priority of the criteria	Rank
Input supply constraints	0.237	IC1	0.015	0.114	0.027	IV
		IC2		0.106	0.025	V
		IC3		0.168	0.039	II
		IC4		0.150	0.036	III
		IC5		0.461	0.109	I
		λ(MAX) = 5.066		Consistency Index (CI) = 0.016		
Production constraints	0.250	PC1	0.031	0.260	0.065	I
		PC2		0.179	0.045	IV
		PC3		0.188	0.047	III
		PC4		0.213	0.053	II
		PC5		0.160	0.040	V
		λ(MAX) = 5.138		Consistency Index (CI) = 0.034		
Marketing constraints	0.144	MC1	0.025	0.25839	0.037	I
		MC2		0.18919	0.027	III
		MC3		0.17086	0.025	IV
		MC4		0.13964	0.020	V
		MC5		0.24193	0.035	II
		λ(MAX) = 5.114		Consistency Index (CI) = 0.028		
Processing and transportation constraints	0.174	PTC1	0.070	0.183	0.032	III
		PTC2		0.276	0.048	II
		PTC3		0.094	0.016	V
		PTC4		0.158	0.027	IV
		PTC5		0.288	0.050	I
		λ(MAX) = 5.114		Consistency Index (CI)=0.079		
Miscellaneous constraints	0.195	MSC1	0.045	0.407	0.079	I
		MSC2		0.175	0.034	II
		MSC3		0.147	0.029	III
		MSC4		0.147	0.028	IV
		MSC5		0.124	0.024	V
		λ(MAX) = 5.199		Consistency Index (CI) = 0.049		

DISCUSSION

Smallholders encountered trouble securing loans due to their limited financial resources and a lack of collateral, which in turn impeded their ability to make investments in the production of poultry. In an analogous manner, Kitalyi et al. (2014) highlighted that lack of access to finance, subsidies, and insurance support serves as a significant hurdle for smallholder poultry producers. The difficulty of backyard poultry farmers to receive veterinary care as well as medications and immunizations at the appropriate times was found to be a key barrier (Bwala et al., 2020). In a bid to combat the health concerns prevalent among backyard poultry producers, the present study triggered dire need for more effective veterinary services as well as improved access to medications and immunizations. Smallholders' efforts to boost the efficiency and viability of their poultry businesses were hampered by their limited access to superior breeding stock and the irregular supply of day-old chicks. The current results align with Rizal[a] et al. (2020), who reported limited access to improved germplasm and scarcity of day-old chicks as key challenges for smallholder backyard poultry producers.

Backyard poultry farmers often rely on free-range systems and kitchen waste to feed their birds because high cost of commercial feed limits their ability to purchase balanced rations (Gupta et al., 2014; Akter et al., 2018). While scavenging and using household leftovers, farmers reduce production expenses, it may compromise the birds' balanced nutrition, highlighting the trade-off between cost-saving and optimal growth in low-input backyard poultry systems. Low hatchability underlined the necessity for improved breeding initiatives and hatchery management strategies to conquer this challenge (Kibet et al., 2020). The lack of cognizant awareness concerning scientific poultry production techniques emphasized the stipulation for capacity building and training programmes to augment smallholder producers' knowledge and expertise in poultry management techniques (Sahu & Singh, 2014; Omondi et al., 2019; Jadoun, 2021). To address low productivity and high mortality in native birds, the study stressed the need for stronger biosecurity, disease control, and better access to vaccines and medicines (Bwala et al., 2020).

The respondents stated that inadequate knowledge of market patterns and prices, hampered their potential to decide wisely and

bargain for higher prices (Leksrisompong et al., 2019). The findings suggested that upgraded market intelligence and more potent market ties might be the crucial components that require urgent consideration to prevail over these roadblocks (Bwala et al., 2020). The respondents specified that due to restricted transportation, substandard infrastructure, and a dearth of market knowledge, they often experience trouble reaching formal marketplaces (Das et al., 2014; Sarker et al., 2017).

The poor transport facilities and amenities affected the market accessibility resulting in detrimental effect on their profitability (Yadav et al., 2018; Musyoka et al., 2020). The present findings of the study anticipated that there is dire requirement for better storage infrastructure and processing amenities since restricted access to processing infrastructure and skills mired the capability of smallholders to add value to their poultry products and capture remunerative prices in the market (Bwala et al., 2020; Rizal[b] et al., 2020). Omondi et al. (2019) revealed analogous findings stating that an acute lack of value addition competencies demands regular capacity building programmes to boost smallholder producers' awareness and proficiency.

Since the predator attacks triggered the farmers to suffer considerable losses while rendering it challenging to run a profitable business, some respondents were found to keep their birds in enclosed structures to mitigate the likelihood of predator attacks and more successfully safeguard their poultry. Farmers reported a higher mortality rate during the winters months when temperature is considerably low. Farmers often relied on kitchen waste or scavenging for their poultry, which could lead to insufficient nourishment and reduced efficiency (Singh et al., 2020). (Kumaresan et al., 2008; Islam et al., 2022) reported analogous results indicating the theft was found to be a substantial concern among backyard poultry farmers.

CONCLUSION

The study analyzed and evaluated the constraints in backyard poultry farming value chain. AHP was used to prioritize various constraints confronted by backyard poultry farmers. In context of overall bottlenecks, production constraints were ranked first, followed by input supply constraints, miscellaneous constraints, processing & transportation constraints, and marketing constraints, and. Furthermore, lack of access to credit, subsidy, and insurance support; high cost of concentrate feed; restricted access to market information, inadequate transportation from production areas to markets, attacks by predators, were identified as the topmost waivers among backyard poultry farmers. Addressing these bottlenecks requires a holistic approach involving government support, investment in infrastructure and research, capacity building for farmers, improved market linkages, and policy reforms to create an enabling environment for the backyard poultry farming value chain to thrive.

DECLARATIONS

Ethical approval and informed consent: The institutional Ethical Committee of Dayanand Medical College and Hospital, Ludhiana, has provided ethical clearance (Ethics approval number: DMCH/R&D/2022/120) to conduct this study.

Conflict of interest: The authors declare that research was conducted in the absence of any commercial or financial relationship that could 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 author takes full responsibility for the final content of this publication.

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Research Note

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Constraints Faced by Developmental Personnel Concerning Livelihood Programmes Across Paniya and Kanikkar Tribes, Kerala

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HIGHLIGHTS

- Institutional and administrative constraints were more severe among personnel working with the Paniya community.
- Political influence affected beneficiary selection more prominently in the Kanikkar region.
- Excessive workload limited sustained field engagement in both districts
- Staffing shortages in Wayanad and poor connectivity in Thiruvananthapuram were reported.

ARTICLE INFO

Keywords: Tribal livelihoods, Development, Constraints, Perspectives, Recommendations.

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ABSTRACT

The study examined the constraints faced by developmental personnel concerning tribal Livelihood Development Programmes (LDPs) among the Paniya community in Wayanad and the Kanikkar community in Thiruvananthapuram. Data were collected from 120 personnel between January and May 2025 using a structured schedule, and constraints were prioritised using Garrett's ranking technique. The results showed that excessive workload was a major challenge in both regions. However, personnel working with the Paniya community reported greater institutional delays and limited field-level staffing, while those working with the Kanikkar community faced stronger political influence and poor transport connectivity. Limited exposure to indigenous knowledge and seasonal migration of household head were notable socio-cultural barriers in both contexts. The findings underline that operational constraints faced by developmental personnel vary across tribal settings and are shaped by administrative, socio-cultural, and infrastructural factors. Addressing these constraints through context-specific planning, improved institutional coordination, and strengthened field-level support is essential for enhancing the effectiveness of livelihood interventions in tribal areas.

INTRODUCTION

Tribal communities in India form an essential part of the nation's socio-cultural fabric, sustaining diverse ecological knowledge systems, indigenous livelihood practices, and community-based resource management traditions. Scheduled Tribes constitute 8.6% of the population, largely residing in forested and ecologically sensitive regions (Dakua et al., 2020). Their livelihoods, rooted in natural resource dependence and wage labour, remain vulnerable to environmental degradation, land-use changes, market shifts, and socio-economic marginalization (Babu et al., 2024). In Kerala, of the 37 tribal communities, comprising 1.45% of the State population, major tribes include Paniya, Kurichiya, Kattunayakan, Kani (Kanikkaran), Muthuvan, and Kuruman, prominently concentrated in Wayanad, Idukki, and the Western Ghats (Balakrishnan & Kurup, 2024). The Paniya community remains one of the most socio-economically marginalized groups, dependent mainly on wage labour and limited land resources (Narayanan et

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al., 2011). In contrast, the Kanikkar tribe in Thiruvananthapuram shows gradual livelihood diversification into farming, wage work, and service sector employment, supported by comparatively higher literacy and landholding (Joy & Ajithkumar, 2018).

Recognizing the need to strengthen livelihood security among tribal communities, various LDPs are implemented through the Scheduled Tribes Development Department (STDD), Local Self-Governments, Krishi Vigyan Kendra (KVK), and Non-governmental Organisation (NGOs) (Kuriakose & Ramesh, 2025). These include skill development, income-generation activities, agricultural extension, credit support, and enterprise promotion (Manoj & Aithal, 2025). The effectiveness of these programmes depends largely on developmental personnel, who bridge policy and field realities and provide insights into operational constraints and context-specific improvements (Anshuman et al., 2023). Although substantial funds are allocated for tribal development, resource allocation and actual community well-being often do not align. Most studies focus on tribal households rather than the perspectives of those implementing development interventions (Suman et al., 2025). Therefore, examining the constraints faced by developmental personnel is essential, as their insights reflect field-level realities and can guide policymakers in designing context-responsive and operationally feasible livelihood strategies (Kumar et al., 2024).

With this backdrop, the present study examines the constraints perceived by developmental personnel involved in LDPs for the Paniya and Kanikkar communities in Wayanad and Thiruvananthapuram. Understanding these perspectives will support improvements in programme planning, coordination, and delivery. Comparing two contrasting tribal contexts enables insights across different stages of tribal livelihood development interventions related to health, food and nutrition, water and sanitation, agriculture and allied activities, income generation, and basic welfare services. The study tests the hypothesis: H_0 : no significant difference in the constraints between the two groups; H_1: a significant difference exists.

METHODOLOGY

The study was conducted among the developmental personnel in Wayanad and Thiruvananthapuram, where the Paniya and Kanikkar communities predominantly reside. The respondents, directly involved in the planning, implementation, and monitoring of LDPs for the Paniya and Kanikkar communities, were selected. To ensure meaningful field experience, only individuals with a minimum of one year of direct engagement with either community were included. Before the main data collection, a pilot study was conducted, followed by expert validation to refine the schedule of constraints. Purposive sampling strategy was adopted to select personnel from various institutions actively involved in livelihood interventions. In Wayanad, respondents were drawn from the Integrated Tribal Development Project (ITDP) (20), Kerala Institute for Research, Training and Development Studies of Scheduled Castes and Scheduled Tribes (KIRTADS) (10), Tribal Extension Office (15), and M.S. Swaminathan Research Foundation (MSSRF) (15). In Thiruvananthapuram, respondents were selected from ITDP (18), Tribal Extension Offices (14), the STDD (16), and the Office of the Chief Wildlife Warden (12). In total, 120 developmental personnel (60 from each district) were surveyed between January and May 2025, ensuring adequate time for field contact and verification. Since the nature of responsibilities, administrative conditions, and socio-cultural contexts vary across regions and tribal groups, the constraints experienced by the respondents were assessed separately in the two districts. The constraints were categorised under four broad dimensions (Lakshmi et al., 2025; Satpathy et al., 2025) and the constraints were prioritised meaningfully, adopting Garrett's ranking technique (Gupta et al. 2020; Bahubalendra et al., 2025; Adithyan et al., 2025; Chaudhary et al., 2025).

RESULTS

Institutional and administrative constraints

These constraints pose major operational challenges to programme implementation. As shown in Table 1, excessive workload was the most serious issue in both Wayanad and Thiruvananthapuram (Rank 1), indicating limited staffing for multiple responsibilities. In Wayanad, delays in administrative approvals followed (Rank 2), while in Thiruvananthapuram, political influence in beneficiary selection and programme prioritisation emerged next (Rank 2). Limited involvement of local self-governance institutions and weak inter-departmental coordination appeared in later ranks. Similar issues of administrative delays and inadequate institutional convergence affecting programme continuity were reported by Das (2025).

Technology and knowledge constraints

Technology and knowledge barriers primarily stem from limitations in cultural familiarity and technical support. As presented in Table 1, in Wayanad, insufficient exposure to indigenous livelihood systems was ranked first (Rank 1), followed by lack of appropriate tools for practical demonstrations (Rank 2), while challenges in culturally relevant dissemination and limited training opportunities followed (Ranks 3–4). In Thiruvananthapuram, inadequate specialist technical support was the foremost issue (Rank 1), with limited exposure to traditional knowledge next (Rank 2), and dissemination and material constraints ranked thereafter (Ranks 3–4). Similar gaps in awareness, demonstration capacity, and adaptation knowledge were reported by Paul et al., (2015), Singh et al. (2018) and Choudhary et al. (2025).

Social and cultural constraints

As indicated in Table 1, in Wayanad, reluctance to adopt new livelihood practices was ranked highest (Rank 1), followed by seasonal migration (Rank 2), gender-based participation differences (Rank 3), and language or communication barriers (Rank 4). In Thiruvananthapuram, seasonal migration was the major constraint (Rank 1), reluctance toward livelihood diversification ranked next (Rank 2), gender-related participation patterns followed (Rank III), and communication challenges appeared least severe (Rank 4). These findings align with Kumar et al. (2024), who emphasised that cultural identity and social hierarchies strongly influence community engagement in development programmes.

Table 1. Constraints as perceived by developmental personnel concerning LDP's (N=120)

S.N.	Constraints	Wayanad		Thiruvananthapuram	
		GMS	R	GMS	R
A.	Institutional and Administrative				
1.	Insufficient time to conduct participatory planning	33.72	5	30.52	7
2.	Delays in administrative approvals	64.74	1	34.26	5
3.	Lack of clarity in programme guidelines	33.5	6	32.8	6
4.	Excessive workload limiting adequate field support	64.16	2	65.34	1
5.	Limited coordination between departments	30.78	7	64.1	4
6.	Limited involvement of local self-governance institutions	62.78	3	61.02	4
7.	Political influences on priority setting and beneficiary selection	60.32	4	61.54	3
B.	Technical and Knowledge				
8.	Limited exposure to indigenous livelihood systems and traditional knowledge	53.7	1	57.3	2
9.	Inadequate training opportunities on tribal livelihood strategies	47.5	4	30.3	5
10.	Difficulty in disseminating livelihood practices in culturally relevant ways	50.1	3	50.5	3
11.	Lack of appropriate tools to demonstrate livelihood practices	51.4	2	43.2	4
12.	Limited availability of technical support from specialist institutions	47.3	5	68.7	1
C.	Social and Cultural				
13.	Language and communication barriers	33.84	4	34.16	4
14.	Reluctance of some tribal households to adopt new livelihood practices	65.48	1	54	2
15.	Gender-based influence on participation in programme activities	47.52	3	47.76	3
16.	Seasonal migration of families disrupting continuity of programme activities	55.16	2	66.08	1
D.	Infrastructural and Logistic				
17.	Poor transport and road connectivity	45.48	3	67.24	1
18.	Inadequate supply of essential inputs for livelihood activities	57.64	2	33.92	4
19.	Lack of storage and processing facilities	33.88	4	53.56	2
20.	Insufficient field-level staff	65.00	1	47.28	3

GS – Garett Score, GMS – Garett Mean Score, R- Rank

Infrastructural and logistical constraints

As shown in Table 1, infrastructural and logistical constraints varied across regions. In Wayanad, insufficient field-level staff was ranked highest (Rank 1), followed by inadequate supply of essential inputs (Rank 2), poor transport connectivity (Rank 3), and lack of storage and processing facilities (Rank 4). In Thiruvananthapuram, poor road connectivity to forest-fringe settlements emerged as the major constraint (Rank 1), followed by limited storage and processing facilities (Rank 2), insufficient staffing (Rank 3), and inadequate input supply (Rank 4). Similar constraints linked to weak connectivity and restricted market access were also reported by Abera et al. (2021).

DISCUSSION

In the institutional and administrative dimension, excessive workload in Wayanad limits sustained field engagement and follow-up, while administrative delays hinder timely delivery of programme benefits. In Thiruvananthapuram, weak involvement of local self-governance bodies and poor inter-departmental coordination reduce community ownership and resource convergence. Monisha and Thomas (2021) similarly reported that bureaucratic delays and procedural rigidity slow tribal development efforts. Choudhary et al. (2025) further noted that fragmented institutional linkages and lack of collaborative planning reduce the effectiveness of livelihood interventions.

Regarding technology and knowledge constraints, limited cultural understanding and weak familiarity with indigenous practices reduce the effectiveness of communication and skill transfer in Wayanad. In Thiruvananthapuram, insufficient technical support restricts the Kanikkars' ability to adopt forest-based and value-addition livelihoods. Earlier work by Nair and Vishnu (2018) also noted that lack of culturally grounded approaches and institutional linkages weakens programme relevance. Limited awareness of adaptation technologies and benefits further reduces adoption, while inadequate training exposure restricts sustainable skill development (Kumar & Nain, 2012; Singh et al., 2018).

With regard to socio-cultural factors, reluctance to adopt new livelihood practices among the Paniyas reduces participation in training and uptake of interventions, while seasonal migration among the Kanikkars interrupts follow-up and programme continuity. Kumar et al., (2024) also noted that when cultural identities and social hierarchies are overlooked, development efforts fail to align with community priorities. Further, Bilavekar et al. (2025) revealed that developmental officials reported limited literacy and low awareness of government schemes continue to impede effective communication and knowledge transfer.

Concerning infrastructural and logistical constraints, limited field-level staffing in Wayanad weakens follow-up and disrupts the continuity of programme activities. In Thiruvananthapuram, poor road connectivity and difficult terrain form the major barriers, restricting mobility, training access, and timely service delivery. Joy and Ajithkumar (2018) also noted that inadequate staffing reduces field presence and programme momentum, while Meeral et al. (2024) highlighted that physical isolation limits value addition and market

opportunities. Additionally, dispersed settlements and weak communication infrastructure further hinder resource delivery and coordination (Kapoor et al., 2021).

CONCLUSION

The study highlights that developmental personnel working with tribal communities experience varied operational and contextual challenges shaped by the socio-cultural and geographical settings of each region. While excessive workload was common across both districts, institutional delays and inadequate field staffing were more critical in Wayanad, whereas political influence and poor connectivity affected implementation in Thiruvananthapuram. Differences in cultural familiarity, technical support, and community engagement further influenced programme outcomes. Strengthening inter-departmental coordination, ensuring timely administrative support, enhancing culturally relevant training, and improving infrastructural access are essential for improving programme delivery. Context-specific, participatory, and sustained interventions are crucial to ensure that livelihood development initiatives effectively support the socio-economic advancement of the Paniya and Kanikkar communities.

DECLARATIONS

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

Conflict of interest: The authors declare that research was conducted in the absence of any commercial or financial relationship that could be 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 author takes full responsibility for the final content of this publication.

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Research Note

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Constraints Affecting the Adoption of Low-Carbon Agricultural Technologies in Kerala

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HIGHLIGHTS

- Unpredictable weather, labour shortages, and high input costs emerged as significant constraints to the adoption of low-carbon agricultural technologies.
- Economic and market constraints surpassed awareness-related barriers.
- Locale-specific extension strategies, highlighting district-level customisation, are essential to overcoming barriers to the adoption of low-carbon agricultural technologies.

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ABSTRACT

The study was conducted during 2025 in the three districts of Kerala, viz., Thiruvananthapuram, Ernakulam, and Kasaragod, to identify the most critical constraints to farmers' adoption of low-carbon agricultural technologies (LCAT). A descriptive research design was administered for data collection, and 270 farmers were selected using random sampling technique. The Garrett ranking technique was applied to quantify the severity of ten predetermined constraints influencing adoption. The results revealed that unpredictable weather, labour shortage, and high input costs were the most severe constraints limiting adoption. Economic and market-related barriers, including the lack of marketing facilities and inputs, also restricted farmers' willingness to adopt low-carbon agricultural technologies. Knowledge-related constraints, including limited awareness of climate change and low-carbon technologies, were ranked lower, indicating that awareness alone was inadequate to drive adoption without tackling structural and financial barriers. Spearman's rank correlation revealed the district-wise variation in the severity of constraints, emphasising the need for location-specific extension strategies, within a broader state-level policy framework to promote Kerala's transition towards carbon-neutral agriculture.

INTRODUCTION

Agricultural practices significantly impact the carbon balance, underscoring agriculture's dual role as both a source of emissions and a carbon sink. (Chen et al., 2020). In this context, how well carbon sequestration and low-carbon agricultural technologies such as reduced tillage, optimized fertilizer and pesticide usage, managing manure and waste, addition of biochar, etc., are increasingly recognized as essential for mitigating climate change while sustaining agricultural productivity (Ozlu et al., 2022).

Since 2018, Kerala has actively been exploring pathways to promote carbon-neutral farming practices, in line with both national climate action objectives and the global agenda for sustainable agriculture. A noticeable milestone is the designation of Meenangadi Panchayath in Wayanad district as India's first carbon-neutral village, which introduces the concept of a "carbon-neutral community",

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emphasizing zero-carbon development and grassroots-level food and energy self-sufficiency (Jayakumar et al., 2018). Complementing this, the State Seed Farm, Aluva, has been declared the first carbon-neutral farm in India, demonstrating the feasibility of low-carbon agricultural technologies at a farm scale (Mani, 2022). The successful implementation of these models positions Kerala to pursue the broader goal of achieving Net Zero status by 2050 through the "Net Zero Carbon Keralam through People Campaign" under the Navakeralam Karmapadhathi, which seeks to integrate community participation with sustainable development initiatives.

Despite these initiatives, the low-carbon agricultural techniques are yet to gain widespread adoption among homestead farms across the state. As reported by Singh et al. (2022), low-carbon agricultural technologies remain insufficiently adopted and scientifically validated. Accordingly, the study aims to identify the significant constraints that hinder farmers from implementing such practices at the household level. As noted by Momenpour et al. (2024), understanding the constraints is essential for policymakers and stakeholders to design targeted, more successful interventions.

METHODOLOGY

Three districts in Kerala, *viz.,* Thiruvananthapuram, Ernakulam, and Kasaragod, which were purposefully selected to represent the state's Southern, Central, and Northern regions, respectively, for the study. A total of 270 farmers were randomly selected for the study, comprising 202 males and 68 females. The study followed a descriptive research design to identify the key constraints to farmers' adoption of low-carbon agricultural technologies.

The Garrett ranking technique was applied to quantify the severity of these constraints perceived by the farmers. On a scale of 1 (most severe) to 10 (least severe), respondents were asked to rank ten pre-identified constraints, derived from the existing literature and focus group discussions with stakeholders. The ranks assigned by each respondent were converted into per cent positions and corresponding Garrett scores. The total and mean Garrett scores of each constraint were calculated, and constraints were then arranged in descending order of their mean scores to establish their relative ranking. Furthermore, the Garrett ranking for the three districts was calculated separately.

Spearman's rank (r_s) correlation coefficient was used to assess the degree of similarity in the rankings of constraints across the three districts. Spearman's rank correlation was computed pairwise between Thiruvananthapuram and Ernakulam, Thiruvananthapuram and Kasaragod, and Ernakulam and Kasaragod.

RESULTS

Apart from identifying the priority, the Garrett Ranking Technique also provided insight into the severity and spread of each constraint. A higher Garrett score indicated not only that the constraint was ranked more frequently as important, but also that it was widely experienced across respondents. This means the constraints were consistently perceived as significant, cutting across different situations, contexts, or respondent groups. The constraint means that weighted scores, mean scores, and corresponding ranks of the constraints identified by farmers in adopting low-carbon agricultural technologies are presented in Table 1. The constraints with higher mean scores were interpreted as the most significant barriers to adopting low-carbon technologies, whereas those with lower mean scores were considered less influential.

Table 1. Overall Garrett ranking of constraints in adopting low-carbon agricultural technologies

Codes	Constraints	GMS	Rank
C1	Lack of climate change awareness	48.51	VII
C2	Lack of low carbon agriculture technology awareness	47.82	VIII
C3	Lack of suitable inputs	54.71	V
C4	High input cost	57.44	III
C5	Lack of proper marketing facility fetching premium price	55.30	IV
C6	High labour shortage	60.56	II
C7	Unpredictable weather	63.85	I
C8	Lack of access to timely weather information	54.15	VI
C9	Lack of access to credit facilities	35.27	IX
C10	Limited access to agricultural extension agencies	20.48	X

GMS: Garrett Mean Score

DISCUSSIONS

The Garrett ranking analysis provided critical insights into the challenges farmers faced when implementing low-carbon agricultural technologies. The study provided a solid foundation for addressing the main constraints by identifying a number of limitations that affect the adoption process (Warshini et al., 2025). According to the analysis, the top barriers were unpredictable weather, labour shortages, and high input costs. These results uncovered the multidimensional challenges farmers face in transitioning to sustainable low-carbon agricultural technologies, such as precision agriculture, straw recycling, and soil carbon sequestration methods (Zhao & Zhou, 2021). The most significant constraint farmers identified was unpredictable weather, highlighting the increasing susceptibility of smallholder farmers to climate variability and extreme events. Irregular rainfall, extended dry spells and temperature fluctuations disrupted the cropping patterns, creating production uncertainty and thereby constraining the farmers' willingness to adopt new technologies (Tripathi & Mishra, 2017). Under such conditions of climate risk, low-carbon agriculture practices that require upfront investment become less attractive to farmers, thus constraining their adoption (Issahaku & Abdulai, 2020; Ling et al., 2022). The second significant constraint identified was the shortage of agricultural labour. Daum et al. (2023) found that many low-carbon agricultural techniques required more labour than conventional, mechanised, and input-heavy practices. Tong et al. (2024) suggested that labour intensive practices like mulching, organic manuring and integrated farming systems were not as feasible due to labour scarcity brought on by rural-urban migration and an ageing farming population. This suggested that farmers were frequently pressured to choose labour-saving, but often carbon-intensive alternatives.

The following three ranking constraints of high input cost (III), lack of proper marketing facility fetching premium price (IV) and

Table 2. District wise Garrett ranking of constraints in adopting low-carbon agricultural technologies

Codes	Constraints	District-wise ranking					
		TVM		EKM		KSG	
		GMS	R	GMS	R	GMS	R
C1	Lack of climate change awareness	51.00	VI	44.08	VII	50.46	VI
C2	Lack of low carbon agriculture technology awareness	52.72	V	41.26	VIII	49.43	VII
C3	Lack of suitable inputs	50.18	VIII	62.30	III	51.66	V
C4	High input cost	59.40	II	55.68	V	57.24	IV
C5	Lack of proper marketing facility fetching premium price	50.33	VII	51.99	VI	63.10	I
C6	High labour shortage	56.61	III	63.36	II	61.71	II
C7	Unpredictable weather	64.73	I	65.92	I	60.79	III
C8	Lack of access to timely weather information	54.59	IV	57.54	IV	50.07	VIII
C9	Lack of access to credit facilities	33.60	IX	37.63	IX	35.06	IX
C10	Limited access to agricultural extension agencies	24.83	X	18.24	X	18.49	X

GMS: Garrett Mean Score; TVM: Thiruvananthapuram; EKM: Ernakulam; KSG; Kasaragod; Rank: R

Table 3. Spearman's Rank Correlation Matrix

Correlation	r_s	P value (5%. Level)
TVM – EKM	0.721*	0.019
EKM – KSG	0.685*	0.029
TVM – KSG	0.552	0.098

*significant at 5% level ($p < 0.05$)

lack of suitable inputs (V) collectively indicated significant economic and marketing barriers. Many LCATs, including biofertilizers, renewable energy-based irrigation systems, or improved composting units, require higher initial investments, posing a significant challenge for small and marginal farmers (Autio et al., 2021; Roy & Ghosh, 2022; Sabu & Roy, 2024). According to the study by Jiang et al. (2022), farmers were likely to prioritise short-term cost reduction over long-term sustainability benefits, when sufficient subsidies or financial incentives were not offered. Additionally, even when farmers adopted such practices, the lack of differentiated markets and reward mechanisms that offer premium prices for low-carbon products limits their economic motivation to continue these efforts.

Even with adequate awareness, adoption remained unlikely due to the absence of supportive structural and economic barriers, as indicated by the lower ranking of the knowledge and awareness-related constraints, such as lack of access to timely weather information (VI), lack of climate change awareness (VII) and lack of low-carbon agriculture technology awareness (VIII). These findings challenged a predictive model introduced by Kuehne et al. (2017), which focused on knowledge, awareness and learning as key factors influencing adoption decisions. The result also emphasized that merely providing information was insufficient to induce behavioral change, as farmers prioritized financial viability and risk management. Nonetheless, the comparatively higher ranking of inadequate access to timely weather information highlighted the importance of actionable, real-time data as a risk-mitigation tool, valued more by farmers than general climate awareness. Accordingly, extension efforts should prioritize the dissemination of location-specific, real-time information rather than focusing solely on general climate education (Mabhaudhi et al., 2025; Sattar et al., 2025).

According to the comparatively lower rankings of lack of access to credit facilities (IX) and limited access to agricultural extension agencies (X), either financial and institutional links were relatively functional among the farmers surveyed, or farmers were not fully aware of the mechanisms available to them. In the latter instance, limited awareness of credit schemes, subsidies and extension services may restrict farmers' ability to take advantage of institutional resources that could otherwise facilitate the shift to sustainable, low-carbon agricultural technologies. Raza et al. (2023) stated that inadequate access to credit constrains farmers' capacity to meet the initial expenses of low-carbon technologies, while weak linkage with the extension agencies limits their exposure to new technologies, best practices, and risk-mitigation techniques.

In view of the observed variations in the rankings of the constraints (Table 2), Spearman's rank correlation analysis was performed. The results (Table 3) revealed that the perceived severity of constraints related to the adoption of low-carbon agricultural technologies was not uniform across all districts. There was a strong and statistically significant correlation between Thiruvananthapuram and Ernakulam as well as Ernakulam and Kasaragod, implying that farmers in Ernakulam district experienced and prioritized the constraints similarly to the other districts. As reported by Devadas & Ushadevi (2018), this similarity may be attributed to the shared agro-ecological environment, possibly due to similar production risks and resource needs, as well as the sound and consistent market linkages and exposure to technology.

In contrast, Thiruvananthapuram and Kasaragod exhibited a non-significant correlation suggesting differences in cropping pattern, resource mobilization, structural and institutional networks access, and socio-economic characteristics of the farm households. Farmers in Kasaragod districts followed more traditional farming practices, faced more structural challenges, primarily related to market facilities. Meanwhile, Thiruvananthapuram is closer to policy institutions and had stronger institutional access, which may therefore lead it to rank knowledge-related constraints higher (Preethi et al., 2022).

CONCLUSION

The study affirms that farmers' adoption of low-carbon agricultural technologies in Kerala is shaped less by awareness deficits and more by perceived risk, economic feasibility, and structural conditions within smallholder farming systems. This

highlights the need to move beyond information-centric approaches and adopt policy frameworks that actively reduce climate and market-related uncertainties faced by farmers. The transition towards carbon-neutral agriculture in Kerala will therefore depend on integrated interventions that align financial incentives, climate-resilient infrastructure and institutional support mechanisms with farmers' risk management priorities. Moreover, Spearman's rank correlation results highlight the importance of complementing the state level strategies with the decentralized, context-specific implementation pathways. These inferences highlight that Kerala's transition to carbon-neutral agriculture and the state's broader objective of net-zero emissions by 2050 require coordinated policy interventions that incorporate financial incentives, weather-based advisories, and proper institutional linkages.

DECLARATIONS

Ethical approval and informed consent: Informed consent was sought from the selected 270 farmers during the course of the research.

Conflict of interest: The authors declare that research was conducted in the absence of any commercial or financial relationship that could 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 author takes full responsibility for the final content of this publication.

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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.

The RESULTS present the data, the facts- what you found/ calculated/ discovered/ observed. It should be written in simple past tense to report your observations on experiment/ fieldwork, its comparison/contrast. Only the salient results need to be presented instead of writing the whole tabular/ graphical data in text. Too many paragraphs are discouraged; one concept must be dealt with at one place and time in one paragraph.

Avoid making too many tables just for the number's sake, do not give socio-personal profile table and text till it is utmost necessary and has some bearing on the other part of the research. **Results should be presented in tabular form and graphs where ever feasible but not both**. The colour figures and plates during printing in black and white may lose information. Mean results with the relevant standard errors should be presented rather than detailed data. The data should be so arranged that the tables would fit in the normal layout of the page. Self-explanatory tables should be typed on separate sheets and carry appropriate titles. **The titles of tables/figures should**

not be more than 12 words. The tabular matter should not exceed 20% of the text. Any abbreviation used in a table must be defined in that table. All tables should be cited in the text. If an explanation is necessary, use an abbreviation in the body of the table (e.g. ND) and explain clearly in footnotes what the abbreviation means. References to footnotes in a table are specified by superscript numbers, independently for each table. Superscript letters are used to designate statistical significance. Use a lower case p to indicate probability values (i.e. $p<0.05$). In general, use numerals, when two numbers appear adjacent to each other, spell out the first (i.e. three districts were selected rather than 3 districts were selected). In a series using some numbers less than 10 and some more than 10 use numerals for all (i.e. 2 splits, 6 plants were selected). Do not begin a sentence with a numeral. Spell it out or rearrange the sentence. Abbreviate the terms hour (h), minute (min) and second (sec) when used with a number in the text but spell them out when they are used alone. Do not use a hyphen to indicate inclusiveness (e.g. use 12 to 14 year or wk 3 and 4 not 12-14 mg or wk 3-4). Use Arabic numerals with abbreviated units of measure: 2 g, 5 d, $4.00, 3% and numerical designations in the text: exp 1, group 3, etc. Figures (histogram/pie chart/another type of charts) should be in editable rich text material with the backup data file. The image of the figure or jpg/jpeg is not be allowed.

The DISCUSSION shows the relationship among the facts, it puts results in context of previous researches, and the emphasis must be on presenting results in relation to established knowledge. The discussion should contain trends, relationships, generalizations, any exception, outlying data, agreement/ disagreement with previous researches with reasons. The discussion should be written in present tense. The discussion should be written in the present tense. Limit the discussion within **400-600** words.

The **CONCLUSION** summarizes principal findings and should not be of more than one paragraph (100-150 words). The discussion explains in general terms the implications of the findings of this research. It has to be written in present tense and the emphasis must be on what should now be accepted as established knowledge. Conclusion should relate back to introduction and hypothesis. The significance of your results or any practical application/ implication must find place in conclusion. Abbreviations, acronyms, or citations should not be used here. It should not be a repetition of the abstract.

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