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EDITORIAL

Global agriculture in 2025 is grappling with interconnected crises driven by conflict, climate change, and economic instability, leading to worsening food insecurity worldwide. On one side, farmers' alliances are voicing concerns over proposed reforms to seed treaties that could threaten their rights, whereas scientists are presenting new evidence that a major overhaul of global food systems is essential to avoid climate disaster and improve health outcomes. Efforts are underway to reform agricultural policies to support farmers and ensure greater resilience against future biotic and abiotic shocks. The experiences gained through *Viksit Krishi Sankalp Abhiyan*, India, provided many insights in the form of demand for innovation, importance of localized knowledge, need for continuous outreach to bridge the research-practice gap, and a holistic approach to agriculture have to go a long way in designing sustainable agricultural framework.

The current issue (October-December 2025) contains six research tools, seven research notes, and twenty-five full-length research papers. The diversity of full length papers focused on; Barriers to handicraft development in rural Saravan, Iran ;Utilization of smartphones for accessing agricultural information by farmers; Disruptions in Lifestyle Due to Escalating Screen Time; A Cross-state analysis of livelihood security among farm women; mapping dairy farmers' preferences for improved feeding practices ; Farmers' livelihood security through sheep farming; Exploring the dimensions of millet awareness among generational cohorts; Exploring consumer behaviour towards zero-sugar beverages; Bibliometric exploration of bullying; Influence of private extension services on practices and perceptions of shrimp farmers; ICT training directions in coastal Odisha; Factors influencing the adaptation behaviour of rice growers to climate change; Adoption and compliance of AI-enabled pest advisories; Crew position-based assessment of fishermen's knowledge needs; Behavioural determinants of secondary agriculture-based entrepreneurs; Determinants of consumer perceptions towards value-added millet products; Determining the knowledge level and accessibility of major ICT tools; Modeling of farmers' preferences towards climate-smart agriculture; Impact assessment of floating and alternative feeds for fish rearing technologies; Influence of livelihood assets on agrochemical vs organic input use; Time management and procrastination patterns among undergraduate agriculture students; Communication and marketing behaviour of tomato growers; Modelling livelihood security of tribal farmers; Use of generative AI by small-scale farmers in Nigeria; and Economic perspective of trends and determinants of paddy stubble burning. Among the Research Tools, Livelihood vulnerability of climate-sensitive farming communities, Attitude towards digital technologies in agriculture, Knowledge test on tick infestation in small ruminants, Farmers' perception of capacity needs under NICRA, Knowledge test on scientific walnut cultivation, and Vegetable growers' attitude towards safety measures in pesticide application were included. Research Note section has been enriched with the studies on Determinants of ARYA adoption for livelihood security, Constraints in the adoption of stress tolerant rice varieties, Perceived constraints among dairy farmers, Constraints in adopting improved chickpea cultivation practices, Perceived benefits and pre-design environmental impact assessment of eco-friendly ornament development, Constraints faced by farmers in adapting to climate change and constraints to digital literacy among joint liability groups. The Scopus cite score during the quarter increased from 1.4 to 1.7 (<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. Satyapriya, 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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Barriers to Handicraft Development in Rural Saravan, Iran: A Bayesian Network and Fuzzy AHP Analysis

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HIGHLIGHTS

- Managerial barriers were identified as the most critical obstacle to handicraft development in Saravan, with strong causal links to financial, marketing, and motivational challenges.
- Integrating Fuzzy Analytical Hierarchy Process (FAHP) and Bayesian Network Analysis (BNA) provided a comprehensive view of barrier prioritization and interdependence.
- The study proposes a multi-level strategy including tourism promotion, market access, education, and policy reforms to revitalize Saravan's handicraft sector and support rural development.

ARTICLE INFO

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ABSTRACT

The study examined the key barriers hindering the development of the handicraft sector in Saravan, Iran, with a focus on identifying their significance and interrelationships. Despite the global recognition of Saravan's Kalporagan pottery, a 7,000-year-old tradition preserved by local women, the region's handicraft industry has faced persistent stagnation. A mixed-method approach was adopted, utilizing the Fuzzy Analytical Hierarchy Process (FAHP) to categorize barriers into six main groups: managerial, motivational-psychological, marketing and sales, financial-economic, skill-technical, and product-based. This study was conducted in 2024. The findings showed that managerial barriers were the most critical, followed by motivational and marketing challenges, while product-related barriers had the least impact. To explore causal connections among these barriers, Bayesian Network Analysis (BNA) was applied, revealing that managerial shortcomings significantly influenced financial and marketing constraints. The study concluded that addressing managerial inefficiencies could alleviate other development obstacles. It emphasized the need for targeted institutional reforms, investment in tourism infrastructure, and improved market access to revitalize Saravan's handicrafts and contribute to sustainable rural development.

INTRODUCTION

Sustainable rural development goes beyond simply infusing financial capital and technological advancements; it is also equally influenced by social, institutional, and cultural factors. Among these, the handicraft sector plays a vital role in fostering local economies, particularly in developing regions. Handicrafts contribute to employment generation, preservation of cultural identity, and

enhancement of community resilience (Akbari et al., 2016; Makhitha, 2017). Although its scale is relatively small, the handicraft industry demonstrates steady growth. Notably, it is the second-largest source of rural employment after agriculture. (Agarwal et al., 2022).

Handicraft enterprises, typically small and owner-managed, often struggle with marketing inefficiencies, management limitations, and production challenges. Owners frequently lack specialized

knowledge in strategic planning and market access (Makhitha, 2016). Studies identify inadequate marketing awareness, financial challenges, and limited competitive capacity as key barriers for rural small and medium enterprises (SMEs) (Journeault et al., 2021). In the Iranian context, numerous investigations highlight the structural and operational challenges faced by handicraft enterprises. For instance, Shams al-Dini (2020) outlines barriers such as international sanctions, inconsistent policy support, weak infrastructure, and poor management practices in Fars Province. Karbasi and Yaqoubi (2018) report similar issues in Sistan and Balochistan, including unregulated imports, cultural shifts, and insufficient advertising. Likewise, Omid et al., (2016) identify deficiencies in marketing and distribution networks in Ilam Province, while Paidar (2016) emphasizes the importance of managerial skills, technical training, and motivational incentives in Qasr-e Qand County. International evidence echoes these challenges in countries such as India, South Africa, and Indonesia, where fragile institutions and limited access to technology hinder the growth of local artisanship (Mohapatra, 2013; Makhitha, 2017; Shah & Patel, 2017; Sharma & Ranjan, 2024; Rahayu et al., 2024; Kademani et al., 2024; Chandre Gowda et al., 2025).

Saravan, located in southeastern Iran's Sistan and Baluchistan province, exemplifies a region where handicrafts hold deep cultural and economic significance. The area is known for its needlework, jewelry making, and particularly Kalporagan pottery, a tradition reportedly practiced for over 7,000 years by local women using ancient hand-forming techniques. In 2017, the World Crafts Council recognized Kalporagan as the first global handicraft village for pottery, while UNESCO recognized it as the site of the world's oldest continuously produced handmade pottery. Despite this cultural prominence, artisans in Saravan face challenges such as limited marketing, insufficient institutional support, and competitive pressures from mass-produced goods (Karimzadeh et al., 2016; Bakhtiari, 2019; Karimzadeh, 2022).

This study draws on institutional theory and entrepreneurship theory to analyze the interplay between external structures and enterprise-level strategies. Institutional theory explains how formal and informal systems shape economic actions, while entrepreneurship theory emphasizes innovation, market orientation, and resourcefulness in overcoming challenges faced by small businesses. The novelty of this study lies in the integration of FAHP and BNA methodologies to not only rank the barriers but also map their causal interdependencies, an approach not previously applied in the context of Iran's rural handicraft sector. This dual-method analysis offers deeper insights into how governance failures reinforce other systemic challenges and proposes a data-driven basis for targeted policy intervention.

METHODOLOGY

This research utilized a mixed-methods approach to identify and prioritize barriers hindering the growth of the handicraft sector in Saravan, located in Iran's Sistan and Baluchistan province. Data collection included both secondary and primary sources. A comprehensive review of the existing literature was conducted to create a conceptual framework that identifies six main categories of obstacles: managerial, motivational-psychological, marketing and sales,

financial-economic, skill-technical, and product-based barriers. These categories and their sub-criteria were then turned into a structured questionnaire containing 82 pairwise comparison items. The content validity of the questionnaire was confirmed by five independent experts, resulting in a Content Validity Index (CVI) of 0.89.

A purposive sample of 30 experts was selected with at least five years of direct experience, ensuring balanced representation in terms of gender and educational background, comprising 12 artisans, 8 cooperative leaders, and 10 local officials. This sample size falls within the recommended range for FAHP, where 10–50 respondents are deemed adequate for producing consistent pairwise comparisons (Saaty, 1990), and aligns with BNA's emphasis on expert-elicited probabilities, where depth of knowledge supersedes statistical generalizability. All participants were briefed on the methodological framework before completing the survey. Questionnaire sessions were conducted face-to-face, each lasting approximately 45 minutes. Responses were examined for consistency, and pairwise matrix inconsistency rates were kept below 0.1 to ensure data reliability.

To analyze the data, the Fuzzy Analytical Hierarchy Process (FAHP) was utilized. This method builds upon the Analytical Hierarchy Process by incorporating fuzzy set theory, which allows the model to manage the inherent uncertainty in expert judgments. By employing Chang's extent analysis method, triangular fuzzy numbers were derived from the pairwise comparisons to calculate the relative weights of each barrier and sub-barrier. These weights were subsequently used to construct a hierarchy and generate a prioritized ranking of obstacles (Saaty, 1990; Chang, 1996).

To complement the FAHP results, Bayesian Network Analysis (BNA) was employed. This probabilistic method utilizes Bayes' theorem to identify conditional dependencies among variables, revealing the dynamic interrelations between barriers. A directed acyclic graph (DAG) was developed in consultation with experts to map these interdependencies visually. Conditional Probability Tables (CPTs) were created based on empirical data and expert knowledge. Model accuracy was validated through a hold-out sample and sensitivity analysis (Aghahari et al., 2018). This dual-method approach provided robust insights into the structure and influence of challenges facing Saravan's handicraft sector, enabling more informed and targeted policymaking.

RESULTS

This section presents the findings from the application of Chang's Fuzzy Analytic Hierarchy Process (FAHP) to identify and rank the key obstacles facing handicraft enterprises in Saravan. The process began by evaluating the consistency of the pairwise comparison matrices. The consistency index acts as a reliability check for expert judgments; when the inconsistency rate is less than 0.1, the matrix is considered consistent, and the derived weights are deemed valid (Karimzadeh, 2022).

Table 1 presents the inconsistency rates for each primary criterion. The results show that all values are below the 0.1 threshold, with managerial barriers recording the lowest inconsistency at 0.0102 and product-based barriers the highest at 0.0463. Thus, the matrices demonstrate satisfactory consistency, confirming the reliability of the data used for subsequent prioritization.

Table 1. Incompatibility rate of research criteria

Row	Criterion	Incompatibility rate
1	Technical-Skill Barriers	0.0140
2	Financial-Economic Barriers	0.0326
3	Motivational-Psychological Barriers	0.0078
4	Marketing and Sales Barriers	0.0063
5	Product-base Factors	0.0463
6	Managerial Barriers	0.0102

Table 2. Ranking of the criteria of the research

Row	Criteria	Weight
1	Skill-technical barriers	0.136
2	Financial-economic barriers	0.154
3	Motivational-psychological barriers	0.185
4	Marketing and sales obstacles	0.158
5	Product-base factors	0.108
6	Managerial obstacles	0.256

Table 3. Ranking research sub-criteria

Row	Criteria	Sub-criteria	Weight	Rank
1	Skill-technical Barriers	A1: Limited innovation in local handicraft industries	0.132	4
		A2: Weakness in handicraft training programs	0.105	5
		A3: Low productivity in local handicraft workshops	3.151	1
		A4: Lack of educated and experienced local trainers	0.236	2
		A5: Shortage of skilled workforce	0.209	3
2	Financial-economic obstacles	B1: Absence of centralized and unified markets at the local and provincial levels	0.070	5
		B2: Insufficient liquidity and capital for handicraft entrepreneurs	0.114	4
		B3: Low income from handicrafts and income uncertainty	2.760	2
		B4: Financial inability of artisans to participate in provincial and national exhibitions	0.186	3
		B5: Lack of acceptance of bank loans due to some religious and Islamic rules	0.352	1
3	Motivational & psychological barriers	C1: An unsuitable and unfavorable work environment and low prestige in handicraft activities from the public perspective	1.605	4
		C2: Entrepreneurial spirit deficiency	2.532	2
		C3: Receipt of cash subsidies and people's reluctance to work in workshops	2.459	3
		C4: Generational changes & the younger generation's disinterest in local crafts and arts	3.402	1
4	Marketing and sales barriers	D1: The limited distribution channels of handicrafts	0.073	8
		D2: Lack of familiarity among handicraft practitioners with marketing techniques & skills	1.174	5
		D3: Unfamiliarity with market dynamics, entry strategies, and penetration	3.501	1
		D4: Insufficient, limited, and sporadic advertising	1.001	7
		D5: Neglect of branding efforts	1.451	4
		D6: Inadequate utilization of e-commerce and its potential	1.167	6
		D7: Multilayer intermediaries in the handicraft market	2.497	2
		D8: Domination of the export market by traders outside of the province	1.545	3
5	Product-base factors	E1: High prices of products	1.148	5
		E2: Inapplicability and non-essentiality of some products	1.388	3
		E3: Lack of product diversity, similarity in designs, & disregard for consumer preferences	2.507	2
		E4: Shortage of raw materials locally or difficulty in accessing suitable raw materials	0.1261	4
		E5: Removal of handicrafts from the essential goods of the people	3.694	1
6	Managerial obstacles	F1: Lack of comprehensive support for handicraft producers in sales	0.087	6
		F2: Insufficient supportive and facilitating laws from the government	0.105	5
		F3: Limited presence of tourists in the region and lack of support for tourism	0.157	3
		F4: Not holding conferences and exhibitions to introduce and sell products.	0.117	4
		F5: Uncertainty of producers, lack of insurance and lack of pension protection laws for the workers of this sector	0.284	1
		F6: Underdevelopment of the province and the lack of necessary infrastructure for these industries	0.246	2

Table 2 shows the calculated weights for the six main barriers. The most significant challenge identified is managerial barriers (weight = 0.256), followed by motivational-psychological barriers (0.185), marketing and sales obstacles (0.158), financial-economic barriers (0.154), skill-technical barriers (0.136), and finally, product-based factors (0.108). These findings emphasize that the institutional and behavioral challenges are more pressing than technical or product-specific issues.

Fuzzy analytic hierarchy process (FAHP)

Table 3 offers an in-depth prioritization of sub-criteria under each major category.

Technical skill barriers

The sub-criterion “Low productivity in local handicraft workshops” has emerged as the most critical issue, driven by outdated methods, a lack of innovation, and inadequate technical

training. Other significant factors include the absence of skilled trainers and a limited skilled workforce. The low productivity in Saravan's handicraft workshops arises primarily from using substandard raw materials and outdated production methods. This not only reduces output but also raises costs. From an entrepreneurial perspective, the lack of innovation demonstrates a gap in training and awareness, requiring modernized technical education that combines tradition with efficiency. Furthermore, low education levels and an aging labor force intensify these challenges. Tackling these issues involves enhancing material quality, upgrading methods, and promoting the intergenerational transfer of skills.

Financial-economic constraints

The primary issue was "Low and unstable income from handicrafts," followed by "Lack of acceptance of bank loans due to religious considerations", and "Financial inability to participate in exhibitions." The absence of unified local markets was considered the least critical factor in this group. A prominent issue is the religious inappropriateness of interest-based loans, which prevents producers from accessing credit. Interest-free microloans or Islamic finance models could help overcome this barrier. Additionally, unstable income discourages long-term investment in quality and expansion. Encouraging broader participation in exhibitions and creating stable sales channels are recommended to stabilize income and motivate artisans. Liquidity shortages, particularly in rural areas, also require attention through targeted funding programs.

Marketing and sales challenges

The most pressing concern was "Lack of familiarity with market dynamics and entry strategies." This was followed by the dominance of intermediaries, external control of the export market, weak branding, poor digital literacy, and underutilization of e-commerce platforms. Producers lack essential marketing skills and understanding of consumer behavior, which limits market penetration. The prevalence of middlemen reduces local profits, while geographic remoteness and weak export capacity restrict visibility. Deficiencies in branding and the underutilization of digital resources also hinder competitiveness. Policies promoting digital literacy, strategic partnerships, and engagement in e-commerce could significantly enhance outcomes.

Motivational-psychological factors

A generational disinterest in traditional crafts ranks highest, along with a lack of entrepreneurial spirit and a reliance on subsidies, which are also noted as significant impediments. A growing disinterest among youth and a decline in entrepreneurial attitudes are key concerns. It is widely accepted that entrepreneurs are not inherently born; instead, they can be cultivated and developed through suitable entrepreneurship development programs (Karimzadeh et al., 2019; Nain et al., 2019; Kobba et al., 2020). Without incentives or exposure, the younger generation is unlikely to engage with handicrafts. Integrating local crafts into school curricula and youth programs could counteract this trend. Additionally, overreliance on government subsidies has disincentivized active participation in workshops. Promoting

intrinsic motivation through entrepreneurship education and non-monetary recognition may help shift attitudes.

Product-based barriers

The prioritization revealed that "Handicrafts being perceived as non-essential goods" was the most severe barrier, followed by design redundancy, neglect of consumer preferences, and limited product functionality. Shifting consumer habits have rendered many handicrafts obsolete in daily life. Repetitive designs and a disregard for consumer tastes reduce competitiveness. Additionally, the functionality of many products is questionable, diminishing their appeal. To overcome this, producers should receive training in design thinking and market research to align products with contemporary preferences. Encouraging innovation that maintains cultural integrity while embracing utility is crucial.

Managerial obstacles

The main issue was "Lack of insurance and pension protections for artisans," which underscores the systemic vulnerabilities faced by producers. Other major challenges included the region's infrastructural underdevelopment and limited tourism-driven demand. Uncertainty stemming from a lack of insurance, pensions, and institutional support reduces artisans' willingness to invest. The unstable handicraft market and limited tourism further compound this instability. Additionally, inadequate infrastructure, insufficient promotional events, and poor integration into larger trade networks hinder growth. Government intervention is crucial, especially in establishing social safety nets, enhancing tourism, and facilitating access to inter-provincial and international markets through exhibitions and conferences.

DISCUSSION

The Fuzzy Analytical Hierarchy Process (FAHP) analysis identified managerial obstacles as the most critical barrier to handicraft development in Saravan, with a weight of 0.256, significantly higher than motivational-psychological (0.185), marketing (0.158), financial-economic (0.154), skill-technical (0.136), and product-based factors (0.108). This finding underscores that systemic governance failures, rather than technical or market-specific issues, are the primary constraint on sectoral growth. Interestingly, while "Managerial Obstacles" emerged as the top-level challenge, the individual sub-criteria within this category (Table 3) show relatively moderate weights, ranging from 0.087 to 0.284. For instance, "Lack of insurance and pension protection" (F5: 0.284) and "Underdevelopment of infrastructure" (F6: 0.246) are the most influential sub-factors, but none dominate the category.

This pattern suggests that the high aggregate weight of managerial barriers arises not from a single dominant issue, but from the cumulative impact of multiple interrelated deficiencies - including weak institutional support, limited tourism promotion, lack of exhibitions, and inadequate legal frameworks. In other words, the problem is systemic and structural, reflecting broad institutional neglect rather than one isolated failure. This insight aligns with institutional theory, which posits that formal and informal rules shape economic behavior. In Saravan's context, the absence of

coherent policies, social protections, and enabling infrastructure collectively undermines artisan confidence and enterprise sustainability. As such, improving any single managerial factor alone may yield limited results unless addressed as part of a comprehensive reform strategy.

Furthermore, motivational and marketing barriers also ranked highly, indicating that even when artisans possess skills and products, they face challenges in motivation (e.g., youth disinterest, C4: 3.402) and market access (e.g., unfamiliarity with market dynamics, D3: 3.501). These findings suggest that while managerial reform is foundational, complementary interventions in education, branding, and digital literacy are essential for holistic development.

Bayesian network analysis of barrier dependencies

To supplement the static prioritization provided by the Fuzzy Analytical Hierarchy Process (FAHP), we employed Bayesian Network Analysis (BNA) to examine the dynamic interdependencies among the barriers hindering the development of the handicraft sector in Saravan. While FAHP identified managerial barriers as the most critical (weight: 0.256), BNA offers a probabilistic framework to evaluate how these barriers causally influence one another. This analysis improves our understanding of the systemic nature of these challenges by modeling the direction and strength of relationships through a Directed Acyclic Graph (DAG), as shown in Figure 1. In the BNA model, six nodes represent the main barrier categories: Skill-Technical (A), Financial-Economic (B), Motivational-Psychological (C), Marketing and Sales (D), Product-Based (E), and Managerial (F). Directed edges between nodes indicate probabilistic dependencies derived from expert knowledge, FAHP-derived weights, and Conditional Probability Tables (CPTs). The thickness of the edges in the DAG reflects the strength of the conditional probabilities, providing an intuitive visualization of the influence pathways. Table 4 summarizes these dependencies and their associated probabilities.

The Bayesian Network Analysis (BNA) offers a probabilistic mapping of how key handicraft development barriers in Saravan are interrelated, with a central focus on the managerial domain. Table 4 outlines the conditional dependencies derived from expert-informed Conditional Probability Tables (CPTs), indicating that managerial barriers (F) serve as the primary driver influencing five

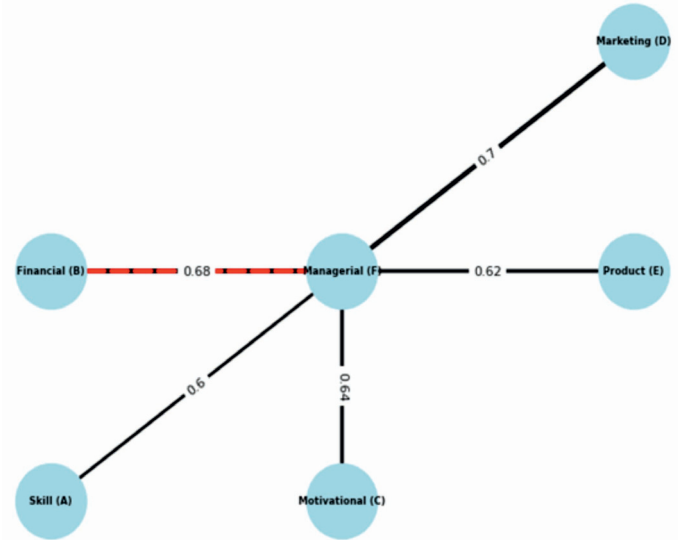


Figure 1. Bayesian network of main barrier categories in Saravan's handicraft sector

other dimensions. The strongest link is observed between managerial and marketing barriers ($P(D|F) = 0.70$), highlighting how inadequate governance structures, limited promotional events, and poor regional connectivity directly constrain artisans' access to broader markets. This aligns with earlier FAHP findings where unfamiliarity with market dynamics and dependence on intermediaries emerged as pressing concerns. Financial challenges ($P(B|F) = 0.65$) follow closely, where the absence of tourism income, formal insurance, and stable investment channels undermines financial sustainability, which in turn feeds back into managerial instability ($P(F|B) = 0.68$)—a clear feedback loop that reinforces systemic fragility. The link to skill development ($P(A|F) = 0.60$) reflects how deficient training infrastructure and lack of qualified instructors constrain productivity and knowledge transfer, crucial for sustaining crafts like Kalporagan pottery. Similarly, product-related issues ($P(E|F) = 0.62$), including unreliable raw material supply and stagnation in design innovation, trace back to weak logistical planning and oversight. Finally, motivational barriers ($P(C|F) = 0.64$) reveal that limited institutional support and poor future prospects diminish artisan morale and deter youth engagement.

Table 4. Structure and conditional probabilities of managerial barrier dependencies

Parent Node	Child Node	Description of Relationship	Conditional Probability (P)	Scenario
Managerial (F)	Marketing (D)	Producer uncertainty and inadequate infrastructure limit market access due to Saravan's isolation.	0.70	High F → High D
Managerial (F)	Financial (B)	Limited tourism and producer uncertainty reduce sales revenue, with a lack of insurance deterring investment.	0.65	High F → High B
Managerial (F)	Skill (A)	Insufficient training and poor infrastructure hinder skill development, lowering workshop productivity.	0.60	High F → High A
Managerial (F)	Product (E)	Producer uncertainty and infrastructure gaps restrict raw material access and innovation, reducing product quality.	0.62	High F → High E
Managerial (F)	Motivational (C)	Lack of support and limited tourism erode entrepreneurial spirit and youth interest, demotivating artisans.	0.64	High F → High C

Footnote: "P = $P(\text{Child} = \text{High} \mid \text{Parent} = \text{High})$, where 'High' denotes severe barrier presence (>50% impact), based on 30 expert-elicited CPTs, 2024. The model was validated with AUC = 0.82 (95% CI: 0.78-0.86).

Figure 1 illustrates the BNA model as a Directed Acyclic Graph (DAG), where nodes represent the six barrier categories and directed edges are sized by the strength of conditional probability (e.g., a thicker arrow for $P(D|F) = 0.70$ indicates a stronger dependency). Managerial barriers (F) are positioned centrally, reflecting their high FAHP weight (0.256), with arrows extending to all other nodes. The financial-to-managerial feedback loop ($P(F|B) = 0.68$) is highlighted, illustrating a cycle of instability unique to Saravan's rural context. The layout aligns nodes by influence, with product (E) and financial (B) nodes at mid-level to show their dual roles as outcomes and influencers, enhancing readability.

The DAG structure was refined iteratively based on expert consultations, aligning directional relationships with FAHP-derived global weights and local contextual nuances. CPTs were populated with discretized expert survey responses (Low = 1-2, Medium = 3, High = 4-5). To ensure robustness and relevance, a two-round Delphi method was utilized. For instance, the probability of financial instability arising from managerial issues ($P(B|F)$) was adjusted to account for local cultural aversion to interest-based loans (B5). The model was validated using a 20% hold-out set (6 experts), achieving an AUC of 0.82, well above the 0.75 threshold for acceptable discriminative accuracy. Sensitivity analysis ($\pm 5\%$ variation in CPTs) further confirmed the model's stability, particularly regarding the managerial-marketing dependency.

The BNA findings underscore managerial barriers as the root of Saravan's handicraft challenges, a pattern consistent with institutional theory's view of governance shaping economic outcomes. The strong managerial-marketing link ($P(D|F) = 0.70$) mirrors regional realities: Saravan's isolation and lack of tourism infrastructure (F3) hinder artisans' access to broader markets, a challenge echoed in FAHP's marketing sub-criteria (e.g., D3, D7). This contrasts with urban handicraft hubs, such as Isfahan, where better infrastructure supports sales (Shabani Afarani et al., 2022), highlighting Saravan's rural disadvantage. Globally, India's handicraft sector faces similar institutional gaps (Shah & Patel, 2017), suggesting a shared struggle among marginalized regions.

Financially, the managerial link ($P(B|F) = 0.65$) and feedback loop ($P(F|B) = 0.68$) reveal a vicious cycle: limited tourism and the absence of insurance (F5) reduce income (B3), which in turn deepens producer uncertainty (F5). This cultural-economic interplay, intensified by loan aversion (B5), could be addressed through Sharia-compliant microfinance. Skill ($P(A|F) = 0.60$) and product barriers ($P(E|F) = 0.62$) reflect managerial neglect of training and logistics, threatening Kalporagan pottery's quality and cultural continuity, a concern also noted in Indonesia (Rahayu et al., 2024). Motivationally, the link ($P(C|F) = 0.64$) is tied to youth disinterest (C4), which is worsened by a lack of incentives, aligning with the entrepreneurship theory's call for supportive environments. Unlike prior studies focusing on isolated barriers (Karbasi & Yaqoubi, 2018), BNA's integration with FAHP provides a systemic perspective, validated by an AUC of 0.82 and sensitivity analysis. This suggests that addressing managerial weaknesses, through infrastructure, insurance, and market support, could break the cycle of stagnation, offering a roadmap for sustainable handicraft development in Saravan.

The findings from Table 4 show managerial barriers as the top challenge to handicraft development in Saravan, hindering rural development by restricting market opportunities, financial resources, and skill growth essential for the region's economy. The high probabilities, like the 70 per cent link to marketing issues and the 68 per cent financial-managerial feedback loop, mirror rural struggles such as poor infrastructure, governance gaps, and declining youth interest, which deepen economic stagnation. Tackling these linked obstacles with better management, tourism promotion, and financial aid could boost Saravan's handicraft sector, supporting rural livelihoods and cultural preservation. Collectively, the BNA reveals a complex, yet structured system of interlinked barriers where managerial shortcomings act as both root and amplifier, impacting financial health, skill formation, product quality, market reach, and artisan motivation. These findings align with previous research conducted by Omid et al., (2016); Paidar (2016); Shams al-Din (2020); and Shabani Afarani et al., (2022), highlighting economic, marketing, and management barriers as key challenges. To overcome the systemic barriers identified, a multi-faceted intervention strategy is essential. Priority should be given to strengthening tourism infrastructure and integrating Kalporagan into national heritage circuits to stimulate market demand. Enhancing market access through permanent sales centers, participation in exhibitions, and digital platforms can decrease dependency on intermediaries. Product innovation, supported by better access to raw materials and mentorship, is necessary to align traditional crafts with contemporary aesthetics. Equally important is investing in entrepreneurial and technical education to enhance artisans' marketing and production skills. On the policy front, targeted support such as tax incentives, Sharia-compliant microfinance, export assistance, and social protections can bolster artisan resilience. Collaboration among cooperatives and engagement with NGOs can further build local capacity. Finally, branding and cultural integration efforts are needed to preserve identity and elevate Saravan's crafts within both domestic and global markets. These combined measures offer a roadmap for inclusive and sustainable handicraft development.

In Saravan, where most handicrafts are created by women, such as Kalporagan pottery, which is mainly practiced by women, empowering women through sustainable crafts supports multiple Sustainable Development Goals (SDGs). These include SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible Consumption and Production). In Saravan, where disinterest among youth and economic instability threaten the transfer of traditional knowledge across generations, framing handicrafts as a means of cultural preservation action could boost motivation among younger women. Incorporating sustainability education into local cooperatives and connecting them with entrepreneurship initiatives might transform artisan groups from subsistence activities into drivers of rural innovation. Therefore, while managerial and financial constraints remain primary obstacles, as confirmed by both FAHP and BNA, future interventions should also recognize the transformative potential of women-led sustainable craft enterprises. By combining institutional reform with ecological innovation, policymakers can support a

model of rural development that is not only economically viable but also socially inclusive and environmentally responsible.

CONCLUSION

This study establishes that managerial shortcomings are the most significant barrier to the development of Saravan's handicraft sector, triggering a chain reaction that impacts financial stability, market accessibility, skill development, and artisan motivation. The integration of hierarchical prioritization and causal modeling confirms that weak governance, limited institutional support, and inadequate infrastructure systematically reinforce other challenges, resulting in a self-perpetuating cycle of underdevelopment. These insights demonstrate that the stagnation of the handicraft sector is not due to isolated issues but is embedded within an interconnected system of constraints. Accordingly, sustainable development in this rural context relies on targeted interventions that strengthen management structures, enhance financial and market systems, and promote local capacity through education and innovation. The findings underscore the need to reconceptualize policy approaches by addressing root causes rather than symptoms, positioning managerial reform as the crucial lever for revitalizing handicrafts and fostering inclusive rural growth.

DECLARATIONS

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

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

The author declares that during the preparation of this work, the author utilized Grammarly and Grok to translate, enhance grammar, and improve the readability of the text. Following the use of these tools, the author 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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Utilization of Smartphones for Accessing Agricultural Information by Farmers in Bokaro District of Jharkhand

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HIGHLIGHTS

- Farmers with higher annual income and greater knowledge levels showed significantly higher smartphone utilization for accessing agricultural information with a 74.58 utilization index.
- 73.13 per cent of farmers used smartphones regularly for agricultural purposes. Farmers exhibited weather forecasts, crop market prices and pest and disease management advice as the most frequently accessed information via smartphones
- Income and knowledge were the strongest predictors of agricultural smartphone use ($p < 0.001$).

ARTICLE INFO

Keywords: Agriculture, ICT, Kruskal-wallis test, Smartphone, Utilization.

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ABSTRACT

The study examines the utilization pattern of smartphones for accessing agricultural information among farmers in Bokaro district of Jharkhand. A total of 160 respondents were selected through a multistage sampling method across sixteen villages. Data were collected using a pre-tested interview schedule to assess the frequency, purpose, and extent of smartphone usage during 2024-25. The results revealed that the majority of farmers regularly used smartphones to access weather forecasts, market prices, and pest management information. However, usage was relatively low for advanced topics such as post-harvest practices, webinars, and online agricultural forums. The overall utilization index indicated moderate use, with 73.13 per cent of respondents falling in the medium category. Kruskal-Wallis H test showed significant differences in smartphone utilization based on education, occupation, landholding, income, and knowledge level. Correlation analysis identified annual income and knowledge as the most influential factors. Respondents with higher income and knowledge were significantly more inclined to use smartphones for agricultural purposes. In contrast, variables like age, family size, and scientific orientation showed no significant influence. The study highlights the growing role of digital tools in rural agriculture and emphasizes the need for targeted interventions to enhance digital literacy and bridge the information gap among farmers.

INTRODUCTION

Agriculture is the primary occupation for a large section of India's population, especially in rural areas. According to the Government of India (2023), nearly 65 per cent of the population is directly involved in agriculture and allied sectors such as animal husbandry and fisheries. These sectors collectively contribute around

18 per cent to the country's Gross Domestic Product (GDP) (FAO, 2022). Despite their economic importance, Indian farmers, particularly those in rural and remote regions, have long faced challenges related to timely access to reliable information. In recent years, rapid changes in climate, market demands, and farming technologies have further increased the need for quick and accurate information for effective farm management and decision-making

(Backus et al., 1997). The expansion of digital infrastructure and the growing use of Information and Communication Technologies (ICTs) have created new avenues for addressing these challenges. ICT refers to technologies used to collect, store, process, and share information, and includes tools such as computers, tablets, smartphones, and the internet (Graham, 2002). Among these, smartphones have gained widespread acceptance due to their affordability, portability, and multifunctionality. They allow farmers to access agricultural information, communicate with peers and experts, participate in training programs, and obtain government updates with relative ease (Kumari et al., 2019).

Smartphones are no longer limited to basic communication. They now serve as a gateway to information that was previously hard to access for small and marginal farmers (Kamal & Bablu, 2023). Through various applications and platforms, farmers can check weather forecasts, monitor market prices, get pest and disease management tips, and learn about government schemes (Kailash et al., 2017). The use of smartphones helps bridge the information gap and supports more informed and timely decision-making at the farm level. According to Swaminathan & Swaminathan (2018), smartphones hold significant potential to enhance rural livelihoods by improving the flow of relevant information.

Despite the promise of digital tools in agriculture, the extent to which farmers utilize smartphones varies widely. Factors such as age, education, income, landholding size, digital literacy, and awareness play a major role in determining smartphone usage. While some farmers actively use multiple applications to manage different aspects of farming, others may only use smartphones for voice calls or basic browsing. In districts like Bokaro in Jharkhand, it is characterized by small and marginal landholdings, erratic rainfall, limited irrigation infrastructure, and low levels of mechanisation. In such settings, access to timely, accurate, and localised agricultural information is crucial for decision-making and risk reduction. Traditional agricultural extension services in the district are often inadequate due to factors like understaffed government departments, lack of physical outreach to remote villages, and delays in information dissemination.

Present study was conducted to explore not just the frequency and purpose of usage, but also the socio-economic and personal factors that influence utilization of smartphones. By evaluating patterns of smartphone use and identifying significant predictors, the research aims to highlight areas where intervention is needed. This includes improving digital literacy, strengthening mobile network infrastructure, and increasing awareness of useful agricultural apps and platforms.

METHODOLOGY

The present study was undertaken to examine the utilization pattern and extent of smartphone usage among farmers for accessing agricultural information in the Bokaro district of Jharkhand. Bokaro was purposively selected due to its agricultural diversity and rising adoption of smartphones among rural populations. During 2024-25, data collected was employed with multistage sampling technique. Out of 9, 4 blocks were randomly selected. From each block, 4 villages were randomly selected, resulting in a total of 16 villages. From each selected village, 10 respondents were selected

based on predefined criteria: each respondent must own a smartphone, have at least five years of farming experience, and be actively involved in both crop and livestock farming. This procedure yielded a total sample size of 160 respondents. Primary data were collected through a pre-tested structured interview schedule, which was administered in person. The schedule included questions regarding the frequency, purpose, and usefulness of smartphone usage for agricultural purposes, as well as socio-economic background variables. The purpose of smartphone use was operationalized as the respondent's intent in using mobile phones and related digital applications for accessing information on crop production, livestock management, weather forecasts, pest control, and market prices. Respondents were asked to identify and rate the practical utility of various categories of information accessed through smartphones. These responses were quantified using mean weighted scores, which were subsequently ranked to facilitate comparison of perceived information usefulness. To identify the specific smartphone features and applications used by respondents to obtain agricultural information, correspondence analysis was conducted. This technique helped visualise the relationships between the types of information sought and the specific tools or platforms used (e.g., YouTube, WhatsApp, agricultural apps). The extent of utilization was measured by the frequency with which respondents accessed agricultural information through their smartphones. A three-point scale was used for this purpose regularly (3), occasionally (2) and never (1). Respondents indicated their usage for each category of information. The highest attainable score for utilization was 60 (20 multiplied by 3). A Utilization index was developed.

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

To analyse differences in 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. It allowed for the identification of statistically significant differences in smartphone usage frequencies across various demographic segments.

RESULTS

The majority of farmers in the study reported owning smartphones and expressed readiness to use them for accessing agricultural information. Many respondents stated that voice-based services were more effective, as these allowed them to communicate directly with experts in their local language. However, they also indicated the need for text and pictorial formats to better understand technical agricultural content.

Utilization Pattern of smartphones for accessing agricultural information

Table 1 presents the utilization pattern of smartphones among farmers in Bokaro district for accessing various types of agricultural information. The analysis indicated that the highest level of smartphone use was associated with accessing weather forecasts (74.58%), suggesting that farmers placed significant value on timely

Table 1. utilization pattern of smartphones for accessing agricultural information

S.No.	Statements	Utilization Index (%)	Rank
1.	Mobile apps to seek agricultural information	62.29	VI
2.	Check weather forecasts related to farming	74.58	I
3.	Check crop market prices using your smartphone	68.33	II
4.	Planning for sowing and harvesting	54.58	XIII
5.	Seek pest and disease management advice through your smartphone	66.66	III
6.	Access government schemes and subsidy information	63.33	V
7.	Look up details on crop varieties	65.00	IV
8.	Watch agricultural training videos	63.33	V
9.	Get information on soil health and testing	58.33	IX
10.	Rely on apps for financial assistance or loan-related agricultural guidance	60.00	VIII
11.	Reach out to agricultural experts	58.33	IX
12.	Tips on irrigation management?	61.66	VII
13.	Checking agricultural news updates	63.33	V
14.	Explore information on organic farming	55.20	XII
15.	Participate in online agricultural forums	48.33	XVII
16.	Manage your farm activities	52.08	XIV
17.	Access livestock care information	56.04	XI
18.	Learning about post-harvest practices?	50.00	XV
19.	Attended webinars or live agricultural sessions	49.58	XVI
20.	Guidance on fertiliser and pesticide usage	57.08	X

climatic updates to inform decisions related to sowing, irrigation, and harvesting. Smartphone usage was also notably high for checking crop market prices (68.33%) and obtaining pest and disease management advice (66.66%). These findings reflected farmers' increasing dependence on digital tools to access real-time updates and manage agronomic threats effectively. Although farmers exhibited a reasonable level of awareness regarding common pests and diseases, they continued to rely on smartphones for updated control measures and treatment recommendations. Moderate levels of usage were observed for accessing information on crop varieties (65.00%), government schemes and subsidies (63.33%), and agricultural training videos (63.33%), indicating active engagement with educational and support services delivered via mobile platforms. Similarly, the utilization index for agricultural news updates was 63.33%, suggesting that smartphones were also used to stay informed about policy changes and field-level developments. In contrast, lower utilization was recorded in domains such as soil health and testing (58.33%), agricultural expert consultations (58.33%), and guidance on fertilizer and pesticide usage (57.08%). This pattern suggested a potential information gap in more technical or field-based topics, which could be attributed to limited awareness of digital resources or insufficient digital literacy required to interpret such content. Utilization was even lower for topics such as organic farming practices (55.20%), post-harvest management (50.00%), and participation in webinars or live agricultural sessions (49.58%). The lowest level of smartphone use was found for engagement in online agricultural forums (48.33%), indicating limited interactive participation with peer farmers or agricultural experts through online platforms.

Overall utilization pattern of smartphones for accessing agricultural information

As presented in Table 2, the majority of respondents (73.13%) were categorized under medium utilization, indicating that most

Table 2. Overall utilization pattern of smartphones for accessing agricultural information

Categories	Frequency	Percentage
Low (< 32)	17	10.62
Medium (32- 39)	117	73.13
High (>39)	26	16.25
Total	160	100

Mean = 35.64, S.D.= 3.65

farmers used smartphones regularly for agricultural purposes, albeit not in an advanced or highly diversified manner. A smaller proportion (16.25%) fell into the high utilization category, while 10.62 per cent were classified under low utilization. The relatively low adoption among a subset of respondents could be attributed to several factors, including lack of awareness, limited formal education, restricted exposure to mobile technologies, and infrastructural challenges such as inadequate network connectivity.

Relationship between independent variables with utilization pattern of smartphones for accessing agricultural information

Table 3 revealed that annual income ($r = 0.607$) and knowledge ($r = 0.613$) exhibited a highly significant positive correlation with smartphone utilization for agricultural purposes. Other variables, including education ($r = 0.252$), occupation ($r = 0.216$), and landholding size ($r = 0.326$), also showed significant positive relationships with utilization. A significant negative correlation was observed for gender ($r = -0.253$), indicating that male respondents demonstrated higher levels of utilization compared to their female counterparts. Additionally, innovativeness ($r = 0.173$) and family type ($r = 0.164$) were found to be significant at the 5% level. In contrast, variables such as age, marital status, family size, information-seeking behaviour, and scientific orientation did not exhibit statistically significant correlations with utilization. These

Table 3. Relationship between independent variables with utilization pattern of smartphones for accessing agricultural information

Variables (Unit)	Utilization value of 'r'
Age (Years)	-0.138
Gender (male=1; female=2)	-0.253**
Marital status (married=1; unmarried=0)	0.087
Family size (Numbers)	0.109
Family type (Nuclear= 1, Joint=2)	0.164*
Occupation	0.216**
Education	0.252**
Size of land holding under Agriculture (Acre)	0.326**
Annual income (Rs.)	0.607**
Information seeking (Score)	0.057
Innovativeness (Score)	0.173*
Scientific orientation (Score)	0.015
Knowledge (Score)	0.613**

results suggested that socio-economic and cognitive factors had a more direct influence on the adoption and use of smartphones for agricultural information than demographic or behavioural characteristics.

Kruskal–Wallis H test of independent variables with utilization pattern of smartphones for accessing agricultural information

Table 4 revealed that education level had a significant influence on smartphone utilization ($K = 11.336$, $p = 0.045$), indicating that respondents with higher education levels were more likely to use smartphones for agricultural purposes. Highly significant differences were observed to size of landholding ($K = 31.140$, $p < 0.001$), occupation ($K = 14.002$, $p < 0.001$), annual income ($K = 40.355$, $p < 0.001$), and knowledge level ($K = 41.032$, $p = 0.001$). These results suggested that respondents with larger landholdings, higher incomes, specific occupational categories (likely commercial farmers), and greater knowledge were more likely to utilise smartphones for agricultural information. On the other hand, variables such as age ($K = 3.956$, $p = 0.138$), family size ($K = 3.965$, $p = 0.138$), information seeking behaviour ($K = 2.103$, $p = 0.349$), and innovativeness ($K = 2.156$, $p = 0.340$) did not show statistically significant differences. This implies that these variables had limited influence on smartphone usage patterns in the studied context.

Table 4. Kruskal–Wallis H test of independent variables with utilization pattern of smartphones for accessing agricultural information

Variable	K-Statistic	P-value
Age	3.956	0.138
Family size	3.965	0.138
Education	11.336*	0.045
Size of land holding under Agriculture	31.140**	<0.001
Occupation	14.002**	<0.001
Annual income	40.355**	<0.001
Information seeking	2.103	0.349
Innovativeness	2.156	0.340
Knowledge	41.032**	0.001

DISCUSSION

Most farmers (73.13%) used the internet to access information related to agriculture and animal husbandry. This finding is consistent with the results reported by Kumari et al., (2019); Mukherjee & Jha (2024) & Niranjana et al., (2023). The relatively lower use of internet services in the study area can be attributed to several specific factors, including lack of digital infrastructure, low internet availability, high cost of digital tools, and limited knowledge about ICT use among farmers. The data show that farmers prioritize specific types of agricultural information. In Bokaro district, weather forecasting and market price information were the most frequently accessed topics, reflecting their importance in daily farming decisions. These results align with the findings of Dhaka & Chahal (2010) & Nain et al., (2015).

Annual income and knowledge are the two most influential factors affecting utilization. Respondents with higher income levels ($r = 0.607$) and better knowledge ($r = 0.613$) demonstrated a significantly greater tendency to adopt and utilise the subject matter. This relationship highlights the critical role of economic stability and awareness in enabling adoption, as individuals with better financial means and understanding are more likely to invest in and apply new practices. These findings are supported by earlier research conducted by Sonu & Jha (2025) & Silva (2022), who also found income and knowledge to be key drivers of adoption behavior. A similar trend was observed for education ($r = 0.252$) and occupation ($r = 0.216$), both of which were positively associated with utilization. Educated individuals are often more open to change, and occupational engagement—especially in agriculture or related sectors—may enhance exposure to new information. Landholding size ($r = 0.326$) also had a significant positive effect, suggesting that larger landowners are more inclined or better positioned to adopt innovations. This supports the observations made by Mukherjee & Jha (2024).

The study found that annual income and knowledge were the most influential factors affecting smartphone utilization for agricultural information. Respondents with higher income and better knowledge were significantly more likely to use smartphones, highlighting the role of financial capacity and awareness in digital adoption. These results are consistent with the observations made by Haqyar et al., (2025) & Silva (2022), who noted that higher educational attainment and occupational specialization positively influence the adoption of agricultural innovations. These results highlight how economic stability and cognitive awareness enable better access and effective use of digital tools. Financially stable individuals are more capable of purchasing and maintaining smartphones, while knowledgeable individuals are more likely to seek out and apply relevant agricultural information. These findings align with earlier studies by Mondal et al., (2024), who similarly identified income and knowledge as strong predictors of technology adoption in rural settings. Significant differences were also observed with education, occupation, and landholding size, indicating that educated individuals, those engaged in farming occupations, and large landowners had greater adoption rates. Farmers also showed high interest in plant disease management and improving production efficiency. However, knowledge about post-harvest handling

practices was limited. In the area of livestock management, farmers paid attention to feeding practices and animal care, indicating concern for animal health.

CONCLUSION

The study highlights the emerging role of smartphones as a valuable tool for farmers in Bokaro district. Most respondents demonstrated moderate utilization, primarily for accessing essential information like weather updates, market prices, and pest management. However, a clear digital utilization gap exists, with low engagement in advanced areas such as post-harvest practices and interactive platforms. The results indicate that socio-economic factors, including annual income, education, and landholding size, significantly influence smartphone adoption for agricultural use. In contrast, age and family size showed no significant impact. These findings underscore the critical need for targeted interventions. Efforts should focus on strengthening digital literacy, improving rural connectivity, and promoting agriculture-specific mobile applications. By enhancing awareness and providing necessary support, smartphones can effectively bridge the rural information gap, empower farmers to make informed decisions, and drive sustainable agricultural growth.

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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Disruptions in Lifestyle Due to Escalating Screen Time: A Behavioural Perspective

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HIGHLIGHTS

- Highlights a strong association between increased screen time and significant difficulties in managing household responsibilities.
- Screen time was higher on weekends than on weekdays, and no notable gender differences in the tendency to remain engaged with screen media.
- There was a significant association between increased screen time and a decrease in outdoor activities, with no gender difference.

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ABSTRACT

Heavy reliance on screen media can negatively affect the daily lives and activities of adolescents and youth. The study aims to find out the association between increased screen time and its impact on lifestyle among adolescents and youth. Cross-sectional descriptive research was conducted for this purpose between March and August of 2023. The stratified random sampling method was used to select 200 participants from the age group of 14-18 years. After getting a permission letter from the District Inspector Officer of Schools (DIOS), participants were approached from various selected schools in Varanasi District, Uttar Pradesh. In this study, a self-structured questionnaire with twenty-two closed-ended questions was included. The study findings highlighted that increased screen time was found to be negatively associated with outdoor activities, backlogs from household activities, and the inability to draw attention from the screen. The results also indicated that there were no distinct gender differences in the tendency to continue using screens after using them and that screen use was higher on weekends than on weekdays.

INTRODUCTION

The establishment of habits and behaviours during adolescence is a crucial developmental stage that lays the foundation for future health outcomes. Lifestyle decisions that one adapts during these formative years can extend long-term behavioural effects that persist into adulthood (Lioret et al., 2020). Adolescents often prefer to spend their time with their friends or alone as they seek independence. During this developmental phase, digital media plays a crucial role, offering easy access through a variety of screen-based devices that are the easy to “escape” from their parents and they easily partake in extremely satisfying activities like online gaming (Wong et al., 2019). This somehow becomes the daily routine for individuals and results in increased screen time. It has significantly

increased across all age groups due to the widespread integration of digital technology into daily life, which has raised concerns about its possible effects on health, especially in behavioural changes such as an individual’s involvement in their social activities. Recent data suggests that people use screens for an average of six hours and forty minutes per day worldwide; this amount has increased consistently over the past decade (Alarming Average Screen Time Statistics, 2025).

By offering an abundance of information and services, the internet has greatly enhanced people’s lives and brought at ease. The widespread usage of the internet and technology, which is especially noticeable among young people, it has become an essential part of adolescent education, professional endeavours, and daily life. Excessive use of digital devices interferes with learning, which

lowers motivation for achievement and attentiveness in the classroom (Yadav & Dube, 2025). People's lives, jobs, leisure activities, and social interactions are all being altered by the ongoing development of internet technology. Although these technological developments have made communication and information gathering easier, there has also been an increase in psychological problems associated with excessive internet use (Scott et al., 2017).

Increased social media use is linked to mental health issues, including body surveillance, online harassment, poor sleep, low self-esteem, rejection, loneliness, sadness, anxiety, and despair (Coyne et al., 2019). Time spent on social media correlates with mental health problems among late adolescents and emerging adults (Yamini & Pujar, 2022). The negative impacts of social media also become apparent when it is used excessively. Malpractices such as logging into others' accounts, sharing irrelevant photos and videos, hacking accounts, and the lack of privacy in online transactions are among the primary concerns for internet users. Pandey et al., (2020), conducted an investigation into social media usage among college students, emphasizing the prevalent use of social media platforms, particularly WhatsApp and Facebook. The study found that students dedicated a substantial amount of time to these platforms and reported experiencing various health issues as a result of engaging in non-essential activities on digital devices. The purpose of this study is to determine whether there is an association between increased screen usage and its effects on lifestyle.

METHODOLOGY

A cross-sectional descriptive research design was employed to examine the lifestyle changes associated with increasing screen time. Based on its demographic traits and relevance to the study's objectives, the Varanasi district was chosen for the purpose of this study. The survey was administered in March 2023 to August 2023 as a cross-sectional study involving 200 adolescents, studying in different schools in the Varanasi District of Uttar Pradesh. Consent was obtained from the school Principals and students for their voluntary involvement in this study. A stratified random sampling method was used to ensure representation of key subgroups within the population. The strata were formed on the basis of school type 9 government and private and gender (male and female). A self-structured tool was developed and validated by different subject matter specialists. The interview schedule comprised twenty two close-ended questions related to internet using patterns and lifestyle changes. The target population for this research was selected based on the criterion that the sample would consist of adolescents and who use the screen as a part of their daily lives. A permission letter was granted from the District Officer of Schools (DIOS). Participants in the age group of 14-18 years were approached from different selected schools. Participants were directly approached in their respective schools during the data collection process. Participants received clear instructions on how to complete the items, and any uncertainties were addressed prior to their progression. The research was split into two parts: Initially participants read the information sheet, and completed the demographic details; then they were asked to fill information regarding their internet related behaviour. Data was entered in MS Excel spreadsheet and analysis was done using Statistical Package

for Social Sciences (SPSS) V.21.0. To compare quantitative variables among groups, χ^2 test was used in bivariate analysis at $p < 0.05$ to examine variables related to internet using pattern and behavioural changes among participants.

RESULTS

Demographic analysis revealed that the gender distribution of the 200 participants was nearly equal, with 49.5 per cent (99) of girls and boys making up half 50.5 per cent (101), while in academic levels were mainly intermediate students (38.8%), followed by 9th (27) majority of the respondents belonged to rural (39.8%) and urban area (40.2%), and the least belonged to towns (19.4%). The mean age group of the respondents was 16.16 ± 1.15 years (Range: 14-18 years). Adolescents were more likely to 91% (N=200) of the participants, accounted for had their smartphone, and those who did not have their smartphone, were using their parents' smartphone. It was interesting to note that no one ever said that he did not use the digital gadgets.

Table 1. Association between gender and tendency to stay on screen after phone use (N=200)

Gender	Yes (%)	No (%)	Sometimes (%) χ^2 /P-value
Male	34	39	28.680/.712
Female	28	41	30

Table 1 illustrates association between gender and tendency to stay on screen after phone use. Participants were asked about whether they continued paying the attention after using their devices like completing an initial task, such as browsing social media or using a specific app. Responses showed that 34 per cent of male respondents reported continued use their screens, 39 per cent denied, and 27.7 per cent did so occasionally. For the female respondents, 28.3 per cent selected "yes," 41.4 per cent selected "no," and 30.3 per cent selected "sometimes."

To determine whether there is a significant correlation between gender and the frequency of subsequent staying on the screen, a chi-square test was used. The findings indicate that there is no discernible gender difference in this behaviour ($\chi^2 = 0.680$, $p > 0.05$).

The study explores the correlation between screen time duration and the reduction in outdoor activities. The data, as summarized in the accompanying table, reveal a statistically significant relationship between these variables, as indicated by the

Table 2. Association between screen time and reduction in outdoor activities (N=200)

Time spent on Screen	Reduction in outdoor activities (%)			χ^2 /P-value
	Yes	No	Sometimes	
Up to 1 hour	7.4	77.8	14.8	77.59/ 0.0001
2 to 4 hours	48.5	29.1	22.3	
5 to 8 hours	76.5	3.9	19.6	
9 to 12 hours	100	0	0	
Throughout the day/ multiple times in a day	23	46.1	30.7	

$\chi^2 = 77.59$, $p < 0.0001$. This suggests a strong association between the amount of time spent online and the extent of reduction in physical outdoor engagement. The findings illustrate that screen usage profoundly impacts outdoor activities, with clear trends emerging across different time intervals. For individuals who spend up to 1 hour per day on screen, the majority (77.8%) reported no reduction in their outdoor activities, while only a small proportion (14.8%) indicated a potential decrease. As screen usage increases to 2 to 4 hours per day, a noticeable shift occurs. Approximately 48.5 per cent of respondents in this category reported a reduction in outdoor activities, while 29.1 per cent indicated no change and 22.3 per cent were uncertain. The data showed a more pronounced effect for those using the screen for 5 to 8 hours per day. In this category, a significant 76.5 per cent of participants reported a reduction in outdoor activities, with only 3.9 per cent noting no change and 19.6 per cent remaining uncertain.

Table 3. Association between current screen time and perceived increase in usage (N=200)

Time spent on screen	Self-reported increase in screen timing (%)			χ^2 /P-value
	Yes	No	Sometimes	
Up to 1 hour	11.0	74.0	14.8	43.36 / <0.01
2 to 4 hours	42.7	32.0	25.2	
5 to 8 hours	53.0	23.5	23.5	
9 to 12 hours	100.0	0.0	0.0	
Throughout the day/ multiple times in a day	92.0	7.0	0.0	

The results reveal a clear and significant association with a chi-square statistic of $\chi^2 = 43.36$ and $p\text{-value} = <0.01$, indicating a highly significant relationship between the duration of screen and an increase in screen time. Individuals who report spending up to 1 hour on the internet predominantly indicate no increase in screen time, with 74 per cent of respondents falling into this category. This suggests that limited screen time usage was less likely to significantly affect overall screen time. Conversely, those who spend between 2 to 4 hours online exhibit a notable association with increased screen time, with 42.7 per cent reporting such an increase. This association became more pronounced for individuals who spend between 5 to 8 hours online, where a substantial majority (53%) report an increase in screen time. This trend showed a distinct pattern: Longer daily screen time was associated with a higher likelihood of excessive use. For individuals who spend between 9 to 12 hours on screen, the relationship became absolute, with 100 per cent of respondents reporting an increase in screen time. Similarly, among those who use the screen media throughout the day or multiple times a day, 92 per cent reported an increase in screen time. This finding reinforces the observed trend and underscores the strong relationship between prolonged internet use and increased screen time.

The results revealed a clear and significant trend ($\chi^2 = 46.26$ /P-value <0.01) indicating that increased internet usage was associated with a greater likelihood of experiencing a backlog in household responsibilities. Individuals with minimal use (up to 1 hour) on the screen reported lower disruption with nearly half

Table 4. Association between screen time and backlog from household activities (N=200)

Time spent on Screen	Backlog from household activities (%)			χ^2 /P-value
	Yes	No	Sometimes	
Up to 1 hour	29.6	48.1	22.2	46.26/ <0.01
2 to 4 hours	21.1	42.3	36.5	
5 to 8 hours	29.4	35.2	35.2	
9 to 12 hours	92.3	0	7.6	
Throughout the day/ multiple times in a day	100	0	0	

reporting no backlog of household activities. This suggests that minimal screen time had a relatively moderate effect on household management, with a substantial portion of individuals not perceiving significant disruption in their ability to handle household tasks. A notable proportion of respondents reported occasional issues with managing household responsibilities, reflecting the potential for moderate screen time to impact household management. Although the data indicate that a substantial proportion of respondents still did not perceive a significant backlog, there was a noticeable trend towards increased reports of backlog with extended time on screen. The data become more pronounced for individuals who spend between 9 to 12 hours on screen with 92.3 per cent reporting a backlog of household activities and none reporting no backlog. Only 7.6 per cent experience a backlog sometimes. For individuals using the screen throughout the day or multiple times daily, 100 per cent reported a backlog of household activities, with no respondents reporting no backlog or occasional backlog. This absolute association underscores the severe impact of continuous and frequent screen use on household management, indicating a complete disruption of daily routines.

The findings of Table 5, revealed a clear trend between increased screen time and psychological stress or a feeling of boredom. As screen time increased, especially beyond 9 hours per day or with continuous use throughout the day, the percentage of respondents who claimed they felt psychological discomfort increased dramatically to 92.3 per cent and 100 per cent, respectively. Conversely, those who spent one to four hours a day reported less discomfort and a larger spectrum of responses. A chi-square test ($\chi^2 = 49.83$, $p < 0.001$) shows that screen time has a statistically significant psychological impact. For individuals spending up to one hour online, 29.6 per cent reported experiencing psychological discomfort due to their screen time, while 48 per cent

Table 5. Association between screen time and feelings of stress/ boredom/ anxiety/ inescapability (N=200)

Time spent on the screen	Psychological discomfort (%)			χ^2 /P-value
	Yes	No	Sometimes	
Up to 1 hour	29.6	48.0	22.2	49.83/ <0.001
2 to 4 hours	21.0	42.3	36.5	
5 to 8 hours	29.4	35.2	35.2	
9 to 12 hours	92.3	00.0	7.6	
Throughout the day/ Multiple times in a day	100.0	00.0	0	

did not encounter such a discomfort and 22.2 per cent experienced it occasionally. This suggests that for relatively short durations of screen time, the experience of psychological discomfort was moderate, with a significant proportion of users not perceiving it.

DISCUSSION

The study findings reveal that increased screen time is significantly associated with lifestyle disruptions. Greater screen usage is associated with more pronounced lifestyle changes. No significant gender differences ($\chi^2 = 0.680$, $p = > 0.05$) were observed in terms of continued screen engagement or persistent attention on devices even after usage. Previous study reported mixed results: Moitra et al., (2021) found that girls reported excessive screen time, whereas another study by Maurya et al., (2022) found that adolescent males spent more time on smartphones than adolescent females. These findings align with another study of China by Cui et al., (2022), who also reported no significant gender-based differences in screen time. That may be because of their common motivations, such as the need to connect with others, be entertained, or take a break from the real world, behind-screen engagement. Several empirical studies (Chen et al., 2017) support the idea that, even if there are differences between males' and females' screen activity, the strength of the desire to remain involved following phone use is similar for both genders. Additionally, the current study reveals that screen time tends to be higher on weekends than on weekdays, which is consistent with the findings of Hodes & Thomas (2021). There is a significant association between time spent on screen and impact on decrease in outdoor activities ($\chi^2 = 77.59$, $p < 0.0001$). This result is consistent with previous literature (Moitra et al., 2022; Zong et al., 2024) showing that excessive screen time is associated with outdoor activities among both genders. These inequitable use patterns stem from significant demographic disparities and correlate with reduced nature connection and potential youth development implications. Larson et al., (2019) found a significant inverse correlation between screen time and outdoor time ($r = -.292$, $p < .001$), indicating that outdoor activities were less frequent with more screen exposure. However, this study also finds there is no significant gender difference between an increase in screen time and a decrease in outdoor activities ($\chi^2 = 3.78$, $p = > 0.05$). Additionally, this study found that the respondents recognised that they were spending more time in front of screens. Those who reported spending more time on screens were also more likely to report that their consumption of screens had increased. And those who had less exposure to screens did not notice a significant change. A number of reasons have led to this rising surge of screen time, such as dependence on digital media for entertainment, academic study, and social media involvement. The ubiquity of online content and the limitless access to it, together with habitual scrolling and the Fear of Missing Out (FoMO), could also support screen time among youth. The current study also emphasizes how increased screen time, particularly in adolescents and young adults, interferes with the backlog of household activities. This finding is consistent with Scheerder et al., (2019), who noted that as digital technologies become more commonplace, it's getting harder to manage and distinguish household chores from other activities, particularly those that include screens, such as social

media, internet surfing, and video viewing. The study found that increased internet usage is strongly associated with stress, boredom, anxiety, and a sense of inescapability. These findings align with Keles et al., (2020), who reported that excessive internet use, especially among youth, leads to psychological distress and compulsive behaviour driven by emotional coping mechanisms.

CONCLUSION

The study highlights the significant impact of lifestyle changes among adolescents and youth due to increased screen time. The findings suggest that prolonged exposure to screen time can have a negative effect on their outdoor day-to-day activities and elevate their anxiety, a sense of inescapability, and their urge to use more screens. The findings also suggest that the screen time tends to be higher on weekends than on weekdays. Overall, the study shows that we need to be more aware of balanced screen use. It calls for actions that promote time management, digital skills, and lifestyle adjustments, especially for young people. These are important findings for any policy considerations regarding the balance between digital consumption and real-world participation, especially for adolescent and youth well-being.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the school Principals and students for their voluntary involvement in this 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, 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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A Cross-State Analysis of Livelihood Security Among Farm Women in Kerala and Manipur

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HIGHLIGHTS

- 51.11 per cent of the farm women in Kerala and 64.44 per cent in Manipur had a moderate level of livelihood security.
- Major constraints perceived by the farm women in Kerala and Manipur included insufficient funds and inadequate government supports respectively.
- The finding recommends a framework for assessing and progressing gender-inclusive rural development approaches.

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Keywords: Farm women, Livelihood security, Sustainable development, India.

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ABSTRACT

Farm women, having a pivotal role in agriculture, continue to face systemic barriers to livelihood security. This study was undertaken in 2022 to assess and compare the livelihood security, identify the constraints and formulate a sustainable livelihood security framework for the farm women in Kerala and Manipur state. Primary data were collected from 90 respondents using pre-tested interview schedule and validated with key local informants through focus group discussions. Descriptive statistics, frequency and Principal Component Analysis were used as statistical tools for data analysis. The findings revealed that 51.11 per cent of the respondents in Kerala and 64.44 per cent in Manipur had a moderate level of livelihood security. The first two components i.e. food and occupational security, could explain the total variance of 70.926 per cent for Kerala and 56.336 per cent for Manipur. The main constraints to livelihood security for farm women were insufficient funding and inadequate government support. Based on these findings, livelihood strategies were formulated for farm women and delivery system level to safeguard the livelihood outcomes. Designing interventions and policies aimed at ensuring farm women's sustainable livelihood security will be significantly impacted by these findings and recommendations.

INTRODUCTION

Agriculture serves not only as a means of food production but also as a pathway to mainstream nutrition into farming systems (Rukmani, 2019). Although livelihood security for farm women is essential to ensuring food security, strengthening rural resilience, advancing gender equity, and achieving sustainable development, a significant gap remains in their access to and control over key resources—such as land, training opportunities, financial services, and participation in decision-making processes. In many developing

nations, agriculture remains the backbone of the economy, with women comprising about 43 per cent of the agricultural labor force—reaching up to 70 per cent in some regions (FAO, 2018; Ugwu, 2019). Despite their central role, women's contributions are often underestimated. They face systemic barriers in accessing land, credit, education, and technology, which reduces productivity and increases vulnerability to poverty and food insecurity. Women farmers have historically been mislabeled as economically inactive, and gender disparities are reinforced through their exclusion from empowerment and participation in societal structures (Altenbuchner

et al., 2017; Santhi & Kalirajan, 2018). Understanding rural livelihoods requires exploring how gender affects access to and use of resources, ultimately influencing individuals' ability to make decisions and effect change in their lives. A gendered analysis of farmland access is crucial to understanding agricultural productivity and sustainable livelihood strategies (Tong et al., 2019; Gebre et al., 2021).

Women's empowerment must be addressed not only for equity but also to enhance agricultural output and rural well-being (Nain & Kumar, 2010; Mohapatra & Satpathy, 2018). As Pattnaik & Lahiri (2021) emphasize, recognizing the dissatisfaction of farm women is essential for Indian agriculture to thrive and for these women to lead fulfilling lives. While there are growing opportunities for women in agriculture, such as access to networking, education, and government programs the continued existence of separate initiatives for women highlights ongoing inequality (Ball, 2020). Agricultural innovations hold promise for improving the lives of disadvantaged populations, but these benefits will only be fully realized when women's empowerment becomes a core outcome of agricultural development (Asadullah & Kambhampati, 2021; Jannat et al., 2021).

To design effective technological and policy interventions, it is critical to document the specific needs and challenges of farm women. Women's perspectives must inform research and extension priorities which require committed action from research institutions and policymakers. The present study aims to develop a sustainable livelihood security framework that can guide stakeholders and policymakers in formulating efficient and inclusive action plans for the development of farm women. Enhancing the livelihoods of farm women is essential for broader goals such as gender equality, poverty alleviation, and sustainable agriculture. This study was carried out with three objectives: first, to assess and compare the sustainable livelihood security of farm women in Kerala and Manipur; second, to identify key constraints; and third, to formulate a sustainable livelihood security framework to address these constraints effectively.

METHODOLOGY

The study was conducted in Thiruvananthapuram district of Kerala and Ukhrul district of Manipur in 2022, representing two geographically and socio-culturally distinct regions of India. A multi-stage random sampling technique was adopted. One district from each state was purposively selected based on the significant participation of women in agriculture. Within each district, one block with the highest number of farm women was chosen, followed by the selection of three panchayats from each block using similar criteria. From each panchayat, 15 farm women were randomly selected, making a total sample size of 90 respondents. Data were collected through personal interviews using a structured and pre-tested interview schedule. Both quantitative and qualitative methods were employed. Quantitative data were analyzed using descriptive statistics such as frequency and percentage with the help of SPSS Version 16.0. Inferential statistics were applied where necessary. For qualitative insights, Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) techniques were employed to capture ground realities and community-level perspectives.

The six components of livelihood security viz. food, occupational, educational, habitat, health and social security were adopted (Rathod et al., 2023). Each component was represented by a different number of statements with distinct scoring ranges. To ensure comparability, the raw scores were standardized into unit scores using the formula:

$$U_{ij} = \frac{Y_{ij} - \text{Min}_j}{\text{Max}_j - \text{Min}_j}$$

U_{ij} = Unit score of the i^{th} respondent on j^{th} component, Y_{ij} = Value of i^{th} respondent on j^{th} component, Max_j = Maximum score on the j^{th} component, Min_j = Minimum score on the j^{th} component

The standardized scores (ranging from 0 to 1) were multiplied by the number of items under each component to assign appropriate weightage. Total livelihood security score for each respondent was computed by summing the weighted unit scores of all six components. Principal Component Analysis (PCA) was conducted using the GRAPES (General R-Shiny Based Analysis Platform Empowered by Statistics) web application to derive the underlying structure and weightage of livelihood components. The constraints faced by the farm women was ranked using Garrett's ranking. The ranks allotted by the respondents were converted into scores by using this technique as given:

$$\% \text{ position} = 100 (R_{ij} - 0.50) / N_j$$

Where, R_{ij} = Rank given for the i^{th} factor by j^{th} individual, N_j = Number of problems ranked by the j^{th} individual

Additionally, Garrett's ranking method was used to convert the percentage of positions produced into scores. After adding up the respondents' scores, mean values were determined.

RESULTS

Livelihood security of farm women

The distribution of livelihood security among farm women in Kerala and Manipur is presented in Table 1a and 1b. In Kerala, 60.00 per cent of the respondents exhibited medium livelihood

Table 1a. Distribution of respondents in Kerala based on livelihood security (n=45)

Status of Livelihood Security	Percentage
Low (< 18.24)	11.11
Medium (18.25 – 20.01)	60.00
High (> 20.02)	28.89
Mean	19.13
Standard deviation	0.89

Table 1b. Distribution of respondents in Manipur based on livelihood security (n=45)

Status of Livelihood Security	Percentage
Low (< 24.69)	13.33
Medium (24.70 – 25.70)	68.89
High (> 25.71)	17.78
Mean	25.2
Standard deviation	0.509

security, followed by 28.89 per cent with high and 11.11 per cent with low security. Similarly, in Manipur, 68.89 per cent of respondents reported medium security, while 17.78 per cent and 13.33 per cent had high and low levels of security, respectively.

Component-wise livelihood security

The result as shown in Table 2a and 2b indicated that in Kerala, 51.11 per cent of respondents exhibited medium food security, followed by 40.00 per cent high and 8.89 per cent low whereas in Manipur, 64.44 per cent had medium, 20.00 per cent high and 15.56 per cent low food security. Kerala had 77.78 per cent of respondents reporting medium occupational security, while 15.55 per cent and 6.67 per cent had high and low, respectively. In Manipur, 68.89 per cent had medium occupational security, 17.78 per cent low and 13.33 per cent high. In Kerala, 71.11 per cent of respondents showed medium educational security, with 15.56 per cent low and 13.33 per cent high. Manipur had 73.33 per cent medium, 22.22 per cent low, and 4.45 per cent high educational security. Medium habitat security was reported by 68.89 per cent in Kerala and 66.67 per cent in Manipur. High habitat security was reported by 20.00 per cent in Kerala and 15.55 per cent in Manipur. In Kerala, 55.55 per cent of respondents reported medium health security, 37.78 per cent high and 6.67 per cent low. In Manipur, 75.56 per cent reported medium, 15.55 per cent high and 8.89 per cent low. Kerala respondents showed 44.45 per cent medium, 31.11 per cent low, and 24.44 per cent high social security. In Manipur, 46.67 per cent had medium, 31.11 per cent high and 22.22 per cent low.

Table 2a. Distribution of farm women in Kerala based on different components of livelihood security (n=45)

Components	Category	Percentage
Food security	Low (< 3.24)	8.89
	Medium (3.25 – 5.21)	51.11
	High (> 5.22)	40.00
	Mean: 4.23, SD: 0.99	
Occupational security	Low (< 5.81)	6.67
	Medium (5.82 – 8.36)	77.78
	High (> 8.37)	15.55
	Mean: 7.09, SD: 1.28	
Educational security	Low (< 8.05)	15.56
	Medium (8.06 – 11.40)	71.11
	High (> 11.41)	13.33
	Mean: 9.73, SD: 1.68	
Habitat security	Low (< 8.32)	11.11
	Medium (8.33 – 10.2)	68.89
	High (> 10.3)	20.00
	Mean: 9.31, SD: 0.99	
Health security	Low (< 4.07)	6.67
	Medium (4.08 – 6.36)	55.55
	High (> 6.37)	37.78
	Mean: 5.22, SD: 1.15	
Social security	Low (< 3.72)	31.11
	Medium (3.73 – 7.6)	44.45
	High (> 7.7)	24.44
	Mean: 5.71, SD: 1.99	

Table 2b. Distribution of farm women in Manipur based on different components of livelihood security (n=45)

Components	Category	Percentage
Food security	Low (< 1.79)	15.56
	Medium (1.8 – 4.54)	64.44
	High (> 4.55)	20.00
	Mean: 3.17, SD: 1.38	
Occupational security	Low (< 7.32)	17.78
	Medium (7.33 – 9.25)	68.89
	High (> 9.26)	13.33
	Mean: 8.29, SD: 0.97	
Educational security	Low (< 6.96)	22.22
	Medium (6.97 – 10.31)	73.33
	High (> 10.32)	4.45
	Mean: 8.64, SD: 1.68	
Habitat security	Low (< 8.6)	17.78
	Medium (8.7 – 10.15)	66.67
	High (> 10.16)	15.55
	Mean: 9.38, SD: 0.78	
Health security	Low (< 0.94)	8.89
	Medium (0.95 – 4.2)	75.56
	High (> 4.3)	15.55
	Mean: 2.62, SD: 1.68	
Social security	Low (< 5.88)	22.22
	Medium (5.89 – 9.17)	46.67
	High (> 9.18)	31.11
	Mean: 7.53, SD: 1.65	

Principal Component Analysis (PCA)

Principal component analysis was conducted to evaluate the contribution of the principal components to the variance in livelihood security, with the results displayed in Table 3. Upon conducting the principal component analysis, it was determined that the first and second principal components were identified as the primary contributors to livelihood security, as indicated by their eigen values exceeding one. PCA results indicated that in Kerala, the first two principal components (PC1 = 2.974, PC2 = 1.282) accounted for 70.93 per cent of the total variance. In Manipur, PC1 and PC2 accounted for 34.63 and 21.71 per cent respectively, explaining 56.34 per cent cumulatively.

Constraints faced by farm women in achieving livelihood security

The study revealed that the major constraints perceived by the farm women in Kerala included insufficient funds (I), non-availability of good quality seeds (II), inadequate land for cultivation (III), inadequate training (IV), lack of marketing facilities (V), crop loss due to wild animals (VI), non-availability of fertilizers (VII), insufficient irrigation facilities (VIII) and lack of farm machinery (IX). In Manipur, the major constraint perceived by farm women were inadequate government support (I), inadequate marketing facilities (II), insufficient irrigation facilities (III), insufficient funds (IV), insufficient transportation facilities (V), inadequate extension services (VI), followed by non-availability of inputs in time (VII), inadequate storage facilities (VIII) and inadequate improved cultivation methods and technology (IX).

Table 3. Contribution of the principal components to the variance in livelihood security for Kerala and Manipur

Principal Component	Eigen value		Variability (%)		Cumulative per cent of variance	
	Kerala	Manipur	Kerala	Manipur	Kerala	Manipur
PC1	2.974	2.078	49.565	34.63	49.565	34.63
PC2	1.282	1.302	21.362	21.707	70.926	56.336
PC3	0.78	0.93	13.007	15.506	83.934	71.842
PC4	0.517	0.753	8.618	12.548	92.551	84.391
PC5	0.253	0.607	4.21	10.112	96.761	94.503
PC6	0.194	0.33	3.239	5.497	100	100

DISCUSSION

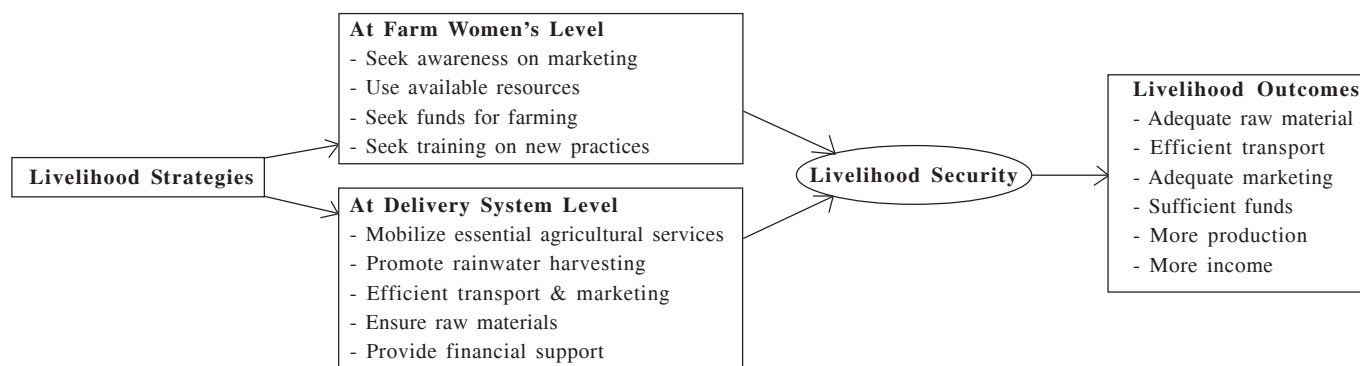
The findings illustrated that most farm women in both states experienced moderate livelihood security, which may be attributed to their medium scores across most livelihood dimensions. These findings are consistent with those of Pradhan et al., (2020); Gautam & Jha (2023); Mishra et al., (2023), who reported similar patterns of moderate security among rural populations. The higher food security in Kerala compared to Manipur is likely due to efficient public food distribution systems, availability of diverse agricultural produce, and better nutritional awareness, which aligns with the findings of Asha (2020); Manikanta & Satpathy (2023). Occupational security was also slightly better in Kerala, possibly due to more stable engagement in agricultural and allied sectors. These results were parallel to the results of Rejula et al., (2017) & Matouleibi et al., (2022). Kerala's strong educational infrastructure explains the higher percentage of respondents with medium and high educational security, aligning with findings from Sathwika (2019). Likewise, better access to sanitation, electricity, and housing facilities contributes to higher habitat security in Kerala. The outcome aligns with the results of Abhishek (2023). The health sector in Kerala is notably advanced and well-maintained, offering adequate medical facilities, contributing to higher health security. This outcome is consistent with Hridya (2018). Interestingly, Manipur was slightly ahead in the proportion of high social security. This may reflect stronger community participation and women's engagement in social activities in the North-East. The outcome is in agreement with the results of Chandana et al., (2023). PCA analysis revealed that food, education, and habitat security were key contributors to PC1 in Kerala, while occupational, health, and social security loaded more strongly on PC2. In Manipur, PC1 was driven by education, habitat, and social security, while PC2

reflected food and occupational security. Negative correlation of health security with PC2 in Manipur suggests differential access or variability in health perceptions.

In Kerala, financial constraints were the predominant issue, signifying restricted access to institutional credit and dependence on informal lending mechanisms. The significance of seed quality and land limitations indicates fundamental challenges in agricultural production and land ownership patterns. The prominent prioritization of concerns such as wildlife-related crop damage and insufficient mechanization indicates specific agricultural vulnerabilities and a lack of technology. In Manipur, the primary constraints were insufficient governmental support, signifying challenges related to policy and governance. This may indicate restricted extension outreach and inadequate utilization of agricultural programs in remote or tribal regions. Marketing and irrigation issues were prioritized, highlighting infrastructural deficiencies that hinder productivity and profitability. Financial limitations were noted, potentially attributable to perceived significance in relation to gaps in institutional support. Transport and storage constraints were highlighted, underscoring the necessity for logistical infrastructure to mitigate post-harvest losses. The prioritization of new technology adoption as a limitation stresses the necessity for targeted training and awareness initiatives for women farmers in the region.

Formulation of a sustainable livelihood security model

Strategies for livelihood were developed at the levels of farm women and delivery systems to ensure favorable outcomes, including the adequate availability of raw materials, efficient transportation, ample marketing facilities, and sufficient funding, resulting in increased production and higher income (Figure 1). It

**Figure 1.** Livelihood security framework

is expected that when farm women efficiently utilize traditional and modern agricultural practices, the yield will improve food security and create surplus income, thereby improving overall well-being (Amayo et al., 2021). Meshram (2024) highlights that technological interventions can enhance the sustainability of agricultural systems, environmental protection, satisfy educational and social needs, and ultimately improve livelihood security. In light of the constantly shifting climate, the results of the study are vital for developing strategies to increase the agricultural sector's resilience and flexibility in order to guarantee food security and the sustainability of livelihoods (Janani et al., 2024).

CONCLUSION

This study was carried out to assess and compare the livelihood security, constraints perceived and formulate a sustainable livelihood security framework for the farm women in Kerala and Manipur. The study indicated that most of the respondents in Kerala and Manipur indicated a moderate level of livelihood security. Insufficient funds and inadequate government support were the major constraints faced by farm women in Kerala and Manipur in achieving livelihood security. This result complements the framework of sustainable livelihoods, which was formulated at the farm women and delivery system level to safeguard livelihood outcomes. These findings aid the need for policies that provide women in agriculture more access to education, markets, credits and agricultural inputs.

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, 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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Mapping Dairy Farmers' Preferences for Improved Feeding Practices Using Paired Comparison Method

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HIGHLIGHTS

- The prioritization of improved feeding practices based on dairy farmers' preferences for acceptability at the field level was carried out using the paired comparison method.
- Salt, year-round green fodder production, and sugarcane tops were the most preferred feeding practices among dairy farmers due to their low cost and easy availability.
- Scientific and advanced practices like silage, urea-treated straw, and bypass fat received low preference, mainly due to a lack of awareness and perceived complexity.

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ABSTRACT

Dairy farmers' preferences for improved feeding practices were assessed in Bareilly district of Uttar Pradesh using a pairwise comparison technique. The findings indicate a strong preference for traditional, low-cost interventions. Salt supplementation ranked highest with a scale value of 2.924, followed by year-round green fodder production (2.730) and sugarcane tops (2.281). These results highlight farmers' favour for easily accessible and cost-effective options. Moderately accepted practices included mineral mixtures (1.862) and fresh vegetable waste (1.787), reflecting a cautious openness. However, more scientifically advanced practices such as anti-methane additives, probiotics, bypass fat, hay, urea-treated straw, and silage were less preferred, with scale values ranging from 1.325 to near zero. This lower acceptance suggests either limited awareness or reluctance to adopt more technical and potentially costly feeding practices. To evaluate the consistency of these preferences, an internal consistency check was conducted. The resulting average discrepancy of 0.090 indicates a reasonable level of internal consistency. Overall, the findings provide a clear picture of current dairy feeding practice preferences, with traditional approaches continuing to dominate farmer choices.

INTRODUCTION

Dairy farming plays a vital role in India's agricultural economy, predominantly sustained by smallholder farmers who typically rear one or two milch animals. India is the world's leading milk producer, with an annual production of 239.3 mt and a per capita milk availability of 471 grams/day (NDDB, 2023–24). For millions of

rural families, dairy farming is both a primary and supplementary livelihood source, offering income security and employment in regions with limited job opportunities. Among the key factors influencing the productivity and profitability of dairy farming, nutrition holds paramount importance. Adequate and balanced feeding is essential for optimal milk production, reproductive efficiency, disease resistance, and overall animal well-being.

Dairy animals require a balanced diet that includes energy-rich feeds, proteins, vitamins, minerals, and an adequate supply of clean water. Proper feeding management not only ensures improved milk yield and better health outcomes but also helps prevent metabolic disorders such as acidosis, milk fever, and ketosis. Effective rumen function, achieved through appropriate feed combinations, enhances nutrient absorption and overall efficiency. Additionally, sustainable feeding strategies contribute to environmental sustainability by reducing methane emissions from enteric fermentation (Kumar *et al.*, 2023). Malnutrition, in contrast, results in poor productivity, increased disease risk, and economic losses for farmers.

To address the challenges of inadequate nutrition, several improved feeding practices have been developed. Chopped sugarcane tops (SCT), when supplemented with oil cake and mineral mixture, provide cost-effective roughage during dry seasons. Urea-treated straws (UTS) enhance low-quality fodder, while hay-making preserves green fodder for lean periods. Fresh vegetable waste (FVW), when properly processed, serves as an economical alternative. Probiotics aid digestion, and salt with area-specific mineral mixtures (MM) correct regional deficiencies. Additional practices like silage preparation, year-round green fodder cultivation (e.g., hybrid Napier), anti-methane additives, and by-pass fat improve productivity and sustainability. Clean drinking water 4-5 liters per liter of milk is essential for animal health and output.

METHODOLOGY

The data for this study were collected from four randomly selected villages namely *Hamirpur*, *Mawai*, *Kalapur*, and *Lakhampur* located in the Bareilly district of Uttar Pradesh. From each village, 15 dairy farmers were randomly selected, resulting in a total sample of 60 participants. Prior to data collection, sensitization programmes on improved dairy feeding practices were conducted in all four villages. Following these sessions, the farmers' acceptance of various improved feeding methods was assessed using the paired comparison technique. As noted by Brown and Peterson (2009), paired comparisons offer a straightforward yet robust method for eliciting binary preferences that can be translated into interval-scale measurements. This method was deemed appropriate for identifying and prioritizing the most widely accepted feeding practices among the respondents. While the summated rating scale remains the most widely used approach in social science research

(Kumar *et al.*, 2015; Singh *et al.*, 2018; Shruti *et al.*, 2019; Kumar *et al.*, 2021; Gupta *et al.*, 2022; Verma *et al.*, 2024), this study adopted the paired comparison methodology due to its suitability for comparative preference assessment. Unlike the scalogram approach of the Guttman scale, which relies on binary response categories such as "agree" or "disagree" (Choudhary *et al.*, 2025), the paired comparison method requires respondents to evaluate all possible combinations of feeding practices and select their preferred option in each pair. This method is based on Thurstone's Law of Comparative Judgment, a psychological scaling approach that allows subjective preferences to be quantified along a psychological continuum (Edwards, 1969). By analyzing the choices made in each pairwise comparison, the relative importance or priority of each feeding practice can be determined.

RESULTS

Eleven improved feeding practices were identified for dairy farmers in Bareilly district based on expert recommendations. These practices were subsequently subjected to pairwise comparison, wherein each possible combination was presented to the farmers for preference ranking. Using responses from 60 dairy farmers, a paired comparison frequency matrix was constructed to capture their expressed preferences among the 11 feeding practices. For example, 46 farmers preferred the inclusion of salt over round the year green fodder production (preferred by 14), while 56 chose salt over both sugarcane tops and probiotics (each preferred by 4 farmers), as shown in Table 1. Similarly, salt was favoured over mineral mixtures by 52 respondents (versus 8), and over fresh vegetable waste by 54 (versus 6). In addition, salt was prioritized over anti-methane feed additives and bypass fat by 58 respondents each (both alternatives receiving only 2 preferences). A large majority 59 farmers favoured salt over hay, silage, and urea-treated straw.

Overall, salt emerged as the most preferred feeding intervention, with a total score of 557. This strong preference is likely due to its widespread availability, ease of use, and low cost, making it a practical and accessible choice for smallholder dairy farmers.

Likewise, year-round green fodder production received a relatively strong preference in comparative judgments, with 59 farmers favouring it over urea-treated straw, followed by 58 selecting it over anti-methane feed additives, probiotics, and silage. Additionally, 56 farmers preferred year-round green fodder

Table 1. The F matrix for 11 improved dairy feeding practices judged by 60 farmers

S.No.	Practices	Salt	GF	SCT	MM	FVW	AM	Pro	BP	Hay	UTS	Silage
1.	Salt	0	14	4	8	6	2	4	2	1	1	1
2.	GF	46	0	4	8	4	2	2	4	4	1	2
3.	SCT	56	56	0	10	8	4	4	2	4	2	2
4.	MM	52	52	50	0	10	8	8	10	8	8	6
5.	FVW	54	56	52	50	0	6	8	4	4	6	2
6.	AM	58	58	56	52	54	0	10	6	8	4	6
7.	Pro	56	58	56	52	52	50	0	10	6	4	2
8.	BP	58	56	58	50	56	54	50	0	10	6	4
9.	Hay	59	56	56	52	56	52	54	50	0	10	4
10.	UTS	59	59	58	52	54	56	56	54	50	0	10
11.	Silage	59	58	58	54	58	54	58	56	56	50	0
	Total	557	523	452	388	358	288	254	198	151	92	39

production over sugarcane tops, fresh vegetable waste, bypass fat, and hay, while 52 preferred it over mineral mixtures. In the case of sugarcane tops, they were favoured by 58 farmers over bypass fat, urea-treated straw, and silage, and by 56 over anti-methane feed additives, probiotics, and hay.

Mineral mixture emerged as a relatively preferred feeding option, with higher preference scores against fresh vegetable waste (10), anti-methane feed additives (8), probiotics (8), bypass fat (10), hay (8), urea-treated straw (UTS) (8), and silage (6). Similarly, fresh vegetable waste was favoured over anti-methane feed additives (6), probiotics (8), bypass fat and hay (4 each), UTS (6), and silage (2).

In the case of anti-methane feed additives, they were preferred over probiotics (10), bypass fat (6), hay (8), UTS (4), and silage (6). Probiotics, in turn, received higher preference compared to bypass fat (10), hay (6), UTS (4), and silage (2). Bypass fat was more preferred than hay (10), UTS (6), and silage (4). Hay was selected more often than UTS (10) and silage (4). However, in the comparison between silage and UTS, the majority of farmers (50) favoured UTS, while only 10 preferred silage.

The frequency matrix (F matrix) was converted into a proportion matrix (P matrix) by dividing each frequency by the total number of respondents (60), as shown in Table 2. After preparing the P matrix, the total proportion (P value) was calculated for each improved feeding practice. Next, the Z matrix was derived from the P matrix using values from the standard normal distribution (Z) Table for each paired comparison as shown in Table 3. The total Z score was then computed for each feeding practice, including

negative values. Subsequently, the mean Z score was calculated for each improved feeding practice. To ensure that all values were positive, the lowest (most negative) mean score was added to the mean score of each improved feeding practice. This adjustment resulted in the final scale values for each improved dairy feeding practice, based on the preferences expressed by farmers. Among the practices, salt emerged as the most preferred (2.924), followed by year-round green fodder production (2.730), sugarcane tops (2.281), mineral mixture (1.862), fresh vegetable waste (1.787), anti-methane feed additives (1.325), probiotics (1.233), bypass fat (0.897), hay (0.671), urea-treated straw (UTS) (0.296), and silage, which was the least preferred as represented in Figure 1.

DISCUSSION

The findings from the paired comparison analysis reveal a clear hierarchy of farmer preferences for improved feeding practices, largely influenced by practical accessibility, cost-effectiveness, and familiarity with the options. Salt (2.924), being a traditional and widely available input, emerged as the most accepted feeding intervention, indicating minimal barriers to adoption. Its top ranking reflects a combination of low economic cost and established trust in its effectiveness. Year-round green fodder production (2.730) and sugarcane tops (2.281), both conventional feed resources, also scored high, suggesting that farmers remain inclined toward natural, farm-available or easily accessible feed sources, especially those that do not demand technical know-how or external procurement. This

Table 2. The P matrix corresponding to the F matrix

S.No.	Practices	Salt	GF	SCT	MM	FV	AM	Pro	BP	Hay	UTS	Silage
1.	Salt	0.000	0.233	0.067	0.133	0.100	0.033	0.067	0.033	0.017	0.017	0.017
2.	GF	0.767	0.000	0.067	0.133	0.067	0.033	0.033	0.067	0.067	0.017	0.033
3.	SCT	0.933	0.933	0.000	0.167	0.133	0.067	0.067	0.033	0.067	0.033	0.033
4.	MM	0.867	0.867	0.833	0.000	0.167	0.133	0.133	0.167	0.133	0.133	0.100
5.	FVW	0.900	0.933	0.867	0.833	0.000	0.100	0.133	0.067	0.067	0.100	0.033
6.	AM	0.967	0.967	0.933	0.867	0.900	0.000	0.167	0.100	0.133	0.067	0.100
7.	Pro	0.933	0.967	0.933	0.867	0.867	0.833	0.000	0.167	0.100	0.067	0.033
8.	BP	0.967	0.933	0.967	0.833	0.933	0.900	0.833	0.000	0.167	0.100	0.067
9.	Hay	0.983	0.933	0.933	0.867	0.933	0.867	0.900	0.833	0.000	0.167	0.067
10.	UTS	0.983	0.983	0.967	0.867	0.900	0.933	0.933	0.900	0.833	0.000	0.167
11.	Silage	0.983	0.967	0.967	0.900	0.967	0.900	0.967	0.933	0.933	0.833	0.000
	Total	9.283	8.717	7.533	6.467	5.967	4.800	4.233	3.300	2.517	1.533	0.650

Figure 1. Scale values of improved dairy feeding practices

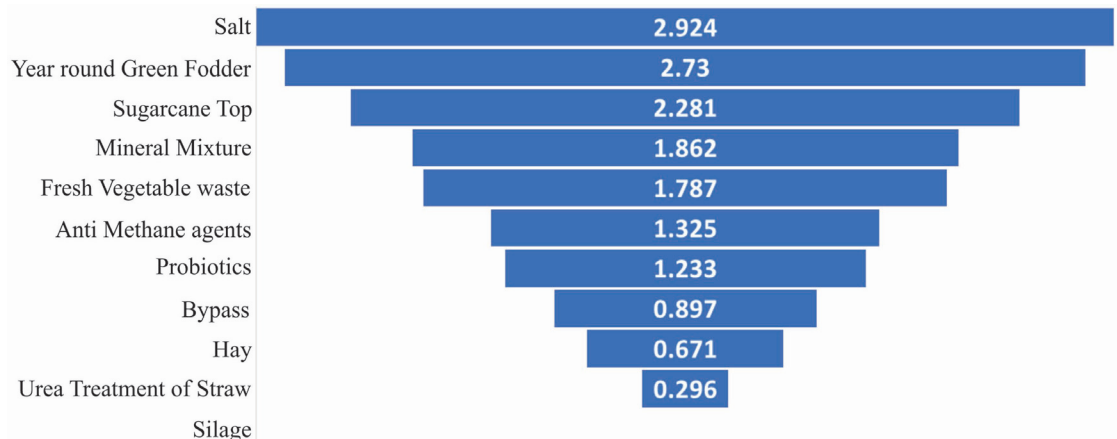


Table 3. The Z matrix corresponding to the P matrix

S.No.	Practices	Salt	GF	SCT	MM	FV	AM	Pro	BP	Hay	UTS	Silage
1.	Salt	0.000	-0.722	-1.499	-1.112	-1.282	-1.838	-1.499	-1.838	-2.120	-2.120	-2.120
2.	GF	0.729	0.000	-1.499	-1.112	-1.499	-1.838	-1.838	-1.499	-1.499	-2.120	-1.838
3.	SCT	1.499	1.499	0.000	-0.966	-1.112	-1.499	-1.499	-1.838	-1.499	-1.838	-1.838
4.	MM	1.112	1.112	0.966	0.000	-0.966	-1.112	-1.112	-0.966	-1.112	-1.112	-1.282
5.	FVW	1.282	1.499	1.112	0.966	0.000	-1.282	-1.112	-1.499	-1.499	-1.282	-1.838
6.	AM	1.838	1.838	1.499	1.112	1.282	0.000	-0.966	-1.282	-1.112	-1.499	-1.282
7.	Pro	1.499	1.838	1.499	1.112	1.112	0.966	0.000	-0.966	-1.282	-1.499	-1.838
8.	BP	1.838	1.499	1.838	0.966	1.499	1.282	0.966	0.000	-0.966	-1.282	-1.499
9.	Hay	2.120	1.499	1.499	1.112	1.499	1.112	1.282	0.966	0.000	-0.966	-1.499
10.	UTS	2.120	2.120	1.838	1.112	1.282	1.499	1.499	1.282	0.966	0.000	-0.966
11.	Silage	2.120	1.838	1.838	1.282	1.838	1.282	1.838	1.499	1.499	0.966	0.000
	Z score	16.157	14.020	9.091	4.472	3.653	-1.428	-2.441	-6.141	-8.624	-12.752	-16.000
	Mean	1.469	1.275	0.826	0.407	0.332	-0.130	-0.222	-0.558	-0.784	-1.159	-1.455
	Mean+1.455	2.924	2.730	2.281	1.862	1.787	1.325	1.233	0.897	0.671	0.296	0.000

Table 4. Theoretical normal deviates corresponding to the scale distances between the practices

S.No.	Practices	Scane value	Silage	UTS	Hay	BP	Pro	AM	FVW	MM	SCT	GF	Salt
			0.000	0.296	0.671	0.897	1.233	1.325	1.787	1.862	2.281	2.73	2.924
1.	Silage	0.000											
2.	UTS	0.296	-0.296										
3.	Hay	0.671	-0.671	-0.375									
4.	BP	0.897	-0.897	-0.601	-0.226								
5.	Pro	1.233	-1.233	-0.937	-0.562	-0.336							
6.	AM	1.325	-1.325	-1.029	-0.654	-0.428	-0.092						
7.	FVW	1.787	-1.787	-1.491	-1.116	-0.890	-0.554	-0.462					
8.	MM	1.862	-1.862	-1.566	-1.191	-0.965	-0.629	-0.537	-0.075				
9.	SCT	2.281	-2.281	-1.985	-1.610	-1.384	-1.048	-0.956	-0.494	-0.419			
10.	GF	2.730	-2.730	-2.434	-2.059	-1.833	-1.497	-1.405	-0.943	-0.868	-0.449		
11.	Salt	2.924	-2.924	-2.628	-2.253	-2.027	-1.691	-1.599	-1.137	-1.062	-0.643	-0.194	

Table 5. Theoretical proportions corresponding to the theoretical normal deviates

S.No.	Practices	Silage	UTS	Hay	BP	Pro	AM	FVW	MM	SCT	GF	Salt
1.	Silage											
2.	UTS	0.384										
3.	Hay	0.251	0.354									
4.	BP	0.185	0.274	0.411								
5.	Pro	0.109	0.174	0.287	0.369							
6.	AM	0.093	0.152	0.257	0.334	0.463						
7.	FVW	0.037	0.068	0.132	0.187	0.29	0.322					
8.	MM	0.031	0.059	0.117	0.167	0.265	0.296	0.47				
9.	SCT	0.011	0.023	0.054	0.083	0.147	0.17	0.311	0.338			
10.	GF	0.003	0.007	0.020	0.033	0.067	0.080	0.173	0.192	0.327		
11.	Salt	0.002	0.004	0.012	0.021	0.045	0.055	0.128	0.144	0.26	0.423	

aligns with prior observations in rural feeding practices, where simplicity and immediacy outweigh novelty.

The moderate acceptance of mineral mixtures (1.862) and fresh vegetable waste (1.787) suggests growing awareness of balanced nutrition, though constraints related to availability, price, or knowledge may be limiting widespread preference. Meanwhile, scientifically advanced or less familiar practices such as anti-methane feed additives (1.325), probiotics (1.233), bypass fat (.897), hay (.671) urea-treated straw (.296) and silage received relatively lower

preference scores. These options likely face challenges due to limited awareness, higher costs, or lack of demonstrated benefits at the field level.

Interestingly, urea-treated straw was preferred over silage, indicating a slight tilt toward technologies that require fewer inputs or simpler methods. However, the overall low preference for both implies the need for stronger demonstration-based extension efforts, capacity building, and showcasing of long-term benefits to encourage adoption of such improved practices.

Table 6. Discrepancies between the theoretical proportions of Table 5 and the observed proportions of Table 2

S.No.	Practices	Silage	UTS	Hay	BP	Pro	AM	FVW	MM	SCT	GF	Salt
1.	Silage											
2.	UTS	-0.217										
3.	Hay	-0.184	-0.187									
4.	BP	-0.118	-0.174	-0.244								
5.	Pro	-0.076	-0.107	-0.187	-0.202							
6.	AM	0.007	-0.085	-0.124	-0.234	-0.296						
7.	FVW	-0.004	0.032	-0.065	-0.12	-0.157	-0.222					
8.	MM	0.068	0.074	0.016	0.000	-0.132	-0.163	-0.303				
9.	SCT	0.022	0.01	0.013	-0.05	-0.08	-0.103	-0.178	-0.171			
10.	GF	0.03	0.01	0.047	0.034	-0.034	-0.047	-0.106	-0.059	-0.259		
11.	Salt	0.015	0.013	0.005	0.012	0.022	-0.022	-0.028	-0.011	-0.193	-0.190	
12.	Sum	0.741	0.098	0.701	0.652	0.721	0.557	0.615	0.241	0.452	0.190	

Internal consistency check

An internal consistency check was performed on the scale values derived for the improved dairy feeding practices, which were arranged on a psychological continuum from least to most preferred. This procedure aimed to evaluate the degree of agreement between the observed (empirical) proportions and the theoretically expected proportions derived from the scale values. It aids in determining how uniform the scale's objects are (Choudhary et al., 2025) and represent precision or accuracy of the measurement (Verma et al., 2025).

To conduct this check, the scale distances between each pair of feeding practices were first calculated to generate theoretical normal deviates, as shown in Table 4. Using these scale distances, a matrix of theoretical proportions corresponding to theoretical normal deviates was generated, presented in Table 5. Next, the discrepancies between the theoretical proportions (Table 5) and the observed proportions (Table 2) were determined as indicated in Table 6.

The discrepancies for all paired comparisons were summed, taking the absolute values into account. Finally, the absolute average discrepancy was computed by dividing the total absolute discrepancy by the number of independent comparisons, calculated as $n(n-1)/2$, where n is 11 in this case. The resulting absolute average discrepancy was found to be 0.090, indicating a reasonable level of internal consistency in the scale.

CONCLUSION

The findings reveal a pronounced preference for traditional, low-cost feeding practices, particularly salt supplementation, year-round green fodder production, and chopped sugarcane tops, which dominate farmer choices due to their familiarity, ease of access, and minimal investment. In contrast, more specialized interventions such as silage, urea-treated straw, anti-methane additives, and bypass fat received lower acceptance, likely reflecting farmers' perceptions of these methods as complex or economically burdensome. This mirrors patterns observed in other agricultural studies where resource-constrained farmers often prioritize simplicity and practicality over unfamiliar innovations. The internal consistency of the preference scale evidenced by an average discrepancy of 0.090 confirms that the farmers' comparative responses align closely with theoretical expectations from Thurstone's paired-comparison model. While

traditional feeding methods continue to dominate the preference landscape among dairy farmers, there is latent potential for the adoption of improved and scientific feeding practices.

DECLARATIONS

Ethics approval and informed consent: Before data collection, sensitization programmes on improved dairy feeding practices were conducted with the prospective participants of the study. Those consented have been included for data collection and analysis purposes.

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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Farmers' Livelihood Security through Sheep Farming in Bareilly District of Uttar Pradesh

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HIGHLIGHTS

- A composite Livelihood Security Index (LSI) was developed and validated using experts' consultation and content validity methods, covering five critical dimensions.
- The overall value of composite index value of 0.617 reflects a moderate level of livelihood security.
- Income, education, flock size, extension contact, and knowledge were found to be significant positive contributors to livelihood security, while credit access showed a negative correlation.

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ABSTRACT

The study was conducted in 2024 to assess the livelihood security of sheep-owning farmers in Bareilly district, Uttar Pradesh. A Livelihood Security Index (LSI) was developed based on five key dimensions: food and nutritional security, economic and marketing security, infrastructural security, social security, and resource use efficiency. Content validity and relevance were tested using scoring methods. Data were collected from farmers using a structured interview schedule, and LSI was computed through standardized scoring and weighted aggregation. Correlation analysis using SPSS (SPSS 26.0) identified the relationship between livelihood security and selected socio-economic variables. Results revealed that most farmers had a moderate level of livelihood security (composite index = 0.617), with resource use efficiency and economic security being the strongest areas. Income, education, flock size, extension contact, and knowledge had significant positive correlations with livelihood security, while credit access showed a negative correlation. The study concluded that targeted interventions in infrastructure, financial literacy, and behavioural capacity-building are essential to enhance the livelihood resilience of smallholder sheep farmers.

INTRODUCTION

Livelihood security encompasses the means and approaches individuals and families adopt to meet fundamental needs. For rural communities, particularly small-scale farmers, securing a stable livelihood is crucial (Chambers & Conway, 1992). Previous studies (Scoones, 1998; DFID, 1999) have emphasized the importance of sustainable livelihoods, linking them to resource availability, market access, and infrastructure development. According to Alinovi et al., (2010), livelihood outcomes represent the objectives that individuals

strive to achieve through their livelihood strategies. These outcomes typically include higher income levels, enhanced well-being, improved food security, reduced vulnerability, and more sustainable management of natural resources. Integrating various farm enterprises can enhance livelihoods by boosting food production, raising net income, increasing overall productivity, and minimizing income disparities between rural agricultural workers and urban industrial labourers. The National Commission on Farmers (2006) also suggests that adopting suitable farming systems is a key strategy for promoting agricultural growth and improving livelihoods. In rural

areas, there are 76.31 per cent of households earn their livelihood from agricultural activities, which includes 29.03 per cent of households who are working as agricultural labourers in the rural area of the state” (NSS, 2005). Sheep farming has emerged as an important livelihood strategy in many parts of India, including Bareilly district of Uttar Pradesh. According to Ellis (2000), livelihood diversification is key to sustaining rural economies, and sheep farming provides an alternative source of income and resilience against economic fluctuations. Despite the government’s periodic implementation of various poverty alleviation programs, these initiatives have largely provided temporary relief rather than creating long-term opportunities for sustainable livelihood generation. The Farmer FIRST Programme (FFP), launched by the Indian Council of Agricultural Research (ICAR), focuses on improving agricultural productivity, sustainability, and livelihood security by integrating farmers’ knowledge with scientific advancements. Through this programme, ICAR-IVRI distributed improved germplasm of Muzaffarnagari ram to resource-poor sheep farmers in the study area, aiming to enhance the genetic merit and growth performance of sheep within the community, foster improved breeding practices, and ensure a sustainable boost in the overall livelihood of the sheep farming community. Apart from that, hands-on training programmes on scientific sheep husbandry were given to farmers. Farmers also visited organized farms to gain a better understanding of scientific sheep farming. This study empirically examines the status of interventions and the effectiveness of sheep farming in securing livelihoods by developing a Livelihood Security Index (LSI) based on five key dimensions. The five dimensions of food and nutritional security, economic and market security, infrastructural security, social security, and resource use efficiency were considered for developing the composite livelihood security index. It also aimed to assess the relationship between various socio-economic, psychological, and communication variables and livelihood security among farmers. Using bivariate correlation analysis in SPSS, key factors such as income, flock size, knowledge, and risk orientation were found to be significantly associated with livelihood outcomes, highlighting critical drivers of rural resilience and well-being.

METHODOLOGY

The study employed a structured approach to develop and validate the LSI. Five major indicators i.e. food and nutritional security, economic and market security, infrastructural security, social security, and resource use efficiency, were identified through literature review and expert consultations. The indicators for each dimension of the LSI were identified in consultation with researchers, farmers, extension professionals, and through review of the literature. The selected indicators were then refined based on the 14 informal criteria proposed by Edwards (1957), leading to the exclusion of some items.

Item analysis is the most important step while developing a valid and reliable index. Not all of the indicators gathered are probably equally significant in assessing farmers’ livelihood security. As a result, these indicators were scrutinised and then screened for inclusion in the final index. Initially, 50 judges were asked to rate the relevance of each indicator on a three-point continuum- Most Relevant, Relevant, and Least Relevant-with scores of 3, 2, and 1,

respectively, as used by Singh et al., (2018) & Verma et al., (2025). After obtaining the responses from 34 experts, the Relevancy Weightage (RW) and Mean Relevancy Score (MRS) for each selected indicator were calculated separately using the given formula.

$$\text{Relevancy weightage} = \frac{(\text{Most relevant} \times 3) + (\text{Relevant} \times 2) + (\text{Least relevant} \times 1)}{\text{Maximum possible score}}$$

$$\text{Mean Relevancy score} = \frac{(\text{Most relevant} \times 3) + (\text{Relevant} \times 2) + (\text{Least relevant} \times 1)}{\text{Number of judges responded}}$$

To assess the livelihood security of the 60 selected respondents, a “*Livelihood Security Index*” was constructed following the framework proposed by Guilford (1954). Different indicators of livelihood security were assigned weights based on rankings provided by a panel of experts and social science professionals. The conversion of ranks into weight values was carried out using the approach outlined by Alfares & Duffuaa (2008). Subsequently, the average value of these weights was computed and used as the final weight for each indicator. A similar approach has been adopted in earlier studies, including those by Girish et al., (2020); Dadabhau & Gopal (2014).

To finalize the statements corresponding to specific livelihood security indicators, expert opinions were sought by circulating the proposed statements among selected judges. Based on the feedback and suggestions received, the final set of statements for each indicator was determined.

$$Z \text{ indj} = \frac{\text{Indicator j-Min j}}{\text{Max j - Min j}}$$

Where, Zindj= Standard indicator j, Max j and Min j = Maximum and minimum value of indicator j

Subsequently, the ‘Livelihood Security Index’ for each indicator across all households was computed using the following formula:

$$LSi = \frac{\sum Zindj}{N}$$

Where, LSi = Livelihood Security for one indicator, $\sum Zindj$ = Summated standardized score of all respondents for one indicator, N= Number of households covered in the study

After computing the Livelihood Security Index for individual indicators, an overall composite “Livelihood Security (LS) Index” was derived using the formula provided below:

$$LSi = \frac{\sum WiHLSi}{\sum Wi}$$

Where, LSi = Livelihood Security, HLSi = Household Livelihood Security, $\sum Wi$ = Summated value of weightage of all indicators

To standardize the index, validity was assessed to ensure that it accurately measured what it was intended to measure, thereby confirming the authenticity of the results. An index is considered valid if it supports logical reasoning and effectively reflects the construct it aims to capture. In this study, content validity was

used to evaluate the index. This was determined using the expert judgment method, which involved consulting subject matter experts to evaluate the appropriateness and comprehensiveness of the indicators. A similar method was used by Shruti et al., (2019) & Verma et al., (2024). Only those indicators that received at least 80 per cent approval from experts were retained, indicating strong content validity.

To examine the relationship between the selected independent variables and the dependent variable, bivariate correlation analysis was conducted using SPSS version 26.0. The correlation coefficients (r) were calculated and evaluated for statistical significance. The dependent variable, Livelihood Security, was denoted as Y_1 . The independent variables included: Age (X_1), Education (X_2), Family Type (X_3), Family Size (X_4), Flock Size (X_5), Annual Income (X_6), Landholding (X_7), Farming Experience (X_8), Extension Contact (X_9), Mass Media Exposure (X_{10}), Knowledge Level (X_{11}), Attitude Level (X_{12}), Adopted Practices (X_{13}), Innovativeness (X_{14}), Risk Orientation (X_{15}), Economic Motivation (X_{16}), and Credit Orientation (X_{17}).

RESULTS

Indicators having a Relevancy Weightage (RW) greater than 0.80 and a Mean Relevancy Score (MRS) exceeding 2.40 were retained. Through this process, the final set of indicators for each LSI dimension was selected, refined, and revised based on expert feedback. The finalized dimensions of the LSI, along with their respective indicators, RW, and MRS values, are presented in Table 1.

Livelihood Security Index values of different dimensions

Livelihood Security Index values (Table 2) highlight the different aspects of livelihood security among respondents. The composite index value of 0.617 reflects an overall moderate level of livelihood security among the respondents, reinforcing the need for balanced and targeted strategies to address specific areas of improvement (Pradhan et al., 2020). The highest index value was observed in resource use efficiency (0.664), indicating that respondents generally manage their resources effectively. Similar findings had been reported where medium to high levels of efficiency were

Table 1. Selected Livelihood Security Indicators with respective Relevancy Weightage and Mean Relevancy Score

Items	RW	MRS
Food and nutritional security		
Sheep farming assists farmers in meeting their daily needs consistently throughout the year.	0.89	2.67
A nutritious meal for family members is affordable if the farmer practices sheep farming.	0.83	2.50
Products obtained from sheep farming contribute to attaining nutritional stability for the family.	0.83	2.50
There is a need to increase expenditure on food to enhance living standards.	0.88	2.64
The resilience of sheep farming households during food insecurity shocks, such as droughts or market fluctuations for food and nutritional security.	0.90	2.70
Economic and marketing security		
Sheep farming gives more net profit per unit as compared to others.	0.91	2.73
Sheep farming reduces reliance on a single enterprise, thereby lowering the dependency ratio.	0.82	2.46
Sheep farming produces consistent income throughout the year	0.84	2.52
There will be greater utilization of the marketing network for promoting sheep and their meat.	0.91	2.75
Sheep farmers who have insurance policies for their animals ensure financial security.	0.89	2.67
Infrastructural security		
Sheep farming enhances both farm and household infrastructure as a result of increased income and social consciousness.	0.85	2.55
Sheep farming promotes utilization of private infrastructure such as credit facility, input sale facilities, medical dispensary etc.	0.85	2.55
Sheep farming enhances farmers' access to and utilization of modern information and communication technology (ICT) tools.	0.86	2.58
Sheep farming creates opportunities for farmers to access and adopt a range of technologies that can contribute to the success and sustainability of their sheep farming operations.	0.89	2.67
Government support programs or initiatives benefited you as a sheep farmer.	0.91	2.73
Social security		
Sheep farming improves the social status of the family due to the additional income generated.	0.83	2.50
Social participation as an office bearer or member in either cooperative societies or any SHG will ensure the social security for the family.	0.82	2.47
Sheep farming helps indirectly in improving the education status of the children's and family due to increase income level	0.82	2.47
Sheep farming has the potential to decrease gender discrimination as women can participate in raising and managing sheep.	0.81	2.44
Awareness about one's right to utilize or access public resources in sheep farming to support their farming activities.	0.82	2.47
Resource use efficiency		
Sheep farming facilitates in effective utilization of the resources, as sheep eat more different type of plants than any other kind of livestock.	0.88	2.64
Utilization of manure and left-over materials in sheep farming is done effectively via agriculture.	0.89	2.67
Sheep helps to clean grains lost at harvest time and thus convert waste feed into profitable products.	0.85	2.55
Sheep farming is cost-effective because of their close grazing nature and ability to utilize very low-set vegetation that no other animal can utilize.	0.89	2.67
Sheep can be profitable occupation for a farmer and can fit well into mixed farming.	0.85	2.55

RW= Relative Weightage, MRS= Mean Relevancy Score

prevalent among farmers using integrated approaches (Chandana et al., 2023). Economic and marketing security (0.649) also ranks high, suggesting stable economic conditions for many respondents, which aligns with evidence that diversified livelihoods and improved market participation enhance economic resilience (Mishra et al., 2023). In contrast, food and nutritional security (0.556) and infrastructural security (0.589) have lower index values, indicating areas where respondents might face more challenges. These gaps are frequently observed in rural regions, especially where agricultural diversification or infrastructure investment is limited (Gautam & Jha, 2023). These insights can guide future interventions to focus on improving food and nutritional security and infrastructure to enhance overall livelihood security.

The Figure 1 plots the distribution of index values in descending order with a cumulative line on a secondary axis as a percentage of the total.

From Table 3, it was revealed that the 48.33 per cent of the sheep farmers belonged to the medium level of food and nutritional

Table 2. Livelihood Security Index values of different dimensions

Indicators	Index value
Food and nutritional security	0.556
Economic and marketing security	0.649
Infrastructural security	0.589
Social security	0.632
Resource use efficiency	0.664
Composite index value	0.617

Table 3. Distribution of sheep farmers according to different dimensions

Dimensions	Percentage
Food and nutritional security	
Low (0.30-0.48)	33.33
Medium (0.49-0.66)	48.33
High (0.67-0.86)	18.33
Economic and marketing security	
Low (0.35-0.53)	30.00
Medium (0.54-0.72)	55.00
High (0.73-0.90)	15.00
Infrastructural security	
Low (0.30-0.48)	35.00
Medium (0.49-0.67)	51.67
High (0.68-0.85)	11.67
Social security	
Low (0.36-0.51)	33.33
Medium (0.52-0.67)	56.67
High (0.68-0.80)	10.00
Resource use efficiency	
Low (0.32-0.50)	25.00
Medium (0.51-0.69)	58.33
High (0.70-0.88)	16.67
Over all LSI	
Low (0.30-0.50)	31.67
Medium (0.51-0.70)	55.00
High (0.71-0.90)	13.33

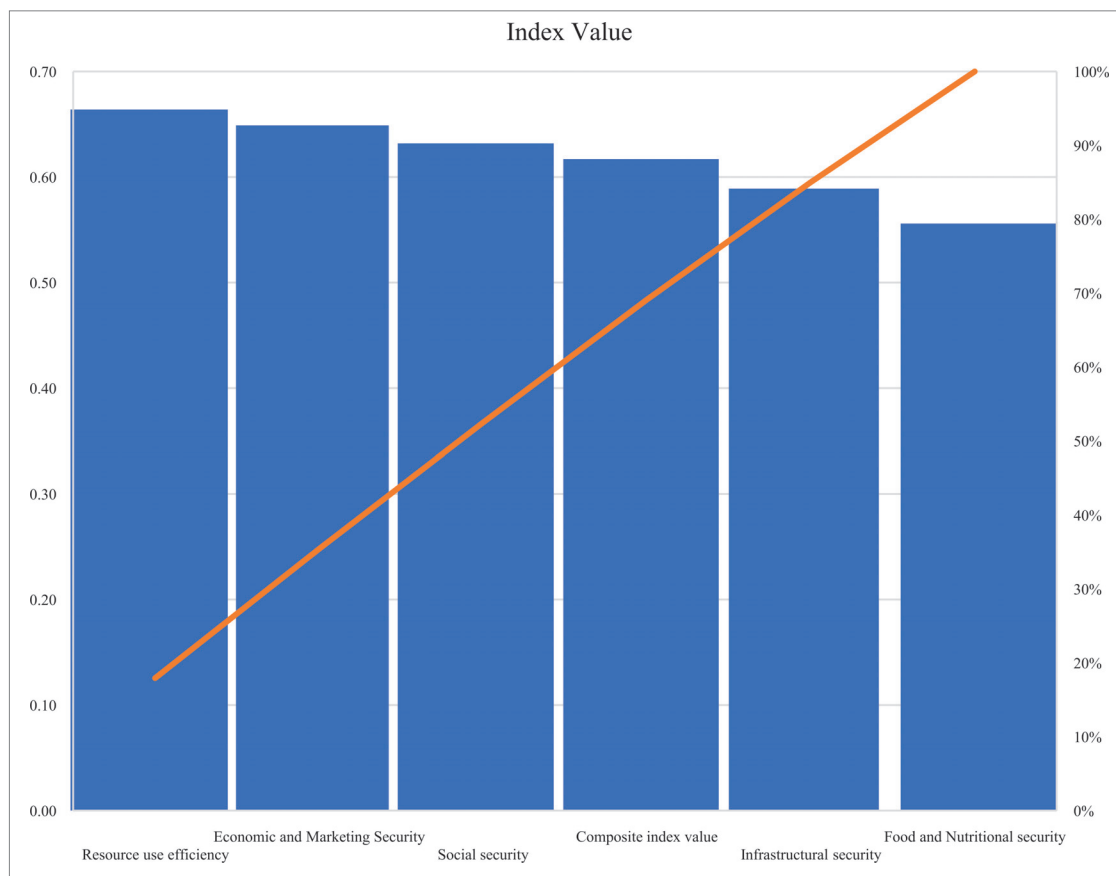


Figure 1. Distribution of index value in descending order

security, followed by 33.33 per cent who belonged to the low level, and 18.33 per cent who belonged to the high level. This indicates that while sheep farming does contribute to the food and nutritional security of farmers, there is a noticeable variation in the levels of security among these farmers. Similar patterns have been observed in other contexts, where a majority of small farmers fell into medium livelihood security levels (Pradhan et al., 2020); (Gautam & Jha, 2023). For economic and marketing security, the majority (55.00%) of the sheep farmers belonged to the medium level, followed by 30 per cent at the low level, and 15 per cent at the high level. The majority of farmers falling into the medium security level could be due to factors such as variable market prices, fluctuating demand for sheep products, and limited market access, which are common determinants affecting livelihood security (Mishra et al., 2023; Chaudhari et al., 2023). The data also indicates that the majority (51.67%) of the sheep farmers belonged to the medium level of infrastructural security, followed by 35 per cent at the low level, and 11.67 per cent at the high level. This predominance suggests that most farmers have basic infrastructure such as shelter and water supply but lack advanced facilities, a finding echoed in research on infrastructure-related livelihood components (Chandana et al., 2023). The distribution of respondents according to their level of social security reveals that a majority (56.67%) fall within the medium category. This suggests a moderate level of access to social resources, which aligns with similar findings in studies across smallholder contexts (Pradhan et al., 2021; Mohammad et al., 2023). Regarding resource use efficiency, the data revealed that 58.33 per cent of the respondents belonged to the medium level, 25 per cent to the low, and 16.67 per cent to the high. This likely reflects a balanced approach to resource management, consistent with observations in livelihood system analyses of small farmers (Gautam & Jha, 2023); (Chandegara et al., 2024). For overall livelihood security, the majority (55.00%) belonged to the medium level, followed by 31.67 per cent at the low and 13.33 per cent at the

high level. The large medium group reflects a pattern commonly found in rural household studies (Mishra et al., 2023). The low-security group, representing nearly a third, signals a need for targeted intervention to enhance access to services and income opportunities, as stressed by Meshram et al., 2024. The small high-security group (13.33%) can provide valuable insights and models of effective livelihood strategies, as highlighted in integrated farming studies (Chandana et al., 2023).

Table 4 presents the correlation analysis between selected socio-economic and psychological variables of farmers and their livelihood security. It highlights the nature and strength of relationships, showing both significant and non-significant associations.

DISCUSSION

Among the variables studied, education exhibited a positive and significant correlation with livelihood security, suggesting that higher education enables farmers to better understand and apply improved farming practices, enhancing their economic resilience and adaptive capacity. Similar observations were reported by Kumar et al., (2019) & Kademani et al., (2020), who emphasized the role of education in increasing farmers' technical competence and decision-making ability. The strongest positive correlation with livelihood security was found for income, implying that better income improves household well-being, access to resources, and adoption of innovations, thereby enhancing livelihood outcomes. This is in agreement with the findings of Sunanda et al., (2014) & Ramya et al., (2017). Flock size also showed a strong and significant positive correlation with livelihood security. A larger flock increases household income and acts as a buffer in times of crisis, particularly in small ruminant production systems. This is corroborated by Kumar et al., (2017), who highlighted that flock size is directly related to profitability in farming. Extension contacts were found to be significantly associated with livelihood security. Regular interaction with extension agents improves access to information, technical guidance, and veterinary care, leading to improved flock management. Kaur & Talukdar (2007) demonstrated that extension services positively influenced productivity outcomes. Knowledge had a significant positive correlation with livelihood security, emphasizing that informed farmers are more likely to adopt good practices, recognize disease symptoms early, and manage resources efficiently. According to Pal et al., (2017), knowledge enhances the decision-making capacity of farmers and increases their readiness to adopt scientific methods in livestock rearing. Attitude and practice were also positively and significantly related to livelihood security. A favorable attitude towards scientific sheep farming enhances willingness to learn and implement new practices, which in turn improves productivity. This aligns with the findings of Kumar et al., (2019), who observed that farmers with positive attitudes and habitual application of improved methods realized higher returns. Risk orientation and innovative proneness also showed strong positive correlation with livelihood security. Farmers with higher risk orientation are more willing to experiment with alternative income-generating strategies and adopt new technologies, thereby enhancing their resilience to uncertainties. Chigadolli et al., (2020) found that risk-tolerant and innovation-driven farmers were

Table 4. Correlation analysis of selected variables of farmers with livelihood security

Independent variables	Livelihood security 'r'
Age	0.151 ^{NS}
Education	.317*
Family type	0.010 ^{NS}
Family size	-0.049 ^{NS}
Flock size	.540**
Annual Income	.607**
Land holding	0.011 ^{NS}
Experience	0.135
Extension agency contact	.500**
Mass media exposure	.351**
Knowledge level	.506**
Attitude level	.412**
Adopted practice	.522**
Innovative proneness	.489**
Risk orientation	.573**
Economic motivation	.344**
Credit orientation	-.259*

** Significant at 0.01 level of probability, * Significant at 0.05 level of probability, NS = Non-Significant

more likely to invest in productivity-enhancing interventions. Mass media exposure and economic motivation contributed significantly to livelihood security. Access to mass media plays a vital role in updating farmers with timely and relevant information, which can influence decision-making and farm planning. These findings are consistent with those of Pal et al., (2017) & Ramya et al., (2017). On the other hand, credit access showed a negative but significant relationship with livelihood security. This might be due to improper use of loans, debt burdens, or lack of financial literacy among farmers, leading to increased economic vulnerability. This observation resonates with the conclusions drawn by Mahadik & Sawant (2012). Variables like age, family type, family size, landholding, and farming experience were found to be non-significant, indicating that these demographic characteristics might not have a direct or strong influence on livelihood security. This could be because livelihood security depends more on dynamic behavioral traits and access to services and resources than on static personal or structural factors. Similar interpretations were reported by Mishra et al., (2020).

CONCLUSION

The livelihood security of sheep farmers was found to be predominantly moderate across various dimensions. Resource use efficiency and economic security indicated good capacity in resource management and income generation, while food, nutritional, and infrastructural security highlighted the need for targeted interventions. The composite index and distribution analysis confirmed that most respondents fell into the medium category, with only a few experiencing high or low levels. Correlation analysis revealed income, flock size, extension contact, knowledge, and risk orientation as strong positive contributors, while education, attitude, practice, and innovative proneness also played significant roles. Conversely, credit access showed a negative correlation, suggesting issues of financial mismanagement. The findings underscore the importance of strengthening knowledge systems, infrastructure, market access, and behavioral competencies to elevate livelihood security.

DECLARATIONS

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

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

The authors declare that during the preparation of 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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Exploring the Dimensions of Millet Awareness among Generational Cohorts

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HIGHLIGHTS

- Millet awareness varies among different generational cohorts such as Generation X, Generation Y and Generation Z.
- Nine dimensions of awareness regarding millet and millet-based products were identified.
- Millet awareness consists of four core dimensions, i.e. health-related, product-specific, environmental, and socio-cultural.
- Understanding generational awareness patterns can inform targeted strategies for promoting millet consumption.

ARTICLE INFO

Keywords: Consumer awareness, Millets, Organic products, Exploratory, Millet awareness, Qualitative.

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ABSTRACT

The rising disposable income and growing awareness of environmental sustainability have driven a shift towards healthier lifestyles across generational cohorts, with millets gaining popularity as a nutritious and sustainable food option. Although rural consumers adopt millet products in their regular diet, urban adoption seems limited. Therefore, the study explored millet awareness among urban consumers from Generations X (aged between 42-60 years), Y (28-42 years), and Z (18-28 years) using a qualitative approach, incorporating in-depth interviews and focus group discussions. The data was analysed through grounded theory methodology adopting the Gioia Technique. The findings revealed nine distinct types of millet awareness and highlighted variations across generational cohorts. Furthermore, the study identified four key dimensions of millet awareness, such as health-related awareness, product-specific awareness, environmental awareness, and socio-cultural awareness, thereby contributing to the existing body of knowledge. These insights provide valuable guidance for marketers, policymakers, and society to enhance awareness and adoption of millets, thereby promoting health, sustainability, and broader sustainable development goals.

INTRODUCTION

Millets are a group of small-seeded grasses cultivated as food crops around the globe. They are consumed primarily in many parts of the Asia and Africa continents (Chaudhary et al., 2023). These are known as nutri-cereals and can be consumed in various forms of food choices. In the dynamic consumer lifestyle, dietary patterns have also undergone a significant change over the years (Gherasim et al., 2020). The food production and marketing system plays a significant role in shaping consumer consumption patterns (Timmer, 2017). Recent studies emphasize the need for sufficient

consumption of healthy diets, which not only have a positive impact on the human body as well as environment friendly, having a sustainable effect (Willet et al., 2019; Latka et al., 2021; Pavan Kumar et al., 2024). The increasing health challenge has led consumers to change their diet preferences by shifting away from staple cereals and making way for healthier foods such as nutri-cereals like millets and other diverse food groups (Singh & Vemireddy, 2023). Furthermore, the change in dietary habits nowadays has led to an upward growth in the focus on nutrition, safety and health function rather than the quantity in the domestic food consumption (Meng et al., 2021)

The consumption of millet has been somewhat limited over the years, resulting in decreased farming of different kinds of millets (Meena et al., 2021). To revamp the millet consumption and create demand for millet and millet-based products, the Government of India proposed to the United Nations to declare 2023 as the “International Year of Millets,” which was seconded by various countries, resulting in the declaration of the same (Thorikonda et al., 2024). To increase the domestic demand of millet, Government of India has taken up various initiatives, for example Indian Railway’s “One station One product” initiative (Rao et al., 2021). Similarly, different state governments have taken initiatives for the upliftment of millet farming and consumption, like the Odisha Millet Mission by the Government of Odisha.

Millets are still not widely adopted by urban consumers in India, despite its acknowledged nutritional worth, environmental advantages, and cultural importance. Urban markets have a significant impact on product innovation, national food trends, and the need for sustainable agriculture (Sanders, 2006). Given that cohorts differ in their cultural attachments, environmental concerns, and health interests (Gray et al., 2019), it is especially important to comprehend how millet awareness varies with generation. Therefore, this study fills a crucial knowledge gap by examining the differences in awareness across Generations X, Y, and Z along nine important dimensions. The study focused on exploring the diverse dimensions of consumer awareness about millets and examining generational variations in the types of millet awareness. A qualitative research technique was used to conduct the research.

METHODOLOGY

The study explored the knowledge and awareness of urban consumers regarding millet-based products of three different generations (Gen X, Y and Z) through a qualitative research approach. The respondents were selected through a purposive sampling technique from tier 1 and tier 2 cities of Odisha, West Bengal, Andhra Pradesh, and Telangana. Customers who consumed millet and millet-based products 3-4 times a week were recruited to be the respondents for the study. The data was collected through in-depth interviews and focus group discussions. The data collection process continued till data saturation was achieved, resulting in a sample size of 34 (11 from Gen X, 13 from Gen Y, 10 from Gen Z) in in-depth interviews. To gain deeper insight into awareness regarding millet and millet-based products, 6 focus group discussions were conducted with 2 FGDs from each generation. Each focus group consisted of 6-8 members, resulting in 15 participants from Gen X, 15 participants from Gen Y, and 16 participants from Gen Z. The combination of interviews and focus groups also enabled triangulation of perspectives, capturing both individual narratives and group-level dynamics to strengthen the validity of the findings. The interviews and FGDs were recorded with the participants’ consent, translated wherever required and transcribed for the data analysis process. After translation and transcription, member checking was done to ensure that the transcribed data captured the participant’s emotion correctly.

The study adopted grounded theory methodology (Glaser & Strauss, 1975) for the data analysis process with the Gioia technique (Gioia et al., 2013) with a two-step iterative data analysis approach to identify the underlying themes of the data. The first-

order analysis classified the data set into various first-order codes, which explained the inherent meaning of the sentence. The fraction of the sentences, such as “Millets are naturally free from gluten”, was coded as “gluten-free”, leading to 90 first-order codes. Furthermore, the second-order analysis was to further classify the first-order codes into various second-order themes. This process was iterative, where the codes were continually compared with the data set. The first order codes, such as “fibre content”, “contains fibre”, “rich in fibre”, were classified under the second order theme “high-fibre content”, resulting in 33 second order themes. Additionally, these second-order codes were categorised under different aggregate dimensions, resulting in the findings of the study. The second-order themes, such as “locally available”, “not readily available”, and “selectively available”, were categorised under a single aggregate dimension named “limited availability” of the millets. The study identified 9 aggregate dimensions such as nutrition, disease prevention, healthier alternative, sustainable farming, social impact, limited availability, product variety, safe consumption, and culture.

RESULTS

The study conducted in-depth interviews with 34 individuals and 6 focus group discussions inclusive of all the generations ageing between 18-60 yrs. Among them all of the respondents were familiar with Finger millet whereas 87 per cent consumed Pearl millet, 26 per cent & 75 per cent consumed foxtail and sorghum respectively. However lesser consumers consumed little millet (14%), proso millet (17%) and kodo millet (20%). The study adopted grounded theory methodology for the analysis of the collected data. The data analysis discovered 9 aggregate dimensions from 33 second order codes which explained the customers’ knowledge regarding different types of awareness regarding millet and millet-based products. The findings identified nutrition awareness among the urban consumers which explores the customers’ awareness of different qualities of millets such as gluten free, vitamin rich, source of energy, high fibre and satiety factors. The customers seemed to be aware of the different diseases such as cardiovascular diseases, hypertension, diabetes, weight management and gastrointestinal issues which can be prevented or kept in control by regular consumption of millets. With the changing lifestyle, the customers are aware of the different millets being an alternative to the traditional food grains such as rice and wheat. Furthermore, the customers also discussed about the positive impact of millet farming on the agrodiversity, organic foods, water efficiency and low carbon emission factors making millet a sustainable farming option. Along with this, millet farming and marketing also results in economic empowerment, cultural preservation, food security and social empowerment highlighting the awareness of urban consumers awareness regarding the social impact of millet farming and consumption. The consumers also discussed about the limited availability which becomes a challenge for them to include in their regular diet. Additionally, the customers also shared regarding the safe consumption knowledge, which is essential for the consumer to retain the benefits of millets without occurring any harm to them. Lastly, various customers discussed about millet being a part of their culture and traditions. The transcripts provided in Table 1 will provide clarity regarding the results. The data structure is provided in Figure 1.

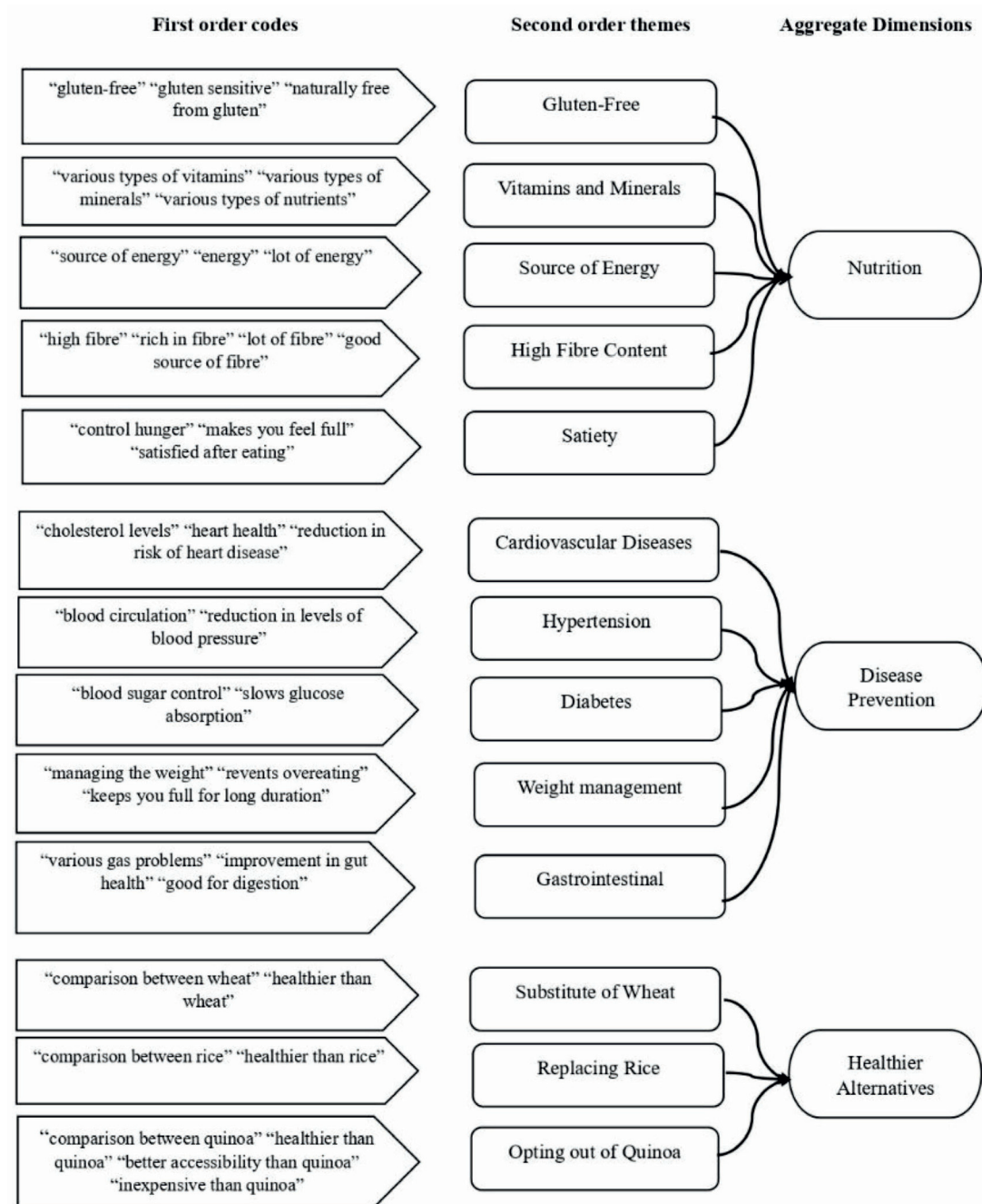
Table 1. Aggregate dimensions with transcript reference

Aggregate Dimensions	Transcripts
Nutrition	“Millets are naturally free from gluten. Finger millet (ragi), pearl millet (bajra), sorghum (jowar), and foxtail millet are all gluten-free.” (P33, 57 yrs) “Millets are full of important vitamins and minerals. Finger millet (ragi) has a lot of calcium Pearl millet (bajra) has magnesium. Foxtail millet provides vitamins and Sorghum (jowar) is rich in iron, magnesium, and B vitamins. Millets are good for any diet and help with overall health.” (P17, 24 yrs) “Millets give me long-lasting energy and satiety without the urge to snack frequently. Millets are good at offering energy for a long duration, which helps to keep hunger in control and is easily digestible.” (P16, 50 yrs) “Millets are rich in fibre, helping with digestion and overall health.” (P12, 34 yrs) “Millets have high fibre content; specifically, Pearl millet and Finger Millet have High fibre content. However, Foxtail millet has Moderate fibre content.” (P7, 20 yrs)
Disease Prevention	“My blood pressure has been under control since I started consuming millets. I feel that this is mainly due to its ability to balance sodium, leading to enhanced circulation.” (P27, 47 yrs) “Millet has been crucial in enhancing the overall health of my family members, particularly, I notice that since we have started to consume millets frequently, we are able to manage diabetes better.” (P9, 46 yrs) “After eating millet cuisines, I feel full, and I am able to avoid overeating, as a result I am able to manage my weight effectively.” (P21, 24 yrs) “I know millets are gluten-free and light on the digestive system, making them one of the best options for those with gluten intolerance or vulnerable to gastrointestinal problems like bloating or indigestion. I feel my gut health has been improved after consuming millet regularly.” (P5, 30 yrs) “Eating millet can be good for my heart health. The high magnesium and fibre content of millet helps in reducing the risk of heart disease.” (P25, 44 yrs)
Healthier alternative	“Millets have high nutritional value in addition to fiber content. Which makes it a complete food unlike wheat which is rich in Carbs.” (P4, 32 yrs) “Millets are better than rice as they have less calories and don't lead to gas. So, I think they are better than rice. I feel I intake less when I eat millet. It makes me feel full; thus, I eat less when I consume millet.” (P26, 22 yrs) “Millets are easier to find and budget friendly compared to quinoa. Because of this, it's a convenient option for our family. They're also rich in fibre and provide steady energy, which is great for keeping me full and satisfied.” (P1, 49 yrs)
Sustainable Farming	“Millets include a wide range of species such as finger millet, pearl millet, foxtail millet, sorghum, and more. This diversity helps maintain genetic variation in agricultural systems.” (P31, 54 yrs) “Growing millet can reduce environmental pollution, as these grains can sustain without artificial fertilizers and pesticides, even in poor soil conditions.” (P23, 35 yrs) “Millet is highly sustainable, unlike water-intensive crops like wheat and rice. These grains can also grow on barren land and survive drought. Moreover, they also prevent erosion and maintain soil health.” (P18, 55 yrs) “Millet cultivation can be done efficiently on less fertile soil, even without artificial additives. Moreover, they also need less input from machines. This leads to lower carbon emission.” (P10, 26 yrs)
Social Impacts	“In areas that lack access to resources, millet cultivation is highly profitable, unlike other crops.” (P19, 33 yrs) “The tribal culture is interlinked with millets; therefore, millet cultivation is vital to preserve the tribal culture and their traditional practices.” (P25, 44 yrs) “As millets can thrive in harsh climates and survive poor quality soil, they are highly effective in solving the food security problems of marginal farmers and tribals.” (P20, 30 yrs) “Cultivation of millets is essential to preserve the culture of tribal communities; by doing so, the social status of tribals is enhanced, as people start to know their culture via consuming millets, and hence respect it.” (P32, 52 yrs)
Limited Availability	“Millet is not easily available in retail stores. Also, it is costly.” (P3, 35 yrs) “In most traditional and local markets, raw millet grains and products made from millet are readily available.” (P8, 48 yrs) “Millet-based products and grains can be purchased through local markets and health food stores or specialized outlets like millet Shakti, as well as e-commerce sites and online platforms that allow us to buy a variety of millet products.” (P24, 21 yrs)
Product Variety	“There are millet-based breakfast cereals like flakes or granola, which are healthy and nutritious for us, also snack options such as millet cookies, energy bars, and puffs, which are tasty as well as healthy.” (P15, 32 yrs) “Ready-to-use ragi and bajra millet flours for making rotis and dosas to instant millet khichdi, millet upma, millet-based instant noodles, snack bars, a range of ready-to-cook range of millet-based products are available in the market.” (P11, 37 yrs) “I have often come across Bajra, which is high in fibre and minerals and Ragi, is also because it is rich in calcium content. This is why people like to eat both Ragi and bajra. I know only about these and have tried these, but there could be more varieties, too.” (P14, 19 yrs)

Table 1 contd....

Aggregate Dimensions Transcripts

Safe Consumption	“Look closely for any extraneous items, such as stones or insects, among the millet grains. Rinse well: In order to get rid of any residue or debris, wash the millet grains under cold running water.” (P33, 57 yrs) “First, we should let millet cool down at room temperature before storing, and we should put it in air-tight containers, which allows them to maintain its quality.” (P7, 20 yrs) “Like any other product, we can check the packaging to see if it is airtight and within the expiry date. If I can smell, I will smell those products and try to get to know if it smells ok or smelling awful.” (P13, 33 yrs)
Culture	“They play a very important role in religious rites, traditional cuisine, and Ayurvedic medicine.” (P27, 47 yrs) “People use millet during different religious and cultural ceremonies, such as Pongal, Onam, Makar Sankranti, and Navratri.” (P2, 27 yrs) “During festivals like Nuakhai, the festival of Odisha, folk songs sung as Nuakhai Bhet Ghat’Folk songs associated with millets are Rajasthan’s Bajra Ni Roti and Karnataka’s Ragi Muddeya Rasa.” (P6, 22 yrs)



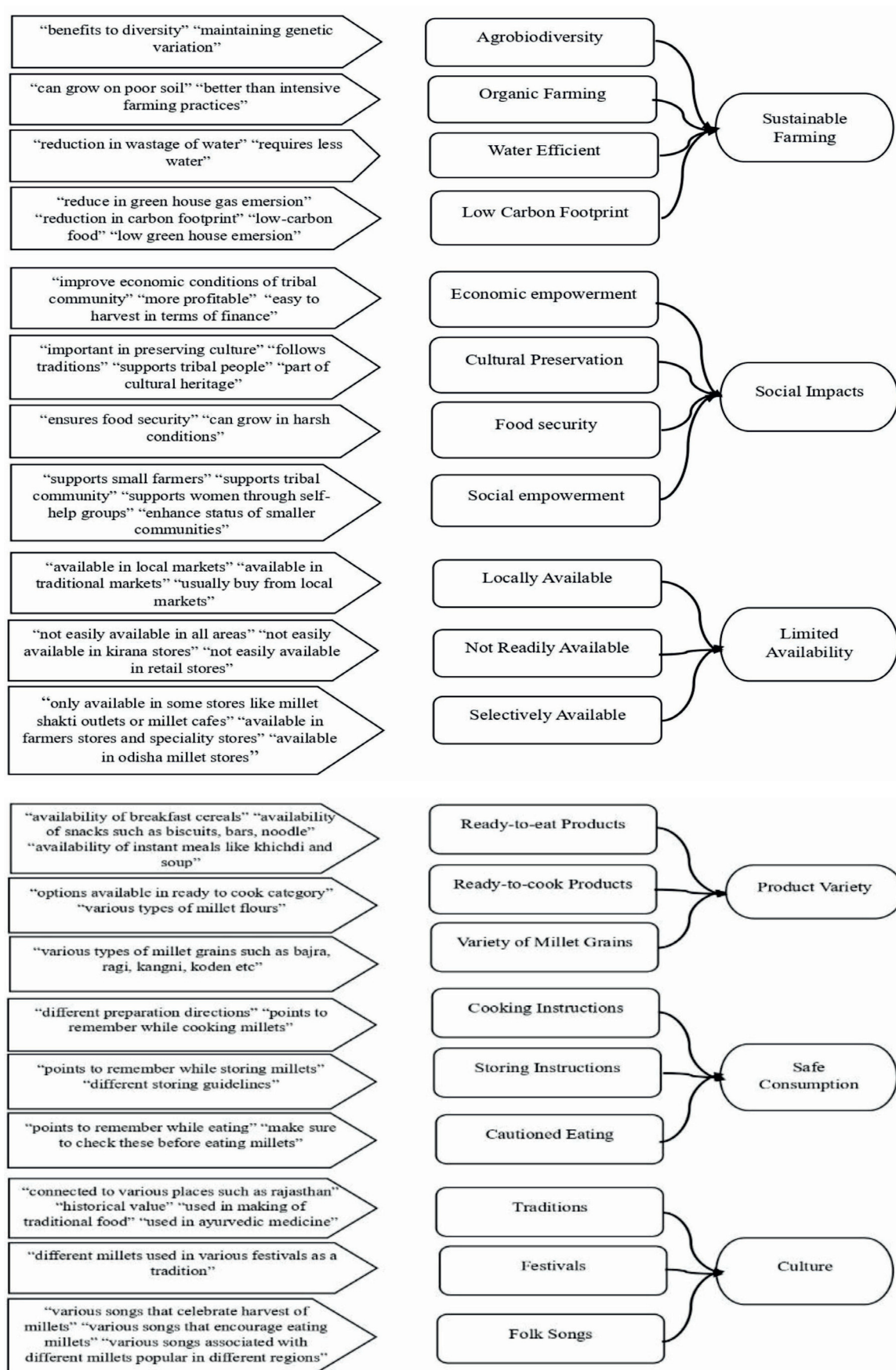


Figure 1. Data structure: first-order codes, second-order themes, and aggregate dimension.

DISCUSSION

The findings revealed that there are nine types of millet awareness among consumers. These nine types of millet awareness were categorized under four dimensions, namely, health-related awareness, product-specific awareness, environment-related awareness and socio-cultural awareness (Figure 2).

The health-related awareness dimension consists of nutrition, disease prevention and healthier alternative types of millet awareness. This indicates the customers knowledge regarding millet

being gluten-free, fibre-rich grain with essential nutrients which help in preventing various chronic illnesses. The product-specific awareness dimension highlights the customer's knowledge regarding different millet grains and millet based ready to eat products as well as preparatory cautions and availability of the products. Furthermore, the environment related awareness discusses about sustainable farming techniques and the influence of millet farming supporting the agrodiversity and impacting on ecological balance. Additionally, the socio-cultural awareness highlights the consumer awareness of millet being part of different cultures along with the

Figure 2. Classification of Types of millet awareness

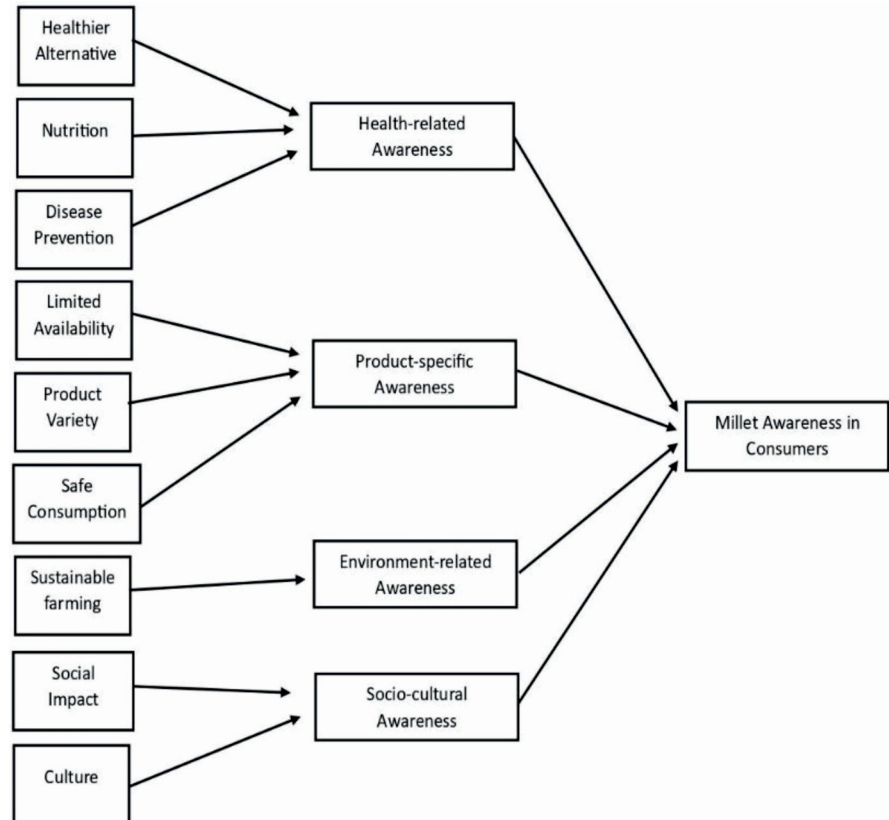


Table 2. Generational differences in different millet awareness dimensions

Awareness Dimensions	Generation X	Generation Y	Generation Z
Health-related awareness	Source of energy Satiety Chronic Disease	Vitamins Minerals Chronic Disease Disease Prevention Alternative to Rice & Wheat	Gluten free Vitamins Minerals Disease Prevention Alternative to Rice & Wheat
Product-specific awareness	Safe consumption Raw millets Limited Availability	Ready to cook Limited Availability	Ready to eat Ready to cook Limited availability
Environment-related awareness	Millet cultivation techniques Agro-biodiversity	Sustainable farming practices Impact on environment Agro-biodiversity	Low carbon footprint
Socio-cultural awareness	Traditional Customs and festivals Songs of millets Women empowerment Social upliftment	Economic empowerments Self-Help Groups	Food security Upliftment of farmers

societal benefits of millet cultivation and promotion. According to Table 2, Generation Y and Z focused more on the role of millets in providing vitamins and minerals and their potential in disease prevention and overall health improvement. Generation X discussed more about satiety, energy levels of millets, and chronic diseases. Generation X demonstrated a greater understanding of the safe consumption of millets. Discussions on product variety were more prominent among Generation Y and Z, with Generation Z showing a preference for ready-to-eat millet products and Generation Y favoring ready-to-cook options. In contrast, Generation X focused more on raw millets. Despite these differences, all generations were equally aware of the limited availability of millets. Therefore, millet cultivation supports sustainable farming. In addition to this, Generation X was more aware of sustainable millet cultivation techniques and agro-biodiversity, while Generation Y was more concerned about sustainable farming practices and their impact on the environment. Generation Z showed more interest in the carbon footprint associated with millet production. Generation Z emphasized issues such as food security and the upliftment of small farmers and women, whereas Generation Y focused more on economic empowerment. Generation X displayed a deeper understanding of the role of millets in traditional customs and festivals, including knowledge of songs associated with millets. This finding extends the studies conducted by Shah et al., (2021) and Singh & Vemireddy (2023) by differentiating between different generations.

The current study provided novel insights into knowledge and awareness regarding millet and millet-based products among urban consumers. The findings extended the study conducted by Shirahatti et al., (2022), which conducted this study from a quantitative perspective. The findings identified unique dimensions of millet awareness among different generations and studied the impact of generational cohorts as well. Furthermore, the study also extends the study conducted by Beera et al., (2024), by considering not only finger millet but also considering other kinds of millets and extending the study by focusing on gen z customers as well. However, in contrast to the study by Dudekula et al., (2023) who studied with the different stakeholders of millet supply chain, this study was undertaken from the perspective of consumers only.

The study organizes these nine types of millet awareness into four key dimensions: health-related awareness, product-specific awareness, environment-related awareness, and socio-cultural awareness. While existing studies have explored consumer awareness of millets (Reddy & Patel, 2023; Shirahatti et al., 2023), systematically categorizing these types into such comprehensive dimensions was overlooked. Therefore, this study provides conceptual framework that enriches academic discourse by providing a structured approach to understanding millet awareness.

The practical implications can be adopted by different spheres of marketing personnel involved in food business such as restaurants, processed food organizations and food corners. Although the millet-based food category has variety of products under its umbrella, the product managers can develop new recipes substituting the traditional food options. Considering the fast-moving lifestyle of the youth, ready to eat and cook product segment can be enhanced having more options to choose from. The

operation managers should oversee the supply chain of millet procurement till to the table of the consumers. The managers should try to bridge the gap in between the demand and supply of millet and millet-based food products.

Converting the Awareness into Action (based on AIDA) should be the primary focus of marketing managers. The marketing managers should promote the nutritional benefits to target the Gen Z customers for increased consumption of millet and millet-based products. Similarly, the managers should focus on disease prevention awareness among the consumers to target the Gen Y and Gen X customers. Furthermore, the limited supply of millets signals an opportunity for small farmers to expand production in terms of both quantity and variety. This can encourage sustainable farming practices, contributing to environmental conservation and mitigating pollution. Collectively, these efforts can improve the quality of life in rural areas while fostering a healthier environment for all.

CONCLUSION

The study highlighted generational variations across various cohorts. Notably, Generation Z exhibited the highest awareness of health-related aspects, while Generation Y demonstrated greater awareness of environmental issues, and Generation X displayed a deeper understanding of sociocultural aspects. Interestingly, product-specific awareness was found to be relatively uniform across all generations, suggesting a shared understanding of millet-related product characteristics regardless of age group. Future research could explore millet awareness in other geographical contexts. Comparative studies could further enrich understanding in this domain. Furthermore, the qualitative approach employed in this study to identify dimensions of millet awareness provides a foundation for future research. Future studies could develop and validate a quantitative scale for millet awareness. Consequently, quantitative and experimental methodologies could also be utilized to provide deeper insights and broader applicability. These directions would contribute to a more comprehensive understanding of millet awareness across diverse contexts.

DECLARATIONS

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

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

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Exploring Consumer Behaviour towards Zero-sugar Beverages: A Case Study of Delhi NCR

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HIGHLIGHTS

- The value of KMO (0.940) and significant Bartlett's Test show the sample is adequate for factor analysis.
- Factor analysis revealed two distinct dimensions: consumer behaviour and consumer perception regarding zero-sugar beverages.
- Chi-squared test indicates a significant association between educational qualification and awareness of zero-sugar beverages among consumers.

ARTICLE INFO

Keywords: Consumer behaviour, Factor analysis, Chi-square test, Zero sugar beverages, Perception.

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ABSTRACT

In recent years, rising consumer health consciousness has led to a significant shift in beverage consumption patterns, especially in urban areas like Delhi National Capital Region (NCR). This research aims to understand consumer behaviour towards zero-sugar beverages in the Delhi NCR. A structured survey of 320 respondents across different age groups, income levels, and health profiles was conducted using a structured questionnaire in 2025 through multistage sampling. Factor analysis was employed as a statistical tool to analyze consumer behaviour and perception towards zero-sugar beverages. A chi-square test was used to examine the relationship between customers' awareness of zero-sugar beverages and their level of education. In the findings, two significant factors had arisen: one concerned consumers influenced by health fears and mistrust; the other was health-conscious or positive consumers, motivated by fitness, health, and informed choices. According to the study, respondents who were highly concerned about their health and concerned about labels preferred sugar-free beverages. There was considerable dissent about the deception that sugar-free beverages are solely for persons with diabetes. The study's overall conclusions indicate that the sugar-free beverage industry in Delhi NCR is still relatively nascent but has a lot of potential.

INTRODUCTION

The global beverage sector has experienced tremendous change as consumer health preferences have changed and worries about sugar-related illness risks have grown (Malik & Hu, 2022). The need for healthy beverage options has increased due to the rising incidence of non-transmissible disorders like weight gain, diabetes,

and tooth disease (Du et al., 2018). Zero-sugar beverages, which provide the taste and enjoyment of conventional sugar-sweetened beverages (SSBs) despite the corresponding calorie consumption, have become one of these fast-expanding categories (Sylvetsky & Rother, 2018). In order to replicate the sweetness of sucrose despite drastically lowering energy content, non-nutritive or low-calorie sweeteners like stevia, sucralose, acesulfame-K, and aspartame are

used in the formulation of zero-sugar beverages (Fitch & Keim, 2012; Gardner et al., 2012). This invention responds to the World Health Organization's (WHO) nutritional guidelines, which intend to minimise the hazards to metabolism and oral disease by limiting the usage of free sugar to less than 10 per cent of overall daily caloric intakes (WHO, 2015). The appeal of these products lies not only in their calorie-free composition but also in advancements in food science and sensory technology, which have enabled manufacturers to enhance flavour profiles and reduce the aftertaste traditionally associated with artificial sweeteners. In addition, businesses are also adding therapeutic substances such as vitamins, herbal extracts, and electrolytes to zero-sugar beverages to promote various healthcare and wellbeing objectives, such as hydration, immune building, and strength improvement (IFIC, 2022).

According to the study of Maiti and Saha (2022), most customers (80%) in metropolitan regions preferred unorganised companies, whereas 78 per cent of customers in rural areas relied on street vendors. Before purchasing, every respondent examined the food's quality, paying particular attention to its colour, shape, and look. Rural residents were marginally more aware of tainted food (68%) than urban residents (64%). According to a survey, Soliga tribes eat more freshly caught fish than Koragas, primarily due to convenience, affordability, and access. Choice variations draw attention to regional differences in tribal purchasing patterns. These observations can help fish vendors and health officials encourage fish eating, particularly to enhance nutrition in Dakshina Kannada and Chamarajanagar (Sajeev et al., 2023).

The study aims to analyse and explore consumer behaviour toward zero-sugar beverages in Delhi NCR, with a focus on identifying the barriers and misconceptions that prevent their adoption. In the Delhi NCR, consumer behaviour and attitudes significantly influence the marketplace trends and purchase practices, especially as zero-sugar beverages emerge as a preferred choice among health-conscious individuals. A similar study on consumer perception towards organic food discloses that market variables, such as availability and belief in genuineness, convenience, and socioeconomic position, influence customer buying decisions. It has been underlined that agricultural extension agencies and other stakeholders must work together to raise awareness and educate the public in order to close the disparity amongst farm-level activities and consumer views and encourage more sustainable consumption patterns (Yadav et al., 2024).

METHODOLOGY

A systematic questionnaire provided through an online survey utilising Google Forms was used to collect and analyse primary data from Delhi NCR. A wide range of people live in Delhi NCR, including health-conscious individuals and students from different economic backgrounds and geographical areas. This variability ensures that the results represent a larger population, making it a perfect place to investigate attitudes and intention to sample non-zero-sugar beverages. Delhi NCR is also known for its extensive food and beverage marketing, metropolitan eating patterns, high consumption of sugar-sweetened drinks by college students, and

ignorance of health issues. A sample of 320 respondents was selected, and data were collected using multistage sampling in 2025. Primary sampling units, defined as (wards/sectors), were selected from Delhi, Gurugram, Noida, Ghaziabad, and Faridabad using probability proportional to size. Within each unit, households or intercept points were systematically chosen, and respondents were stratified by education, age, and gender to ensure accurate population representation. A structured questionnaire was designed to gather information, which contained closed-ended questions to assess awareness, perception, and willingness to consume zero-sugar beverages. A 5-point Likert scale was used which was already test and found reliable in the study of Yadav et al., (2024) to design the questions and gather information about consumer behaviour regarding zero-sugar beverages and the barriers and misconceptions that prevent consumers from adopting zero-sugar beverages.

Factor analysis was employed to analyse and interpret the data by using IBM SPSS 22 software. The data met the requirements for factor analysis. The KMO value was above 0.6. Bartlett's test of sphericity was significant ($p < 0.05$). These results show there were enough correlations among variables. Therefore, the dataset was suitable for reliable factor extraction. Factor analysis was used to identify the factors responsible for identifying the concerned consumers, influenced by health fears and mistrust, and health-conscious or positive consumers, motivated by fitness, health, and informed choices.

The chi-square test was used to check the relationship between the educational qualification of respondents and their awareness towards zero-sugar beverages. A similar test was performed to check the relationship between farmers' demographic profile and their awareness of climate change (Kumar & Saxena, 2024). The hypothesis formulated for checking the association between the educational qualification of respondents and their awareness of zero-sugar beverages:

H_0 : There is no significant association between the educational qualification of respondents and their awareness of zero-sugar beverages.

The Pearson Chi-Square value was 20.371 with three degrees of freedom and the value of p (level of significance) 0.000, which was significantly below the threshold of 0.05 which demonstrate the statistically significant relationship between the variables examined. With three degrees of freedom and a significance level of 0.003, the Likelihood Ratio value 14.195 provides additional evidence for a meaningful relationship.

RESULTS

Factor analysis was conducted to analyse the consumer behaviour and perception towards zero-sugar beverages. The results were drawn after analysing the data were presented in the following tables.

Table 1. KMO and Bartlett's test Table

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.940
Bartlett's Test of Sphericity	Approx. Chi-Square	3153.121
	df	105
	Sig.	.000

Table 1 reflected the outstanding Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy score of 0.940, indicating that the dataset was appropriate for factor analysis. The parameters were suitable for structure discovery because of their high KMO value, which means an elevated degree of shared variance. Furthermore, the correlation matrix did not constitute an identity matrix, as confirmed by the significant results of Bartlett's Test of Sphericity (Chi-square = 3153.121, df = 105, $p < 0.001$). It indicated that the variables have important links with one another, which supports proceeding with factor analysis.

Table 2 identified two components based on their eigenvalues being greater than 1. An additional 19.69 per cent of the total variance was explained by the second component, which has an eigenvalue of 2.954, while the first component's initial eigenvalue of 7.020 accounts for 46.80 per cent. These two elements work together to explain 66.49 per cent of the cumulative variance, indicating a significant representation of the original dataset (Table 2). Following rotation, which redistributes the explained variance for improved interpretability, the first and second components

account for 30–12 per cent and 36–38 per cent, respectively. This rotated solution offers a more balanced and transparent structure of the underlying factors, indicating that these elements successfully capture most of the dataset's information.

The first component can practically be a group of closely associated variables that capture one aspect of the studied construct. In contrast, the second aspect might capture a separate but complementary value. By decreasing multicollinearity and enhancing model stability, such a distinct separation promotes conceptual comprehension and makes it easier to perform follow-up analysis.

The rotated component matrix showed two clear factors shaping consumer views on zero-sugar beverages. Component 1 revealed perception of concerns included harmful preservatives, bad taste, artificial sweeteners, long-term health risks, and higher prices of zero-sugar beverages for consumers. This suggests a group of consumers affected by fear, distrust, and scepticism about zero-sugar drinks. On the other hand, Component 2 reflected positive views and motivations. It was strongly connected to the belief that zero-sugar beverages are healthier, help with weight management,

Table 2. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.020	46.800	46.800	7.020	46.800	46.800	5.456	36.375	36.375
2	2.954	19.692	66.492	2.954	19.692	66.492	4.517	30.117	66.492
3	.661	4.409	70.901						
4	.590	3.933	74.834						
5	.573	3.822	78.657						
6	.421	2.810	81.467						
7	.407	2.711	84.177						
8	.376	2.508	86.685						
9	.352	2.346	89.032						
10	.331	2.204	91.236						
11	.295	1.964	93.200						
12	.286	1.905	95.105						
13	.267	1.781	96.886						
14	.253	1.689	98.575						
15	.214	1.425	100.000						

Extraction Method: Principal Component Analysis.

Table 3. Rotated component matrix

Statements	Component 1	Component 2
I regularly read labels to check for sugar content in beverages.	-.231	.653
I believe zero-sugar beverages are healthier.	-.024	.822
I feel that zero-sugar beverages help in maintaining weight.	-.197	.825
Advertisements influence my decision to try zero-sugar beverages.	-.158	.772
Price is a deciding factor when choosing between zero-sugar and regular beverages.	-.181	.805
I am willing to pay more for zero-sugar beverages	-.148	.773
I prefer zero-sugar beverages over regular sugary drinks.	-.207	.789
I believe that zero beverages smell artificial or have an off-putting aroma.	.634	-.257
I think zero-calorie beverages contain harmful preservatives.	.838	-.220
I avoid zero beverages because they have an unpleasant taste.	.888	-.206
I think zero-sugar beverages are only for people with diabetes or health issues.	.888	-.206
I believe zero-sugar beverages cause long-term health problems.	.798	-.189
I believe that the artificial sweeteners used in zero beverages are unsafe.	.825	-.097
Zero-sugar beverages are too expensive compared to regular soft drinks.	.824	-.169
I believe that zero beverages smell artificial or have an off-putting aroma.	.832	-.050

and are worth a higher price. It also considered the impact of ads and pricing.

Table 4 indicates that the rotated component matrix contained two identified factors: one reflects the consumer behaviour towards zero-sugar beverages, and the other demonstrates the consumer perception towards zero-sugar beverages. The first factor of consumer behaviour towards zero-sugar beverages includes statements that demonstrate positive attitudes and active engagement, such as reading labels on a regular basis (loading = 0.825), thinking about the health benefits (0.822), and being influenced by advertisements (0.789). These products show consumers embracing healthier options despite cost concerns and making well-informed decisions. The factors, with a high Cronbach Alpha of 0.901 and a strong eigenvalue, demonstrate the behaviour-related items' exceptional internal consistency and dependability.

The second factor, consumer perception, reflects doubts and negative views about zero-sugar beverages. It covers health concerns such as beliefs that artificial sweeteners are harmful (0.798) or may cause long-term health problems (0.824) and sensory aversions, including aversion to artificial taste or smell (0.888). A common misunderstanding that zero-sugar beverages are exclusively for people with diabetes or health-conscious people is also brought to

light by the perception factor. This factor exhibits extremely high reliability, indicating a strong coherence in the negative attitudes held by specific consumer segments, with a Cronbach's Alpha of 0.932. Together, these two elements provide a fair assessment of the psychological and motivational obstacles to the uptake of sugar-free beverages.

The findings of Table 5 indicated a strong relationship between consumers' awareness of sugar-free beverages and their level of education. The Pearson Chi-Square value of 20.371 depicted a statistically significant link between the variables under investigation, as demonstrated by a p-value of 0.000, far lower than the 0.05 criterion. According to the high numbers in the YES category relative to their expected values, respondents with higher educational backgrounds (graduate, postgraduate, and above) overwhelmingly reported knowing about zero-sugar beverages. On the other hand, those with only a 12th pass had a higher unawareness count (5) than anticipated (10), suggesting that their awareness was comparatively lower. In general, awareness rises with educational attainment, indicating that consumers' understanding of sugar-free beverages was significantly influenced by education. The results were significant at a 5% significance level, and insufficient evidence supports the null hypothesis. So, the null hypothesis was

Table 4. Factors Identified from rotated component matrix

Factors Name	Statements	Eigen Value	Cronbach Alpha
Consumers' behaviour towards zero-sugar beverages	I regularly read labels to check for sugar content in beverages.	0.825	0.901
	I believe zero-sugar beverages are healthier.	0.822	
	I feel that zero-sugar beverages help in maintaining weight.	0.805	
	Advertisements influence my decision to try zero-sugar beverages.	0.789	
	Price is a deciding factor when choosing between zero-sugar and regular beverages.	0.773	
	I am willing to pay more for zero-sugar beverages	0.772	
	I prefer zero-sugar beverages over regular sugary drinks.	0.653	
Consumer perception towards zero sugar beverages	I believe that zero beverages smell artificial or have an off-putting aroma.	0.888	0.932
	I think zero-calorie beverages contain harmful preservatives.	0.888	
	I avoid zero beverages because they have an unpleasant taste.	0.838	
	I think zero-sugar beverages are only for people with diabetes or health issues.	0.825	
	I believe zero-sugar beverages cause long-term health problems.	0.824	
	I believe that the artificial sweeteners used in zero-calorie beverages are unsafe.	0.798	
	Zero-sugar beverages are too expensive compared to regular soft drinks.	0.634	
	I believe that zero beverages smell artificial or have an off-putting aroma.	0.888	

Table 5. Association between educational qualification and awareness of zero-sugar beverages among consumers

			Awareness of zero-sugar beverages		Total
			No	Yes	
Educational Qualification	12th Pass	Count	5	8	13
		Expected Count	1.0	12.0	13.0
	Graduate	Count	9	115	124
		Expected Count	9.3	114.7	124.0
	Postgraduate	Count	0	26	26
		Expected Count	2.0	24.1	26.0
	Higher Studies/ Above Postgraduate	Count	10	147	157
		Expected Count	11.8	145.2	157.0
Total		Count	24	296	320
		Expected Count	24.0	296.0	320.0

rejected, and the alternative hypothesis will be accepted. It depicts a significant association between educational qualification and awareness of zero-sugar beverages.

DISCUSSION

The study explored the market landscape and consumer behaviour associated with zero-sugar beverages in the Delhi NCR region, offering insights into motivations, awareness levels, purchase behaviour, and the socio-demographic influences shaping this emerging segment. The findings demonstrate a strong relation between awareness and positive behavioural intent, indicating that consumers are more likely to adopt zero-sugar beverages if they actively engage with product information, such as reading labels and considering health benefits. In contrast, unfavourable opinions stemming from health worries and sensory dissatisfaction severely impede the uptake of sugar-free beverages, underscoring the influence of false information and product experiences on consumer sentiments. A major factor in the uptake of sugar-free beverages is consumer preferences. According to research, beverage sweetness positively impacts consumer utility, making sweeter beverages less susceptible to price fluctuations and competition (Jensen et al., 2024). The implication is that health-conscious consumers might be drawn to sugar-free beverages, which are frequently considered healthier options (Gupta et al., 2021). Further consumer behaviour assessment depicts that consumers think zero-sugar beverages are a healthy option, read labels properly, and are influenced by price and advertisement. Consumers frequently read beverage labels to determine the amount of sugar and think sugar-free drinks are healthier and aid in weight maintenance. Additionally, participants report that price sensitivity and advertisement exposure significantly impact their purchase decisions, indicating the importance of external factors like these. On the other hand, some consumers perceive that zero-sugar beverages contain some harmful preservatives, bad tastes, and think these drinks are only made for diabetic persons. Some consumers believe that zero-sugar beverages have an artificial or unpleasant smell, contain harmful preservatives or unsafe artificial sweeteners, and are only meant for individuals with health conditions such as diabetes.

There is a prevailing notion that zero-sugar drinks may lead to long-term health problems and are overpriced compared to their regular counterparts. The study of Yadav et al., (2024) also portrays the attitude of consumers and perception towards organic food products. Agribusiness success is shaped by the entrepreneurial atmosphere, which also affects agripreneurs' attitudes. The experimental study of Miller et al., (2022) states that most participants (75.5%) in this experimental study read warning warnings about sugary beverages and artificial sweeteners carefully, and more than half (55.3%) said that the labels caused them to think about the health risks associated with sugary drinks. Additionally, a lot of people thought drinking sugar-free beverages would help them lose weight, but some people were worried regarding artificial sweeteners and preservatives. The findings of this study reveal a significant association between educational qualification and awareness of zero-sugar beverages among consumers. The study of Coskun & Kayisoglu (2018) finds that the percentage of people who comprehend and value the information on food labels increases dramatically with educational attainment.

CONCLUSION

This study thoroughly explains the attitudes, driving forces, and obstacles that consumers in the Delhi NCR area have regarding sugar-free beverages. The increasing need for better beverage options is undoubtedly due to rising health consciousness. However, there is still a limited shift from awareness to regular intake. These behavioural insights revealed that more label-conscious and health-conscious respondents had higher preference scores for beverages with no added sugar. In the meantime, there was general disagreement about myths like the idea that sugar-free drinks are only for people with diabetes or that they contain dangerous preservatives. The study's overall conclusions indicate that the sugar-free beverage industry in Delhi NCR is still relatively new but has a lot of potential. This study has significant implications for policy, including the need for focused publicity efforts and educational programs to dispel myths and foster consumer confidence in order to encourage the use of zero-sugar beverages.

DECLARATIONS

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

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

The authors declare that during the preparation of 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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Bibliometric Exploration of Bullying, Workplace Bullying, and Cyberbullying based on the Scientific Scopus Quantum

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HIGHLIGHTS

- The workplace bullying studies plateau; cyberbullying rises, indicating the digital growth between 1999 and 2024.
- Espelage and Einarsen have made significant contributions with solid international partnerships, especially in the US, the UK, and Scandinavia.
- Key topics, including workplace dynamics, teenage victimization, and digital harassment, were found through keyword co-occurrence.
- Co-authorship analysis emphasizes strong worldwide cooperation, highlighting the necessity of inclusive, flexible, and multidisciplinary approaches, particularly in under-represented areas

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ABSTRACT

The study examines the landscape of bullying research, with a focus on workplace bullying and cyberbullying, utilizing Scopus-indexed publications from 1999 to 2024. A total of 20,406 publications were analyzed, including 14,051 on bullying, 1,583 on workplace bullying, and 4,772 on cyberbullying. A bibliometric analysis was conducted using descriptive and network techniques to evaluate research productivity, trends, and collaborations. Key findings reveal that citations for bullying peaked in 2015, with workplace bullying research stabilizing, while cyberbullying research has shown sustained growth, reflecting the rise of digital platforms. Co-authorship analysis highlights strong international collaborations, with significant contributions from scholars like Espelage, D.L., and Einarsen, S., and leading research hubs in the U.S., U.K., and Scandinavia. Keyword co-occurrence identified critical themes such as workplace dynamics, adolescent victimization, and digital harassment. Emerging clusters in healthcare and family dynamics highlight underexplored domains that require further investigation. Future research should address bullying's socio-psychological impacts and develop innovative methodologies to mitigate its evolving challenges in diverse settings.

INTRODUCTION

Bullying, a behaviour linked to negative ego optimization, has evolved, with workplace bullying and cyberbullying gaining significant research attention over the past 25 years, with 45000 documents due to their profound effects on individual well-being,

organizational health, and social dynamics. Most studies, approximately 75 per cent studies, focus on Western cultures, which limits understanding of global bullying dynamics and cultural variations (Giorgi et al., 2015; Escobar et al., 2023). Only 11-14 per cent non-Western countries are underrepresented in bibliometric analyses, highlighting the need for research in diverse socio-economic

contexts to uncover unique influences on workplace bullying and victimization (Einarsen et al., 2020; Samnani, 2024; Escobar et al., 2023). Longitudinal studies examining the long-term psychological, social, and economic impacts of bullying are scarce (Olweus, 1993; Hymel & Swearer, 2015). Additionally, the intergenerational transmission of bullying behaviours and their implications across families and workplaces remain underexplored (Kowalski et al., 2014). Limited research also examines how intersectional factors like race, gender, socioeconomic status, and disability shape bullying experiences (Hoel et al., 2021).

As digital platforms and ICT evolve, cyberbullying research lags, often focusing on mainstream platforms while neglecting newer spaces like TikTok, Discord, and the metaverse (Patchin & Hinduja, 2012; Mukherjee & Jha, 2024). Real-time monitoring and AI-based interventions are emerging but remain underexplored regarding ethics, accuracy, and efficacy (Huang et al., 2021). Following 2010, research on cyberbullying surged due to rising public awareness and the proliferation of social media, necessitating studies on privacy-conscious AI systems to combat bullying across diverse digital environments (Patchin & Hinduja, 2012; Huang et al., 2021). The rise of remote work and gig economy models has introduced challenges like virtual harassment, which are underrepresented in bullying literature (Giorgi et al., 2015). Research must address how remote and hybrid dynamics influence bullying and evaluate anti-bullying programs in diverse contexts (Samnani & Singh, 2012). Enhanced methodologies can illuminate trends like leadership training and policy interventions (Hoel et al., 2021).

The geographic distribution of research highlights the dominance of the United States, the United Kingdom, and Australia in bullying research (Einarsen et al., 2003). Scandinavian countries, notably Norway, have made significant contributions to the literature on workplace bullying, with institutions such as the University of Bergen leading the field (Giorgi et al., 2015). Cyberbullying research shows growing contributions from Spain and China, emphasizing its global reach (Wright, 2017). Collaborative networks have been instrumental in advancing research, with international partnerships fostering the exchange of diverse cultural and methodological perspectives (Hong et al., 2019).

Despite substantial progress, significant gaps remain in understanding bullying's cultural nuances and its manifestation in underrepresented regions. The dominance of studies from English-speaking and developed countries underscores the need for equitable representation (Espelage & Hong, 2017). Cyberbullying research must focus on longitudinal studies to capture the evolving nature of online harassment in response to technological advancements (Kowalski et al., 2014). Additionally, exploring the intersection of bullying with mental health, family dynamics, and healthcare systems can offer insights into sustainable intervention strategies (Hymel & Swearer, 2015).

METHODOLOGY

The bibliometric method is divided into three steps: the first one is database selection, identification, and acquisition. Based on past literature and the results, it was decided to choose Scopus (Elsevier's database) since it is a major and vast database focused on various domains, providing the necessary information for both

qualitative and quantitative analysis (Jenkins, 2017). The search string finalized for "Articles, abstract, and keywords" was used, so that if the keywords were present in the document, related documents would be shown in the output. The output from the database was retrieved using a set of search terms that focused on "bullying," "workplace bullying," and "cyberbullying" concepts. The synonyms for these search items were explained clearly and connected using the "OR" operator. Concepts associated with the "AND" and "AND NOT" operators were used to exclude records related to other terms (Suman et al., 2025).

The second one is the clarification and formatting of highly cited documents by using different filtration techniques in MS Excel. Results were limited to journal articles for the years 1999-2024. In addition, the language of the articles and the publication stage was limited to English due to feasibility and visibility, and the final publication. Boolean "AND" was utilised to restrict the study findings to mental health concerns, and "AND NOT" was employed to omit additional research articles; Boolean "OR" was utilised to optimise the results. The dataset was consequently further condensed to 14051 articles for bullying, 1583 articles for workplace bullying, and 4772 articles for cyberbullying.

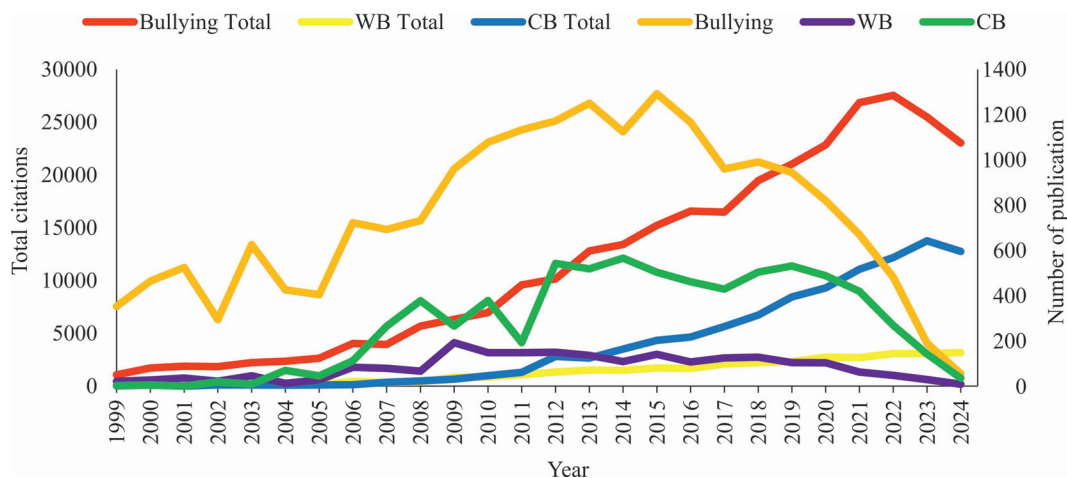
The third and last one is the analysis and visualization of highly cited documents. To investigate patterns in the dataset, the basic descriptive analysis creates several tables and charts. Trends in the concept area were identified using these preliminary charts and tables that were added to the study of the year-wise number of publications, citations, top five countries, journals, authors, and keyword evolution analysis (Agarwal et al., 2022). Following that, keyword analysis and evolution were carried out using VOS viewer, which was utilised to actively analyse the most influential papers, journals, authors, and nations based on their publications and citations (Roy et al., 2024).

RESULTS

As shown in Figure 1, the fifty articles published on the bullying concept date from 1999, and two articles were published on workplace bullying, while only one article was published on the cyberbullying concept. The maximum number of annual publications appeared in 2022, with a total of 1285 on the bullying concept, and 148 publications appeared in 2024 for workplace bullying, while 642 publications appeared in 2023 for cyberbullying. From 1999 onwards, the number of publications rises exponentially for bullying, workplace bullying, and cyberbullying, with a little bit of fluctuation. The trend, however, was interrupted for three years (2017, 2023, and 2024), in which the number of publications was lower than expected for the bullying concept. The trend of workplace bullying concept was interrupted every two or three years between 1999 and 2024, in which the number of publications increased and decreased. The trend of the cyberbullying concept was also interrupted from 1999 to 2003 regularly, even, though the publication was found null in 2001. After 2013 publication rises exponentially every year for cyberbullying.

In addition, a total of 7545 citations were in 1999 and the trend in the number of annual citations increased with interruption for the bullying concept. The highest number of citations was recorded in 2015 with 27694 and the lowest number of citations

Figure 1. Trends in publications and citations in concepts with the year-wise production rates
Note: CB = Cyberbullying; WB= Workplace bullying. Publication- Bullying Total, WB Total, and CB Total, Citations- Bullying, WB, and CB



was recorded in 2024 for the bullying concept. A total of 458 citations were in 1999 with a considerable rise in the number of citations each year, reaching a peak in 2009 with 4112 citations and reaching a low level in 2024 with 179 citations for the workplace bullying concept. The cyberbullying concept found 43 citations in 1999 and null citations in 2001 due to zero publications. The highest publication was found in 2014 with 12119 citations while the lowest publication was found in 1999 with 43 citations except in 2001.

Then, Table 1 shows the top five authors with the most published articles in twenty-five years. The top five authors have published (n=502; 3.58%) articles out of a total of (n=14051; 100%) bullying articles of which Espelage, D.L. published (n=133; 0.95%), the Hong, J.S. published (n=110; 0.78%), Salmivalli, C published (n=104; 0.74%), Thornberg, R. published (n=78; 0.56%), and Veenstra, R. published (n=77; 0.55%) articles respectively. The top five authors have published (n=197; 12.44%) articles out of a total of (n=1583; 100%) workplace bullying articles of which Einarsen, S. published (n=54; 3.41%), Nielsen, M.B. published (n=47; 2.97%), Einarsen, S.V. published (n=34; 2.15%), Notelaers, G. published (n=32; 2.02%), and Baillien, E. published (n=30; 1.90%) articles respectively. The top five authors have published (n=199; 4.17%) articles out of a total of (n=4772; 100%) cyberbullying articles of which Wright, M.F. published (n=49; 1.03%), Vandebosch, H. published (n=48; 1.01%), Ortega-Ruiz, R. published (n=38; 0.80%), Wachs, S. published (n=34; 0.71%), and Smith, P.K. published (n=30; 0.63%) respectively.

Then, Table 2 shows the top five journals with the most published articles in twenty-five years. The top five journals have published (n=1343; 9.56%) articles out of a total of (n=14051; 100%) bullying articles of which the Journal of Interpersonal

Violence published (n=441; 3.14%), the International Journal of Environmental Research and Public Health published (n=245; 1.74%), Journal of School Violence published (n=230; 1.64%), Journal of Youth and Adolescence published (n=229; 1.63%), and Child Abuse and Neglect published (n=198; 1.41%) articles respectively. The top five journals have published (n=179; 11.3%) articles out of a total of (n=1583; 100%) workplace bullying articles of which the International Journal of Environmental Research and Public Health published (n=50; 3.16%), Frontiers in Psychology published (n=36; 2.27%), the Journal of Nursing Management published (n=36; 2.27%), Work and Stress published (n=28; 1.83%), and International Archives of Occupational and Environmental Health published (n=28; 1.77%) articles respectively. The top five journals have published (n=673; 14.09%) articles out of a total of (n=4772; 100%) cyberbullying articles of which Computers in Human Behavior published (n=202; 4.23%), International Journal of Environmental Research and Public Health published (n=188; 3.94%), Journal of Interpersonal Violence published (n=103; 2.16%), the Frontiers in Psychology published (n=95; 1.99%), and Children and Youth Services Review published (n=85; 1.78%) respectively.

Then, Table 3 shows the top five countries with the most published articles in twenty-five years. The top five countries have published (n=9922; 70.65%) articles out of a total of (n=14051; 100%) bullying articles of which the United States published (n=5309; 37.7%), the United Kingdom (UK) published (n=1883; 13.4%), Australia published (n=1042; 7.42%), Canada published (n=992; 7.1%), and China published (n=696; 4.95%) articles respectively. The top five countries have published (n=892; 56.35%) articles out of a total of (n=1583; 100%) workplace

Table 1. Top five authors based on the number of publications, with their percentage

Bullying			Workplace bullying			Cyberbullying		
Authors	Pub.	%	Authors	Pub.	%	Authors	Pub.	%
Espelage, D.L.	133	0.95	Einarsen, S.	54	3.41%	Wright, M.F.	49	1.03%
Hong, J.S.	110	0.78	Nielsen, M.B.	47	2.97%	Vandebosch, H.	48	1.01%
Salmivalli, C.	104	0.74	Einarsen, S.V.	34	2.15%	Ortega-Ruiz, R.	38	0.80%
Thornberg, R.	78	0.56	Notelaers, G.	32	2.02%	Wachs, S.	34	0.71%
Veenstra, R.	77	0.55	Baillien, E.	30	1.90%	Smith, P.K.	30	0.63%
Total	502	3.58	Total	197	12.44	Total	199	4.17

Table 2. Top five journals based on the number of publications with their percentage

Bullying			Workplace bullying			Cyberbullying		
Journals	Pub.	%	Journals	Pub.	%	Journals	Pub.	%
Journal of Interpersonal Violence	441	3.14	International Journal of Environmental Research and Public Health	50	3.16	Computers in Human Behavior	202	4.23
International Journal of Environmental Research and Public Health	245	1.74	Frontiers in Psychology	36	2.27	International Journal of Environmental Research and Public Health	188	3.94
Journal of School Violence	230	1.64	Journal of Nursing Management	36	2.27	Journal of Interpersonal Violence	103	2.16
Journal of Youth and Adolescence	229	1.63	Work and Stress	29	1.83	Frontiers in Psychology	95	1.99
Child Abuse and Neglect	198	1.41	International Archives of Occupational and Environmental Health	28	1.77	Children and Youth Services Review	85	1.78
Total	1343	9.56	Total	179	11.3	Total	673	14.09

Table 3. Top five countries based on the number of publications and their percentage

Bullying			Workplace bullying			Cyberbullying		
Countries	Pub.	%	Countries	Pub.	%	Countries	Pub.	%
United States	5309	37.78	United States	323	20.40	United States	1301	27.26
United Kingdom	1883	13.4	Australia	204	12.89	Spain	470	9.85
Australia	1042	7.42	United Kingdom	144	9.10	China	417	8.74
Canada	992	7.1	Norway	141	8.91	United Kingdom	393	8.24
China	696	4.95	Canada	80	5.05	Australia	288	6.04
Total	9922	70.65	Total	892	56.35	Total	2869	60.12

bullying articles of which the United States published (n=323; 20.4%), Australia published (n=204; 12.89%), the United Kingdom (UK) published (n=141; 9.10%), Norway published (n=141; 8.91%), and Canada published (n=80; 5.05%) articles respectively. The top five countries have published (n=2869; 60.12%) articles out of a total of (n=4772; 100%) cyberbullying articles of which the United States published (n=1301; 27.26%), Spain published (n=470; 9.85%), China published (n=417; 8.74%), the United Kingdom (UK) published (n=393; 8.24%), and Australia published (n=288; 6.04%) respectively.

Network analysis

The network displays keywords that form clusters (Figure 2), where nodes and linkages connect graphs that depict the associations between words. The size of the nodes, which stand in for the keywords, is correlated with how frequently the keyword occurs in the documents; the larger the node, the more frequently it appears (and vice versa). The connections between two nodes are shown by the linkages, or edges. The link's breadth indicates the strength of this association; a wider link indicates a stronger relationship (Van Eck & Waltman, 2010). The minimum number of repetitions of the keyword was fixed at 5. Only 2246 out of the 24055 author keywords reached the cutoff and were plotted. The co-occurrence with author keywords produces a total of 12 clusters, 32642 links, and 79099 total link strengths. Every cluster color represents a different cluster in which cluster 1 consists of 170 items, followed by cluster 2 (154 items), cluster 3 (118 items), cluster 4 (109 items),

cluster 5 (102 items), cluster 6 (90 items), cluster 7 (84 items), cluster 8 (42 items), cluster 9 (39 items), cluster 10 (37 items), cluster 11 (36 items), and cluster 12 (19 items). The keywords based on occurrences only top five keywords selected in which first keyword is "bullying" consisting of 5876 occurrences, 15858 total link strength, and 971 links, followed by the second keyword "cyberbullying" consisting of 2333 occurrences, 6202 total link strength, and 757 links, third keywords is "adolescents" consisting of 1480 occurrences, 4475 total links strength, and 678 links, fourth keywords is "victimization" consisting of 1274 occurrences, 3906 total link strength, and 667 links, the fifth keywords is "adolescence" consisting 865 occurrences, 2622 total link strength, and 551 links.

The minimum number of occurrences of the author's documents was fixed at 5. Of the total author co-authorship of 44239, only 2183 met the threshold and were plotted. The author's co-authorship based on documents produces 911 items, 35 clusters, 6545 links, and 18094 link strengths. Every cluster color represents a different cluster, and a total of the top ten are considered in this study. The cluster 1 consists of 221 items, followed by cluster 2 (67 items), cluster 3 (56 items), cluster 4 (42 items), cluster 5 (41 items), cluster 6 (40 items), cluster 7 (39 items), cluster 8 (29 items), cluster 9 (28 items), and cluster 10 (28 items). The based on total link strength, the top five authors selected which first author (wang x.) consisting of 298 total link strength, followed by the second author is (Hong J. S.) consisting of 270 total link strength, the third author is (Espelage D. I.) consisting of 235 total links strength, fourth author is (Salmivalli C.) consisting of 234 total link strength,

Figure 2: Co-occurrences network of keywords visualization

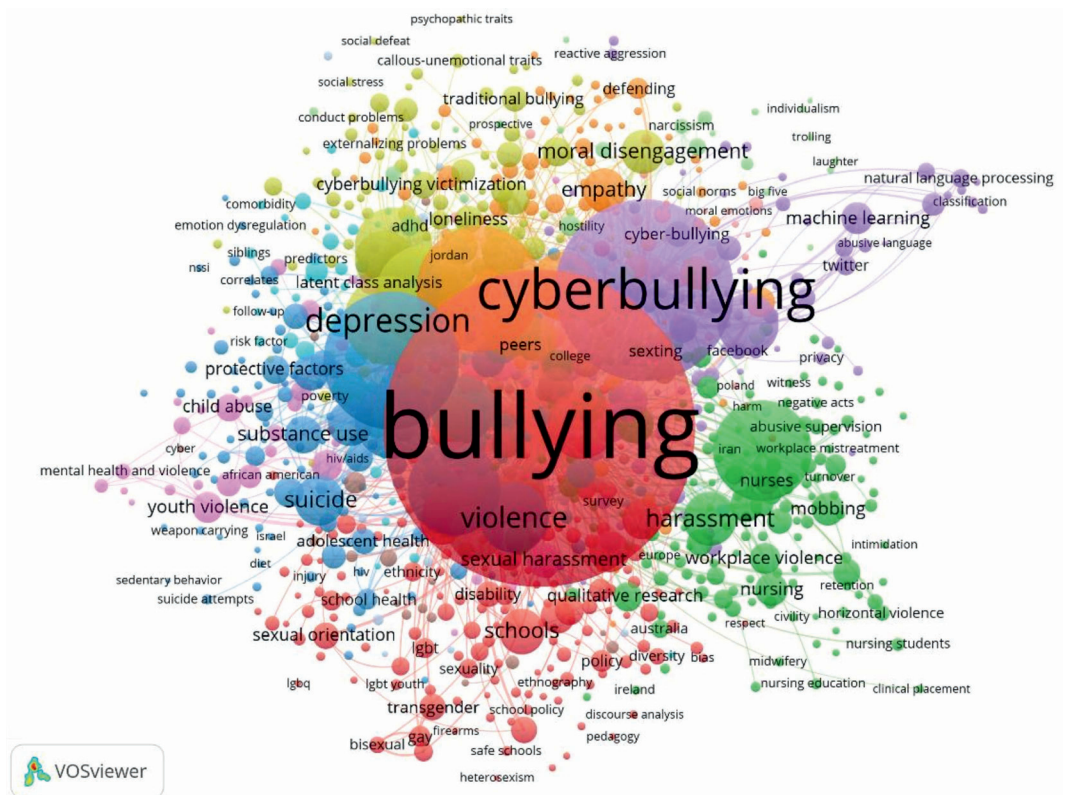
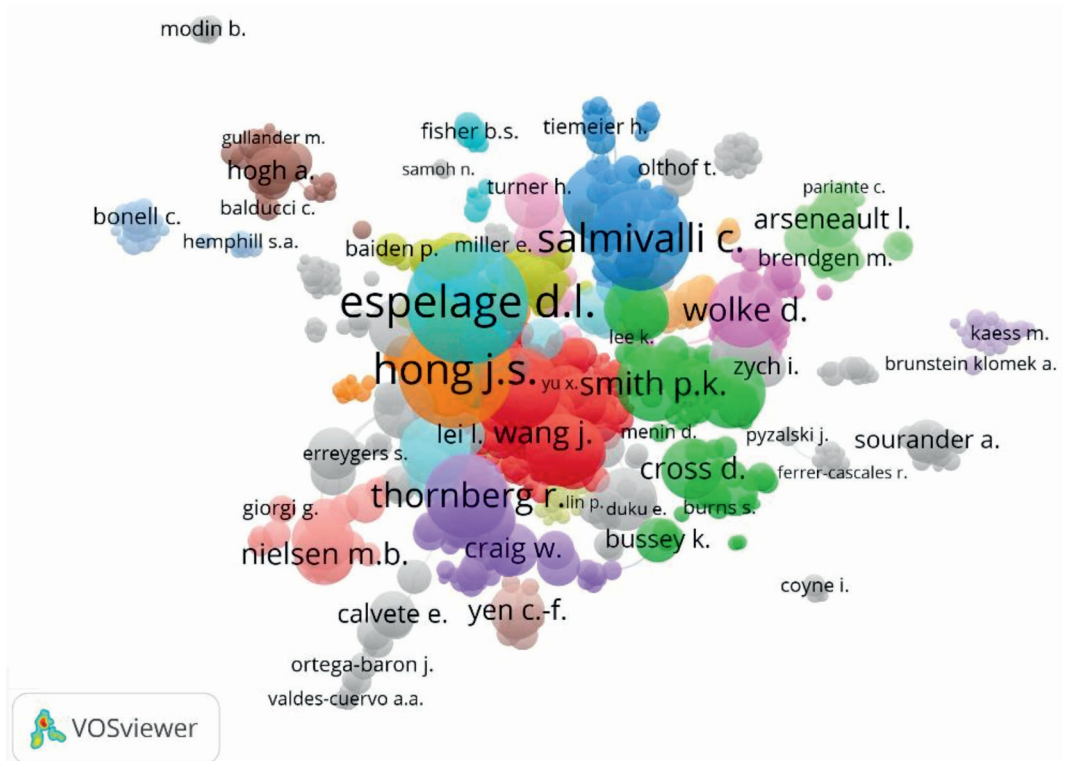


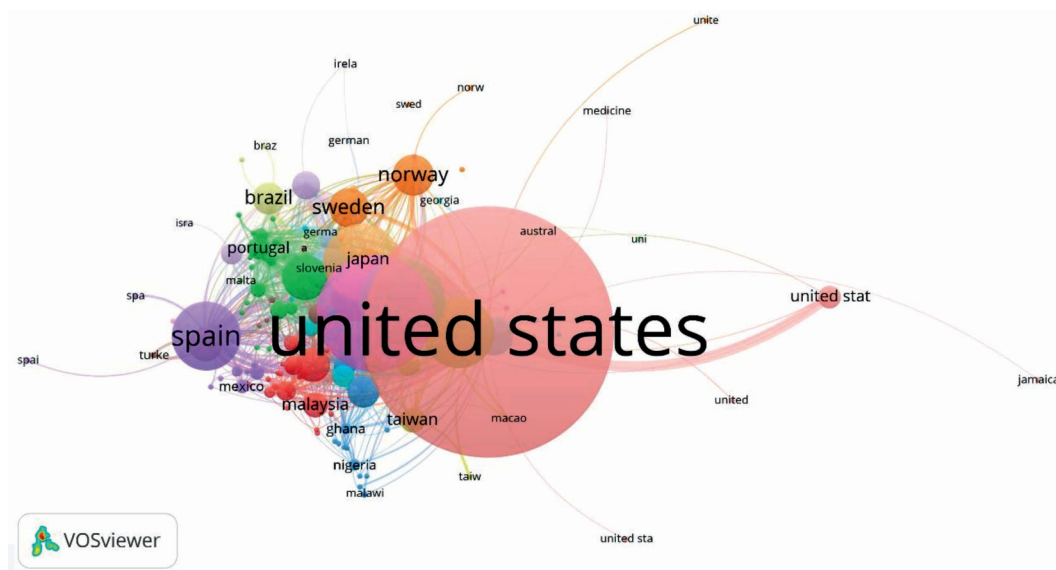
Figure 3. Author and co-authorship network



The fifth author is (Wang Y.) consisting of 211 total link strength. The based on the citations, the top five authors were selected in which first author is (Smith P. K.) consisting of 11143 total citations, followed by the second author is (Espelage D. I.) consisting of 9764 total link citations, third author (Salmivalli C.) consisting of 9724 total citations, fourth author is (Einarsen S.) consisting of 7813 total citations, and the fifth author is (Wolke

D.) consisting of 7786 total citations. The based on the documents, the top five authors were selected which first author is (Espelage D. I.) consisting of 142 total documents, followed by the second author is (Hong J. S.) consisting of 129 documents, the third author is (Salmivalli C.) consisting of 109 total documents, the fourth author is (Thornberg R.) consisting of 83 total documents, and the fifth author is (Wang X.) consisting of 80 total documents published.

Figure 4. Co-authorship and countries network



To describe the collaboration connection of publications in different countries and regions from 1999 to 2024, we make a co-authorship analysis at the level of country/region and author. The minimum number of occurrences of the author's documents was fixed at 5. Of the total author countries, 1026, only 150 met the threshold and were plotted. The author's countries, based on documents, produce 150 items, 17 clusters, 1946 links, and 11183 link strengths. Every cluster colour represents a different cluster, and a total of the top ten are considered in this study. The cluster 1 consists of 23 items, followed by cluster 2 (23 items), cluster 3 (14 items), cluster 4 (12 items), cluster 5 (11 items), cluster 6 (11 items), cluster 7 (9 items), cluster 8 (7 items), cluster 9 (7 items), and cluster 10 (6 items). The based on documents, citations and total link strength, the top five countries selected first country is (the United States) consisting of 6931 documents, 259405 citations, and 2985 total link strength, followed by the second country is (the United Kingdom) consisting of 2337 documents, 100544 citations, and 1806 total link strength, the third country is (Australia) consisting of 1505 documents, 47347 citations, and 1047 total links strength, the fourth country is (Canada) consisting of 1300 documents, 52712 citations, and 871 total link strength. The fifth country is Spain, composed of 1091 documents, 26615 citations, and 792 total link strength.

DISCUSSION

The analysis of bullying, workplace bullying, and cyberbullying research trends reveals important insights into the dynamic and evolving nature of these topics. The concept of bullying experienced a steady rise in citations, peaking in 2015, a surge reflecting the increasing scholarly attention at that time (Einarsen et al., 2003). Workplace bullying followed a similar pattern. It began with 458 citations in 1999 and rose steadily, reaching a peak of citations in 2009. Since then, the citation count has gradually decreased, reaching a low in 2024, suggesting a stabilization of interest in the topic (Giorgi et al., 2015). Cyberbullying exhibited a distinct trajectory, with slow initial growth in citations, starting in 1999, followed by a significant rise in 2014.

The earliest publications on bullying date back to 1999, with just two articles on workplace bullying and one on cyberbullying. Since then, the number of publications has increased dramatically, peaking in 2022, when 1,285 articles on bullying were published. Workplace bullying saw 148 publications in 2024, while cyberbullying had 642 publications in 2023, marking exponential growth over time (Hymel & Swearer, 2015). For bullying, publication numbers fell below expectations in 2017, 2023, and 2024, while workplace bullying showed similar interruptions between 1999 and 2024, with periodic increases and decreases in publication activity. Cyberbullying's publications exhibited consistent growth after 2013, aligning with the increasing prominence of digital platforms and online harassment (Kowalski et al., 2014).

The geographic distribution of the bullying concept, the top five countries—the United States, United Kingdom, Australia, Canada, and China confirms long-standing concern. The United States led with 5,309 articles (Einarsen et al., 2003). This dominance underscores the major role these countries play in bullying research. In workplace bullying, the top five countries—the United States, Australia, the United Kingdom, Norway, and Canada highlights expertise and epicentres of particular specializations. The United States contributed 323 articles, while Australia, Norway, and Canada made significant contributions, highlighting the strong focus on workplace bullying in Scandinavian countries (Giorgi et al., 2015).

The top five journals for bullying-related research published 1,343 articles, representing 9.56 per cent of the total 14,051 articles. The *Journal of Interpersonal Violence* led with 441 articles. These journals are central to bullying research, covering various aspects like violence, public health, and education (Einarsen et al., 2003). For workplace bullying, the top five journals published 179 articles, accounting for 11.3 per cent of the total 1,583 articles. The *International Journal of Environmental Research and Public Health* is in the top. These journals reflect the interdisciplinary nature of workplace bullying research, encompassing public health, psychology, and occupational health (Giorgi et al., 2015). In the area of cyberbullying, *Computers in Human Behavior* led with 202 articles. These journals address the intersection of technology, behavior, and mental health (Kowalski et al., 2014).

Regarding authors, the top contributors in bullying research include Espelage, D.L., Hong, J.S., and Salmivalli, C., for general bullying research, with Espelage leading with 133 articles. In workplace bullying, Einarsen, S., Nielsen, M.B., and Einarsen, S.V. made significant contributions, with Einarsen leading with 54 articles. For cyberbullying, Wright, M.F., Vandebosch, H., and Ortega-Ruiz, R. were key contributors, with Wright leading with 49 articles (Wright, 2017; Vandebosch & Pabian, 2013).

CONCLUSION

In conclusion, this bibliometric analysis highlights key trends in the intellectual development and research landscape of bullying, workplace bullying, and cyberbullying, offering important implications for future international studies. The sustained growth of cyberbullying research, largely fuelled by the rise of digital platforms, underscores the need for research to focus on developing effective digital tools and frameworks to combat online harassment. Additionally, the strong international collaboration identified through co-authorship networks highlights the importance of global cooperation, particularly in integrating underrepresented regions to ensure a comprehensive understanding of bullying behaviors across diverse cultural contexts. The interdisciplinary nature of bullying research, encompassing workplace dynamics, healthcare, and family systems, further supports the need for integrated research methodologies across fields like psychology, sociology, public health, and technology. By strengthening global partnerships, ensuring equitable representation, and focusing on sustainable interventions, the international research community can enhance the effectiveness of bullying prevention and mitigation strategies.

DECLARATIONS

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

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

The author declares that they have thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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Influence of Private Extension Services on Practices and Perceptions of Shrimp Farmers

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HIGHLIGHTS

- The study focuses on the perception of shrimp farmers regarding private extension services for improving productivity and income.
- Adopting a pluralistic extension model that combines public and private extension services would improve service delivery, affordability, and farmer engagement.
- A high percentage of the determinants influence the perception level of shrimp farmers on private extension services.

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ABSTRACT

The study conducted in 2025 (January to April) to evaluate the perceptions of shrimp farmers regarding private extension services, focusing on quality, accessibility, cost, and impact on farming practices in Tamil Nadu, India. A sample of 150 shrimp farmers was selected using proportionate random sampling from five districts; Nagapattinam, Thanjavur, Thiruvarur, Cuddalore, and Ramanathapuram. Data were collected through a structured interview schedule and was analysed using SPSS software. The findings revealed that shrimp farmers generally held positive views of private extension services, particularly regarding updated market information (51%), addressing the needs of small and marginal shrimp farmers (50%), regular visits by extension agents (45%), and technical expertise (49%). However, challenges like geographical barriers (85%), lack of awareness (76%), and high service costs (59%). Among 17 variables, 10 were found to be significantly associated with shrimp farmers' perception levels. Multiple regression analysis revealed that independent factors accounted for 64.7 per cent of the variation in farmers' perceptions. The study suggests enhancing private extension services by addressing affordability and improving collaboration between the public and private sectors to improve shrimp farming productivity and income.

INTRODUCTION

India is a leading shrimp-producing and exporting nation, with shrimp contributing more than 70 per cent of the country's total aquaculture exports. The industry has grown at a rapid rate

following the introduction of favorable government policies introduction of exotic species such as *Penaeus vannamei* and proactive participation of private stakeholders (MPEDA, 2021). Andhra Pradesh, Tamil Nadu, Odisha and West Bengal are the major states of shrimp aquaculture. Despite, the role of public extension

services such as the Department of Fisheries and research centers such as ICAR-CIBA and ICAR-CMFRI in technology transfer and farmer training their outreach and performance have at times been hampered by limited manpower, infrastructure and operating budgets (CIBA, 2024). Private extension services under such conditions have assumed importance as an alternative and complementary sources of technical guidance for shrimp farmers. Private extension providers in India include: feed and input firms, pharmaceutical firms, hatcheries and nurseries, experts, government officials, processors/exporters offering backward integration. Shrimp farming is a prominent economic activity in Tamil Nadu, India and it makes a substantial contribution to the state economy in employment generation and export earnings. The sector is supported by good coastal conditions, trained human resources and increasing world demand for shrimp. Spontaneous expansion of shrimp farming generated a chain of challenges, primarily disease management, environmental sustainability and compliance with international quality standards. Extension services can address these challenges by educating farmers to become knowledgeable, skilled and technologically advanced to improve productivity and sustainability. Traditionally, public extension services have been the primary source of assistance for farmers (CAA, 2023).

Private extension services have introduced a new paradigm, offering specialization and market-oriented solutions to farmers. Understanding the perception of shrimp farmers on private extension services in terms of the quality of the service, accessibility, cost, and its effect on farming is the foremost objective of the present study. Deepthi et al., (2024b) established a positive farmers' attitude towards private sector extension services and their existence in twelve major regions. It also established fourteen limitations that hinder the utilization of such services, such as accessibility, affordability, and farmers' trust. The study showed that approximately 40.05 per cent of the respondents reported having a high awareness level of private extension services, while 40.55 per cent reported having a moderate level of awareness. These findings show that a high percentage of shrimp farmers utilize private extension service experts to boost their production levels. Moreover, a report by the Central Institute of Brackish Water Aquaculture (CIBA, 2024) showed the importance of extension services in establishing sustainable aquaculture practices. The report showed the importance of effective extension strategies and the role of private extension staff in knowledge transfer to farmers. This study sought to establish how shrimp farmers' perception of various private extension services plays an important role in enhancing shrimp farming practices.

METHODOLOGY

This study was conducted during 2025 (January to April) to assess the level of perception of shrimp farmers regarding private extension services in the state of Tamil Nadu, India. A study sample size of 150 shrimp farmers were selected from the target districts using a proportionate random sampling technique. The total registered shrimp farms in Tamil Nadu was 2220 (CAA, 2022-23). Five districts were selected for the study based on the highest number of registered shrimp farms namely; Nagapattinam (n=50), Thanjavur (n=28), Thiruvavur (n=25), Cuddalore (n=24) and

Ramanathapuram (n=23). The level of perception of shrimp farmers regarding private extension services was taken as the dependent variable. To better understand the impact of various factors on farmer perceptions, the study considered 17 independent variables, grouped into four categories: socio-personal, socio-economic, socio-communicational and socio-psychological. To measure the level of perception, a pre-tested interview schedule was developed with 15 questions. These questions were grouped under three significant service dimensions: Reliability & responsiveness; expertise & knowledge; and productivity & resources. The responses were measured using a 5-point scale: 5 - Strongly agree, 4 - Agree, 3 - Undecided, 2 - Disagree and 1 - Strongly disagree. This allowed for the quantitative assessment of farmers' perceptions across various dimensions of private extension services and identified areas with effective services or scope for improvement. Data collected through interviews were analysed using the SPSS. Descriptive statistical tools such as frequency and percentage analysis were used, along with spearman's correlation and multiple linear regression analysis, to establish the relationship between the shrimp farmers' perception levels and their socio-personal characteristics. This analytical approach ensured statistically significant findings and provided actionable information for enhancing private extension services in the shrimp farming sector. Spearman's correlation measures the strength of ranked variable relationships from -1 to +1 and Multiple linear regression analyzes how multiple factors affect one outcome. Spearman's Rank Correlation Coefficient (ρ):

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}$$

Where, ρ = Spearman's rank correlation coefficient, d_i = difference between ranks, n = number of observations.

Multiple Linear Regression:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \epsilon$$

Where, Y = dependent variable, β_0 = intercept, $\beta_1 \dots \beta_k$ = coefficients, $X_1 \dots X_k$ = independent variables, ϵ = error term.

RESULTS

Perception level of shrimp farmers towards private extension services

The result on the perception level of shrimp farmers towards private extension services was evaluated through 15 structured statements using a five-point scale and the results were shown in Table 1. The findings revealed a predominantly positive perception across several service dimensions.

Reliability and responsiveness

A majority of farmers felt that private extension personnel visited them regularly, making it the most significant factor in terms of reliability and responsiveness. Following closely, 33 per cent of farmers considered government extension services reliable, showing that a considerable portion found government services dependable, though less frequent compared to private services. Another

Table 1. Perception of shrimp farmers regarding private extension services

Statements	Percentage				
	SA	A	UD	DA	SDA
Reliability and Responsiveness					
Are government extension services more reliable in delivering farm-related support?	3	33	30	31	3
Do you believe private extension services are more responsive than government extension services?	1	36	33	30	0
Do private extension personnel visit farmers on a regular basis?	27	45	4	24	0
Is the time spent by private extension agents during visits sufficient to address your farming needs?	5	42	25	28	0
Expertise and Knowledge					
Do private extension services effectively meet the needs of small and marginal farmers?	7	50	20	22	1
Do you feel that private extension personnel possess the technical expertise required to solve your problems?	5	49	27	18	1
Do these services assist you in making better planning and farm-related decisions?	7	47	17	28	1
Are private extension agencies effective in delivering technical knowledge related to shrimp culture?	19	39	18	24	0
Do private extension agents motivate you to adopt new or modern farming technologies?	17	31	17	35	0
Do private extension services keep you updated with current market information such as prices and demand?	8	51	32	9	0
Productivity and Resources					
Have private extension services helped improve your farm productivity and income?	26	47	19	7	1
Are private extension services affordable for most farmers, including those with limited resources?	9	44	22	25	0
Are inputs such as feed, seed, fertilizers, & machinery made available to you on time by private extension agents?	12	48	8	32	0
Do you receive assistance in accessing financial or credit support from private extension agencies?	10	39	29	22	0
Do private extension services support you in timely management of soil and water health?	19	40	32	8	1

SA- Strongly Agree, A- Agree, UD- Undecided, DA- Disagree, SDA- Strongly Disagree

important factor was the time spent by agents during visits, with 42 per cent of farmers feeling that the time was sufficient to address their needs. This indicated that many farmers believed the visits were adequately comprehensive. However, 36 per cent of farmers agreed that private extension services addressed their needs more effectively than government services, which highlighted the perception that private services were more responsive, but still not as universally agreed upon as regular visits or reliability.

Expertise and knowledge

Private extension services were widely recognized for effectively meeting the needs of small and marginal farmers, with 50 per cent agreeing on this point. Additionally, 49 per cent of farmers believed that private extension agents had the technical expertise required to solve their farming challenges. However, despite these positive evaluations, there was some mixed feedback regarding decision-making assistance. Forty-seven percent agreed that these services helped in planning. A similar divide occurred when evaluating the effectiveness of private extension services in providing shrimp culture-specific knowledge, where 39 per cent agreed. The motivation to adopt new farming technologies was another area of division, with 35 per cent disagreeing that extension agents effectively encouraged adoption. On a positive note, private extension services received high marks (51%) for keeping farmers informed about market trends, such as prices and demand.

Productivity and resources

The impact of private extension services on farm productivity and income was generally viewed positively, with 47 per cent farmers agreeing and 26 per cent strongly agreeing that these services contributed to improvements. However, affordability remained a concern, as 44 per cent agreed that private services were affordable, suggesting that the costs may have been prohibitive for some

farmers, particularly those with limited resources. Timely access to critical farm inputs, such as feed, seed, fertilizers, and machinery, was reported positively by 48 per cent of farmers, highlighting a gap in the provision of essential resources. The support for obtaining financial or credit assistance from private extension agencies was also mixed, with 39 per cent agreeing that help was provided. Finally, while 40 per cent of farmers agreed that private extension services supported the timely management of soil and water health, indicating a need for improvement in environmental management practices.

Association between independent variables and shrimp farmers' perception of private extension services

The results from the study to analyse the association between selected independent variables (X_1 – X_{17}) and shrimp farmers perception on private extension services are given below (Table 2). Age and shrimp farming experience had the highest positive correlations, with values of 0.656 and 0.629, respectively ($p < 0.01$). This suggested that older farmers and those with more experience in shrimp farming tended to have a better perception of these services. Contact with extension agencies and mass media exposure also showed strong positive correlations of 0.502 and 0.562, respectively ($p < 0.01$), indicating that regular interaction with extension agents and increased access to media information improved farmers' views of these services.

Farmers with a scientific orientation, risk orientation and economic motivation showed positive correlations of 0.317, 0.446 and 0.494, respectively ($p < 0.05$ and $p < 0.01$), suggesting that farmers with a greater inclination toward research-based practices, openness to risk and a focus on economic gains had more favorable perceptions of private extension services. In contrast, educational level, pond size and annual income showed very weak or no significant correlations (e.g., 0.022, -0.002 and -0.013, respectively),

indicating these factors did not significantly influence farmers' perceptions. Interestingly, farm size had a weak negative correlation of -0.179 ($p < 0.05$), suggesting that larger-scale farmers may have perceived private extension services less favorably, possibly due to established farming systems or reliance on other support mechanisms (Table 2).

Multiple linear regression analysis on the perception of the shrimp farmers on private extension services

The R-square is 0.647 for the perception level, i.e., the independent variables of the model account for almost 64.7 per cent

Table 2. Association between independent variables and shrimp farmers perception on Private Extension Services

Independent variables	Correlation coefficient (r)
Age (x_1)	0.656**
Educational level (x_2)	0.022NS
Shrimp farming experience (x_3)	0.629**
Ownership of farm (x_4)	0.177*
Farm size (x_5)	-0.179*
Pond size (x_6)	-0.002NS
Annual Income (x_7)	-0.013NS
Annual Expenditure (x_8)	0.022NS
Marketing channel (x_9)	-0.115NS
Contact with extension agencies (x_{10})	0.502**
Mass media exposure (x_{11})	0.562**
Utilization of ICT tools (x_{12})	-0.147NS
Need of extension services (x_{13})	-0.444**
Innovativeness (x_{14})	0.011NS
Scientific orientation (x_{15})	0.317*
Risk orientation (x_{16})	0.446**
Economic motivation (x_{17})	0.494**

NS = Non-Significant, ** = Significant at 0.01 level, * = Significant at 0.05 level

of the variation in perception. This is an indication that the model is a good fit to extent, i.e., the model accounts for a high percentage of the determinants of perception level of shrimp farmers on private extension services (Table 3).

The regression results, several variables influenced shrimp farmers' perceptions of private extension services. Age had a significant positive effect, with a coefficient of 0.254 and a p-value of 0.010 ($p < 0.01$), indicating that older farmers held more favorable views of these services. Shrimp farming experience also had a positive relationship, with a coefficient of 0.084 and a p-value of 0.022 ($p < 0.05$), suggesting that more experienced farmers perceived the services more positively. Annual income was another significant factor, with a coefficient of 0.073 and a p-value of 0.046 ($p < 0.05$), meaning wealthier farmers had better perceptions of private extension services. Similarly, contact with extension agencies showed a positive impact, with a coefficient of 0.234 and a p-value of 0.012 ($p < 0.05$), indicating that farmers who interacted more with extension agents had more favorable perceptions. Economic motivation also played a role, with a coefficient of 0.131 and a p-value of 0.046 ($p < 0.05$), suggesting that farmers motivated by financial gains viewed the services more positively. In contrast, educational status, ownership of farm, farm size, and pond size had no significant impact on perceptions, as their p-values were above 0.05. Additionally, variables such as annual expenditure, marketing channel, utilization of ICT tools, need for extension services, innovativeness, scientific orientation, and risk orientation showed no significant effect on farmers' perceptions.

Challenges of shrimp farmers towards private extension service

Figure 1 revealed private extension services played a crucial role in improving shrimp farming by providing expert advice on health management, feeding practices and overall farm productivity.

Table 3. Multiple linear regression analysis on shrimp farmers' perception of private extension services

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	Reg. Coeff. B	Std. Error	Beta		
Age (x_1)	0.254	0.097	0.355	2.624	0.010
Educational status (x_2)	-0.002	0.017	-0.006	-0.098	0.922
Shrimp farming experience (x_3)	0.084	0.044	0.173	1.908	0.022
Ownership of farm (x_4)	0.054	0.072	0.043	0.751	0.454
Farm size (x_5)	-0.101	0.075	-0.104	-1.346	0.181
Pond size (x_6)	0.130	0.096	0.082	1.353	0.178
Annual income (x_7)	0.073	0.038	0.158	1.931	0.046
Annual expenditure (x_8)	-0.019	0.053	-0.028	-0.358	0.721
Marketing channel (x_9)	0.006	0.048	0.008	0.135	0.893
Contact with extension agencies (x_{10})	0.234	0.146	0.143	1.601	0.012
Mass media exposure (x_{11})	0.082	0.116	0.060	0.710	0.056
Utilization of ICT tools (x_{12})	0.039	0.057	0.041	0.682	0.497
Need of extension services (x_{13})	0.011	0.063	0.015	0.181	0.857
Innovativeness (x_{14})	0.063	0.072	0.059	0.871	0.385
Scientific orientation (x_{15})	0.068	0.057	0.091	1.193	0.235
Risk orientation (x_{16})	0.085	0.048	0.143	1.780	0.077
Economic motivation (x_{17})	0.131	0.065	0.149	2.014	0.046

R square = 0.647, Adjusted R Square= 0.601, Std. Error of the Estimate= 0.339

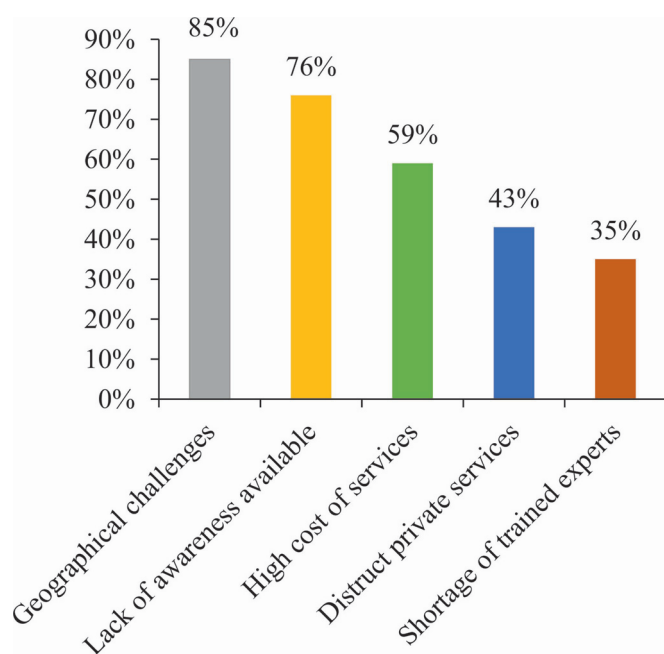


Figure 1. Challenges faced by shrimp farmers with private extension services

However, shrimp farmers faced several significant challenges in accessing these services, which impacted their ability to adopt best practices and enhance their economic outcomes. The most significant barrier was geographical access, with 85 per cent of the 150 respondents reporting that remote farming areas, often with poor infrastructure and high transportation costs, made it difficult for extension services to reach them. This limited access delayed the implementation of improved farming techniques and reduced farm efficiency. Another major challenge was a lack of awareness about available services, which 76 per cent of the 150 respondents highlighted. Many farmers were unaware of the resources that could have helped improve their farming practices due to ineffective communication and outreach by service providers. The high cost of services also posed a challenge, reported by 59 per cent of the 150 respondents. Private extension services often charged for consultancy, training and technology, making it difficult for small-scale farmers to afford these services. Distrust in private services was another issue, with 43 per cent of the 150 respondents indicating they felt these services were profit-driven rather than genuinely focused on farmer welfare. Finally, 35 per cent of the 150 respondents noted a shortage of trained experts with specialized knowledge of shrimp farming, especially in rural areas, limiting the support available for adopting new technologies and practices. Addressing these challenges through improved communication, reduced costs and more access to skilled professionals could have helped empower farmers to improve farming practices, boost productivity and achieve better economic outcomes.

DISCUSSION

The present study analyzes the impact of private extension services on shrimp farming in Tamil Nadu. The findings indicate

that these services have a positive impact on farm productivity and income. Therefore, it can be inferred that promoting private extension services enhances shrimp farming productivity and income in the region. This finding is supported by earlier literature on private extension services in agriculture and aquaculture, which show similar positive outcomes for shrimp farming, although some studies exhibit the similar results (Kavakebi et al., 2023; Kabir & Islam, 2023; Rojas et al., 2020; Deepthi et al., 2024b). Also identifies several factors that influence the performance of private extension services in Tamil Nadu. For instance, the regularity of visits by extension agents positively impacts shrimp farming productivity. This finding aligns with previous research, which suggests that regular visits from extension agents are crucial for providing ongoing support and ensuring the successful adoption of new practices (Mamun-ur-Rashid et al., 2018; Ganpat et al., 2017; Nyairo, 2020; Kumar et al., 2025). Additionally, the timeliness of inputs, such as feed, seed and fertilizers, plays a significant role in improving farm operations. Previous studies emphasize the importance of timely input delivery in boosting agricultural productivity (Global Seafood Alliance, 2023).

Moreover, the study suggests that the technical knowledge provided by private extension agents significantly impacts shrimp farming outcomes. This knowledge indirectly promotes better practices in areas such as disease control, water quality management and feed optimization. In contrast, there is a positive correlation between the level of technical knowledge offered by extension services and the performance of shrimp farming. These findings align with previous research, which highlights the crucial role of technical expertise in improving agricultural practices and productivity (Iakovidis et al., 2023; Farshad & Niknami, 2024; Misra et al., 2025). Affordability remains a significant concern for shrimp farmers, as only 47 per cent of respondents find private extension services affordable, indicating the financial barriers that many farmers face in accessing these services. This issue is consistent with previous research, which highlights the challenges smallholder farmers encounter when services are beyond their financial reach. The affordability issue is particularly concerning for farmers with limited resources who are dependent on accessible and cost-effective support to enhance productivity and income (Bakang et al., 2024). The study finds that while shrimp farmers recognize the impacts of climate change, their adaptive capacity remains limited due to inconsistent and costly extension services. This aligns with earlier findings that emphasize the need for extension services to be more adaptive and tailored to the specific challenges posed by climate change in agricultural practices (Pradhan et al., 2025). Socio-economic factors, such as the experience of farmers and their contact with extension agencies, significantly influence their perceptions and ability to adapt. These findings echo research that shows how crucial socio-economic factors, including farm size, income and access to resources, are in determining the effectiveness of agricultural and shrimp farming services (Sabu et al., 2025; Deepthi et al., 2024a).

CONCLUSION

The study reinforced the importance of private extension services in supporting the shrimp farming industry, particularly in improving productivity and farm income. However, several

challenges persist, especially the affordability, consistency, and delivery of the private extension services, and fulfilling the need for more targeted advice. The findings highlighted the value of a pluralistic extension model that combines both public and private extension systems to maximize outreach and effectiveness of private extension services. Policymakers and extension providers should consider strengthening collaboration between the public and private sectors for improving service delivery mechanisms and addressing farmers' concerns on costs and expenditures. These efforts can lead to more sustainable aquaculture practices and improved farmer well-being in the shrimp farming sector.

DECLARATIONS

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

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

The authors declare that during the preparation of 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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Towards Digitally Enabled Extension Services: ICT Training Directions in Coastal Odisha

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HIGHLIGHTS

- There exists a generational ICT skill divide among public extension functionaries.
- The priority training needs differ hugely with role and exposure.
- ICT training frequency has increased, but the gap persists.

ARTICLE INFO

Keywords: Accessibility, Awareness, Competency, ICT, Priority training areas, Training need.

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ABSTRACT

The study was conducted in 2024 to assess the knowledge and accessibility of common ICT tools, training need assessment, and attendance in programs for ICT applications. A total of 248 public extension workers, chosen from four coastal districts, were split into two groups based on their hierarchical responsibilities. While both groups were aware of fundamental ICT tools like PCs and smartphones, there was a notable difference in advanced tools like AI interfaces, drones, and modern digital accessories. While Group 2 (junior officers) demonstrated greater exposure to emerging technology, they were less skilled in basic digital document management, which was prioritized for training. Group-1 members expressed the most prominent training needs in basic troubleshooting and cybersecurity, along with Google tools. There was an overall increasing trend in participation in activities related to ICT applications for years, which showcases a sort of optimism in skills' upscaling efforts.

INTRODUCTION

In any society, knowledge and information are essential to rural development and socioeconomic progress (Chandra et al., 2023). Information management has been easier in recent years due to a number of advancements in information and communication technologies (ICTs) (Angello, 2015). Achieving the Sustainable Development Goals (SDGs) depends on the dissemination and use of knowledge and information, which are increasingly indispensable components of modern life (Panda et al., 2019). However, the number of extension workers has been decreasing while farming families have been increasing (Sethy & Mukhopadhyay, 2020). Extension personnel cannot reach out to every farmer's doorstep

because in reality, there is only one extension worker available for 2879 farmers in India (Mukherjee and Maity, 2015). Consequently, the role of information technologies, particularly those that make communication easier, is vital in bringing about the socio-economic revolution (Musungwini et al., 2023). Information and communication technologies are a broad category that includes a variety of devices, networks, services, applications, software, methods, and technologies that are essential for storing, managing, processing, retrieving, and sharing information (Haqyar et al., 2025). Transparencies, slides, tapes, cassette recorders, radios, newspapers, and other traditional and basic audio-visual aids are only a few examples of ICTs. More sophisticated and contemporary tools include computers, smartphones, the internet, satellites, sensors,

GPS, AI interface-based software and devices, and many more (Khatri et al., 2024).

ICTs are crucial for information sharing among agricultural stakeholders. Using ICT to advance agriculture has enormous promise (Kumar & Prasad, 2017). The importance of information and communication technology (ICT) in agricultural development has increased significantly in the digital age. Nevertheless, despite the expansion of ICT infrastructure in rural regions, extension workers' ability to effectively use ICT tools is still restricted because of capacity gaps along with infrastructural limitations, and a lack of formal training (Gow et al., 2020). Frequently, extension staff are unable to take advantage of interactive media, digital platforms, GIS tools, and mobile applications for information exchange, advisory services, or farmer input (Tata & McNamara, 2018).

The public extension functionaries must therefore be proficient in technology if ICT-based extension is to be more successful (Spielman et al., 2021). Training of extension staff is directly related to the development of necessary competencies among the extension workforce within extension organizations (Ahsan et al., 2022), in which ICT training must be prioritized (Busungu et al., 2019). Chaudhary et al., (2024) suggested that in order to improve usability, information departments and agricultural directorates should modify the contents of contemporary instruments to better suit the demands of farmers and their socioeconomic circumstances. In this regard, an investigative attempt was made for the assessment of the ICT training scenario of extension functionaries in coastal Odisha.

METHODOLOGY

The study was conducted in four districts of Odisha-Bhadrak, Balasore, Jajpur and Cuttack randomly. The respondents were extension functionaries, being classified into two groups: 51 seniors comprising Chief District Agricultural Officers (CDAO), ADO, Block Agricultural Officer (BAO), and 197 junior officials, making a sample of 248 respondents. The questionnaire, formulated after literature review and expertise consultation, was pretested on the officials, supported with explanation in the local Odia dialect, and feedback obtained served insights for finalizing the interview schedule (Jayasingh & Mishra, 2024). Data collection occurred through interviews in their workplace during September 2024 to May 2025 under ex-post facto design.

ICT Awareness and accessibility concerns about the scenario of ICT tools in terms of their awareness and availability for the respondents during their work time. Extension functionaries received a detailed list of ICT tools and rated them based on awareness and accessibility on three three-point continuum, such as 'fully aware', 'partially aware', and 'least aware' with their respective scores of 3, 2, and 1, respectively. The obtained scores were later taken as input in the following:

$$\text{Awareness Percentage} = \frac{\sum(f_i \times W_i) \times W_{\max} \times 100}{N}$$

$$\text{Accessibility Percentage} = \frac{\sum(f_i \times W_i) \times W_{\max} \times 100}{N}$$

Where, f_i = Frequency of each category

W_i = Weight assigned to each category

$W_{\max}$ = Maximum possible weight for normalisation = 2

Training need was operationalized as the necessity of an extension official to bridge the gap between 'what is' and 'what ought to be'. In this, ten key priority training areas as items were identified after undergoing a literature review, followed by expert advisory with respect to extension functionaries of the state. Then, each item was rated by extension functionaries on a three-point continuum, viz., 'most needed', 'needed', and 'least needed' with their corresponding scores of 3, 2, and 1, respectively. After the responses were transformed to total scores of each item, the training need score as employed by Khan et al., (2023) was obtained as follows:

$$\text{TNS} = \frac{\text{Total score of item}}{\text{Total number of respondents}}$$

This was administered for both the group's total, adding up to 248 respondents. The mean score of each group was calculated. This was followed by finding the higher need interest group. The group with the greatest mean training need score was the one with higher need interest for that particular priority training area. Based on priority area of training the groups were further ranked.

RESULTS

ICT Awareness and accessibility

The result in Table 1 depicts the awareness and accessibility of various ICT tools and techniques amongst both groups of extension functionaries. It was found that mobile phones were well-known as well as easily accessible tools for all the respondents. The likes of computers or laptops, along with a Wi-Fi system, though, were known by all but less accessible for Group-2 personnel. Advanced peripherals like tablets, scanners, laser pointer/laser pen, and public address system were found to have less than 50 per cent accessibility to both groups. In case of programs, the Group-2 members showcased a greater extent of awareness and accessibility for the programs, excluding the MS Office. Web browsers, search engines, and personal mail were known and used as well by both groups of functionaries.

WhatsApp and YouTube, being the most well-known and accessed applications, were found to be the undisputed social media platforms for all of those extension functionaries, followed by Facebook. In case of other platforms which were of recent applications with the likes of Research Gate, Instagram, etc., the members of Group-2 displayed significant numbers in the parameters of awareness and accessibility in comparison to Group-1 by significant margins. Popular platforms like Zoom and Google Meet were found to be the most well-known and accessible in both groups for conferencing purposes.

In case of financial transaction applications, Google Pay and Phone Pe were used by both groups, but with others, there was more inclination from the side of Group-2 members in comparison to Group-1 counterparts. Under the slot of 'ICT agricultural apps', at first is about the cent percent in availability and accessibility for the 'Agricultural Extension App', and in the second, the

Table 1. Distribution of Extension Functionaries Based on ICT Awareness and Accessibility

Category	Group-1		Group-2	
	Aware- ness (%)	Accessi- bilit (%)	Aware- ness (%)	Accessi- bilit (%)
Tools and Peripherals				
Computer/Laptop	100	100	100	73
Mobile	100	100	100	100
Tablet	64	21	75	51
LCD Projector	87	42	93	84
Printer	100	93	100	83
Scanner	76	42	86	43
External storage	64	58	74	67
Smart TV	76	49	83	61
Camcorder or Digital camera	96	78	100	62
Laser pointer/laser pen	63	32	67	52
Public address system	78	43	79	48
Modems/routers/wi-fi	100	63	100	59
Bluetooth/USB/Headphones	83	51	100	79
Programme				
Microsoft office	87	50	100	79
Adobe reader	23	11	65	53
File explorer	36	24	78	65
Drive PDF viewer	18	04	75	56
Adobe illustrator	13	00	43	15
Web browsers	97	93	100	100
Search engine	94	92	100	100
Personal mails	100	100	100	100
Applications				
Agriculture glossary	54	3	62	32
Google services	58	44	67	53
Dictionaries	65	43	93	78
Grammar check	68	25	94	83
File sharing	64	56	83	79
Social-networking platforms				
ResearchGate	51	11	64	43
Academia	46	07	62	41
WhatsApp	100	100	100	100
Facebook	100	72	100	83
Instagram	57	31	100	76
Twitter	81	22	100	56
YouTube	100	100	100	100
LinkedIn	61	12	73	47
Conferencing				
Google meet	78	66	100	86
Cocubes	21	08	46	32
Zoom	74	68	100	82
Microsoft teams	42	17	62	47
Webex	33	12	54	31
Financial transaction app				
Google pay	92	64	100	100
Phone pay	95	68	100	100
Paytm	88	43	100	71
SBI yono	46	12	100	73
Amazon pay	32	07	73	42

Table 1 contd...

ICT agricultural apps				
MKisan	100	81	100	94
Agrisnet	83	63	887	72
Kisan Suvidha app	76	51	83	71
Agricultural Extension app	100	100	100	100
e-Nam	100	76	100	82
Modern Tools				
Interactive AI	43	08	72	65
DSS	12	02	62	33
Drones	83	32	89	21
Robots	54	00	57	00

percentages were less in values for Group-1 members but with narrowed gaps against Group-2. In the bracket of 'Modern tools', even though both possessed awareness in enough numbers, yet very feeble numbers in terms of accessibility for them.

Training areas and training need interest

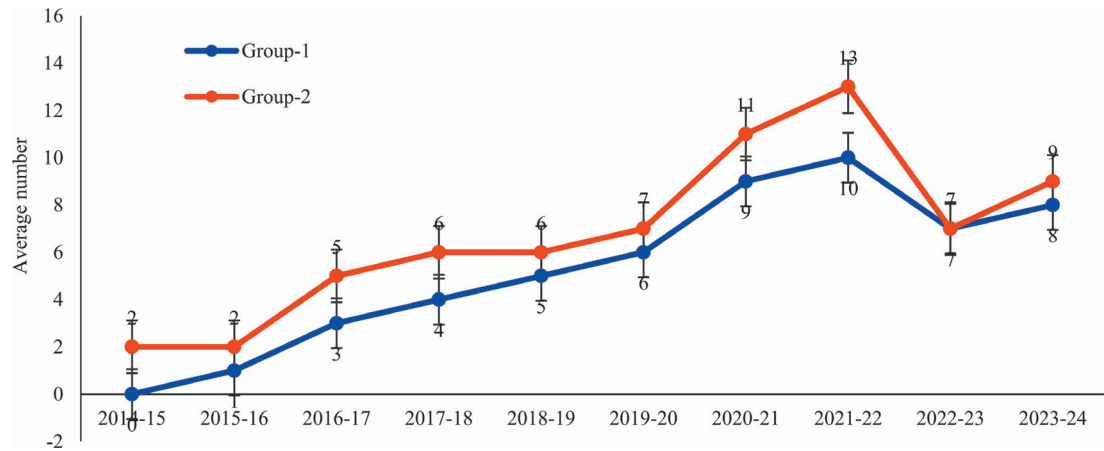
The result in Table 2 portrays the priority training areas and need interest of both the groups. Group-1 prioritised areas like 'Basic Troubleshooting and Cybersecurity', 'Google tools for collaboration', 'Use of Microsoft Excel and PowerPoint', 'Financial and e-Commerce app usage' and 'Safe and Effective use of social media'. The items being flagged as higher need interest by the Group-2 were 'File handling and document management', 'Digital communication and conferencing platforms', 'Operation of advanced peripherals', 'Introduction to emerging technologies', followed by 'Usage of mobile applications'. While comparing the gap between the training scores obtained from both the groups, it can be inferred that the gap was wider in case of training areas like File handling and document management', 'Google tools for collaboration', 'Operation of advanced peripherals', 'Introduction to emerging technologies', 'Use of Microsoft excel and PowerPoint' along with 'Usage of Agriculture-specific Mobile Applications'. Upadhyaya et al., (2019) also concurred with the conclusion in their study, analogous to the findings.

Attendance at training/seminar/lecture/webinars

According to the data in Figure 1, the attendance to programs in the likes of training, seminar, lecture or webinars has increased in the timeline from 2014-15 to 2023-24, whereby the Group-2 extension functionaries were in larger numbers on a year-by-year basis in comparison to Group-1 extension functionaries. Initially, the attendance level was very low in the starting period of 2014-15 but it has picked up pace from the next timeline onwards till 2023-24, whereby the eight and nine such events were attended by the extension people from Group-1 and Group-2, respectively. This trend peaked its form during the COVID-19 pandemic in 2020-21 whereby Group-1 had attended nine events, whereas Group-2 had attended thirteen such events, which were the highest participation in their respective groups. Even if attendance decreased a little after the pandemic, it was still higher than it was before 2019, suggesting that ICT was still used in professional development. Group-2 attended 68 events throughout the course of the decade, compared

Table 2. Distribution of extension functionaries based on priority training areas and training need interest

Training Areas	Group-1 Mean TNS	Group-2 Mean TNS	Higher need interest
File Handling and Document Management	1.45	2.45	Group-2
Digital Communication and Conferencing Platforms	2.27	2.29	Group-2
Basic Troubleshooting and Cybersecurity	2.04	2.03	Group-1
Google Tools for Collaboration	2.02	1.30	Group-1
Operation of Advanced Peripherals	1.80	2.29	Group-2
Introduction to Emerging Technologies	1.76	2.12	Group-2
Use of Microsoft Excel and PowerPoint	1.85	1.09	Group-1
Financial and e-Commerce App Usage	1.66	1.61	Group-1
Usage of Agriculture-specific Mobile Applications	1.65	0.91	Group-2
Safe and Effective Use of Social Media	1.25	0.96	Group-1

Figure 1. Year-Wise Average Number of ICT Training/Seminar/Lecture/Webinar attended by extension functionaries

to 53 for Group-1, indicating that Group-2 had more exposure to ICT application scenarios.

DISCUSSION

A fractured digital foundation was indicated by their simultaneous display of notable deficiencies in core digital competencies like file handling, document management, and communication platform utilization. Senior officers (Group-1), on the other hand, were not exposed to newer, collaborative, cloud-based tools, which were becoming more and more important in digital extension ecosystems, despite being reasonably skilled at basic digital operations. Based on factors including age, training exposure, and maybe employment expectations, this generational gap suggests that technology adaptability was evolving. Public extension workers have significant gaps and generational differences in their knowledge of ICT, accessibility, and training requirements. Even though both senior (Group-1) and junior (Group-2) officers were universally aware of and used basic technologies like computers and cell phones, there were noticeable differences in how they used more sophisticated digital peripherals and software. Group 2, which consists of younger and newly hired employees, shows a higher level of expertise with contemporary ICT technologies such as drones, AI interfaces, Google apps, and mobile applications for agriculture (Nyarko & Kozari, 2021).

Experienced and senior agricultural extension workers require training in areas like basic troubleshooting, cybersecurity, Google tools, Microsoft Excel and PowerPoint, financial and e-commerce apps, and social media to bridge digital skill gaps. As digital tools

increasingly shape agricultural outreach and communication, such training enhances their efficiency, credibility, and adaptability. It empowers them to handle tech-related issues, present data effectively, access online financial services, collaborate remotely, and safely engage farmers through digital platforms, ultimately improving service delivery in a modern extension system (Asante, 2024). Inexperienced junior extension workers seek training in file handling, digital communication platforms, advanced peripherals, emerging technologies, and agriculture-specific apps to build foundational and job-relevant digital skills (Indraningsih et al., 2023). These areas were essential for managing records, conducting virtual outreach, operating modern devices like projectors or drones, and staying updated with innovations. Familiarity with agriculture apps enables them to provide timely, tech-driven advisories to farmers. Such training ensures they become confident, competent, and future-ready professionals in a digitally evolving agricultural extension system (Umunakwe et al., 2025).

The increasing trend in the participation of all the extension functionaries in the events of trainings, seminars, lectures or webinars, across the significant dip since post COVID-19 pandemic era, it enhances their knowledge base, encouraging knowledge-sharing, fostering professional growth and updates them with modern practices, ultimately improving the quality of agricultural extension services. Over the last decade, particularly after 2016, Group-2 has taken part in more ICT-related events, reaching its climax during the COVID-19 pandemic. This highlights the influence of contemporary professional development techniques on digital exposure in addition to being consistent with their increased

understanding of sophisticated tools (Gow et al., 2020). However, greater involvement has not been translated into proficiency, particularly in fundamental digital skills, highlighting the disconnect between training materials and real-world demands (Badhan, 2020). The results highlight the need for role as well as ICT training, even though digital inclusion in extension services was increasing. In disaster-prone coastal Odisha, strategic planning regarding training content, frequency, and delivery methods can aid in bridging these digital divides and eventually improve the reach, relevance, and resilience of extension services.

CONCLUSION

Training in ICT tools empowers extension workers in India to disseminate timely information, improve farmer outreach, enhance knowledge sharing, and increase the adoption of innovative agricultural practices, boosting productivity and livelihoods. The study emphasizes the value of specialized ICT training programs to improve Odisha's public extension workers' digital proficiency. The training requirements of senior and junior extension officers differ; the former need to improve their skills in collaborative and analytical digital tools, while the latter need to acquire fundamental skills in document management and communication platforms. Inequalities in digital readiness, accessibility, and usage continue to exist despite a rise in involvement in ICT capacity-building initiatives during the past ten years. Adopting a digitally inclusive strategy will guarantee that Odisha's extension services are adaptable, durable, and pertinent to the changing demands of the agricultural sector.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents and their organizations 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, 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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Factors Influencing the Adaptation Behaviour of Rice Growers to Climate Change in Andhra Pradesh, India

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HIGHLIGHTS

- Deep summer ploughing and the use of suitable high-yielding varieties were adopted by all the farmers.
- Education, farm income, and information-seeking behaviour had a positive effect on the adaptation behaviour of rice cultivators, whereas farm size, farmer-to-farmer information exchange, and change resistance were found to have a negative influence on the adaptive behaviour of farmers to climate change.
- Lack of suitable varieties and quality seeds, price fluctuation in the market, low technical knowledge on climate-resilient rice cultivation, and lack of availability of weather-based insurance for rice were the most important problems in adaptation to climate change.

ARTICLE INFO

Keywords: Climate change, Adaptation practices, Rice growers, India.

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ABSTRACT

The rice producers of Andhra Pradesh face the problem of declining productivity due to climate change factors. Climate change has hit the paddy growers of Andhra Pradesh hard and they need to adopt adaptation practices to counter the effects of changing climate. The study has identified and ranked the adaptation techniques followed by 240 paddy growers on the basis of extent of adoption. Multiple regression analysis was done to identify the factors influencing climate change adaptation behaviour of the rice cultivators. It was observed that education, farm income and information seeking behaviour have a positive effect on the adaptation behaviour, whereas farm size, farmer to farmer information exchange and change resistance were found to influence negatively the adaptive behaviour of farmers to climate change. The problems faced by the farmers in adaptation to climate change have also been identified and ranked. Lack of suitable varieties and quality seeds, price fluctuation in the market, low technical knowledge on climate resilient rice cultivation and lack of weather based insurance for rice cultivation were the most important problems that the rice cultivators faced in adaptation to climate change.

INTRODUCTION

Andhra Pradesh (commonly known as rice bowl of India) is the eighth largest in India covering an area of 1,60,205 km². There are two regions in the state namely Coastal Andhra and Rayalaseema and hence, the two regions are more often referred as *Seemandhra*. There are 13 districts, nine (9) in Coastal Andhra and four (4) in Rayalaseema. The rice productivity in Andhra Pradesh varies across districts and ecosystems, with an average yield of 3,333 kg/ha. The

state contributed 7.89 million tonnes of rice in 2024-25 from 2.16 million hectares of land that was put to rice cultivation (Khokhar, 2025). Due to rapid climate change, many abiotic factors such as rainfall, drought, flooding, temperature, and solar radiation are severely affecting the production of rice at various growth stages. It is predicted that almost 51 per cent of rice cultivation and production would be reduced during the next century due to global climate change (Hussain et al., 2020). *Basmati* and *Sona Masoori* are popular rice varieties cultivated in Andhra Pradesh using a blend

of traditional and modern knowledge. There has been a marked decline in the production of rice owing to the adverse effects of climate change on rice cultivation in the state.

Rice cultivation is heavily dependent on climatic factors, particularly rainfall and temperature, making these variables crucial for understanding seasonal crop dynamics (Kumar et al., 2025). Any fluctuations in rainfall and temperature can have a significant impact on rice productivity, resulting in yield variability. Similarly, greater maximum and minimum temperatures which imply a cloud-free atmosphere, more sunshine hours, and warmer night temperatures, all of which stimulate photosynthetic activity and assimilation, resulting in higher rice yields. The shortened growth period, combined with reduced biomass production, ultimately results in a significant reduction in crop yield (Blum, 2005; Kamoshita et al., 2008). The decline in area and production has been attributed to drought like conditions and adverse weather patterns such as cyclones during the previous season (Rao, 2024).

By taking appropriate steps towards adaptation, it is possible to change the climate challenges into opportunities to increase crop yields. These actions mainly include changes and adjustments in the farming systems, such as soil and water management practices and shifting of crop cultivation dates. Studies show that farmers' adaptive capacity and adaptation behaviours are largely shaped by factors associated with the nature of the farming household (Khan et al., 2022). So, adaptation which is identified as one of the measures to reduce the negative impact of climate change in agriculture is needed urgently to reduce the adverse impacts of climate change in the state. Considering the importance of adaptation to climate change so as to reduce the adverse effect of climate change on rice cultivation in Andhra Pradesh state, this study was taken up to study the adaptation behaviour of rice cultivators to climate change, to identify the factors that influence the adaptation behaviour of rice growers, and important problems that the rice cultivators faced in adaptation to climate change in Andhra Pradesh.

METHODOLOGY

Out of 13 districts of the state, three districts viz East Godavari, West Godavari and Krishna were selected purposively for the study as they are the highest rice producing districts under Godavari and Krishna Delta regions with fertile soil and full irrigation facilities. Out of these three districts, two mandals from each district were selected using simple random sampling technique. The selected mandals were Samalkot and Kajuluru (East Godavari), Unguturu and T.P. Gudem (West Godavari), Mudunepalli and Movva (Krishna). From each mandal, two villages were selected using simple random sampling technique. Thus a total of twelve villages were selected for the study. Twenty, respondents from each village were selected, thus making a total of 240 respondents. Data were collected from the selected respondents by using the interview schedule developed for the study.

Based on review of literature and expert consultation, 13 profile characteristics of rice growers were selected and included in the study. They include gender, age, education, size of household, farm size, farm income, farming experience in rice cultivation, farmer to farmer information exchange, knowledge about local agro-climate,

credit and subsidy orientation, information seeking behavior, preparedness for adaptation and change resistance.

Adaptation to climate change was operationalized as the capacity of the rice growers to adapt themselves against the adverse effects of climate change by adopting the adaptation practices (both traditional and scientific practices) in terms of total number of adaptation practices and total score of adoption of the adaptation practices. Twelve climate resilient adaptation practices which were followed by most of the farmers and endorsed by state department of agriculture were considered in the present study. A score of one (1) is assigned to each of the 12 practices, if the farmer follows the practice. The total score was then obtained by summation of only those adaptation practices that were followed by the farmers. Secondly, the same farmers were asked about the level of adoption of the 12 practices on three-point continuum, viz., full adoption, partial adoption and non-adoption with assigned score of two (2), one (1) and zero (0) respectively. Thus the total score of adaptation of every farmer to climate change was obtained as follows:

Total score of adaptation to climate change = Total number of adaptation practices followed by the farmers + total score of adoption to adaptation practices.

Multiple Regression Analysis was further used to identify the most significant factors which influence the climate change adaptation behaviour of the farmers.

RESULTS

Level of adoption of the adaptation practices

The level of adoption of 12 adaptation practices by the farmers was analyzed and ranked (Table 1). It was observed that there was 100 per cent adoption in adaptation practices like deep summer ploughing and the use of suitable high-yielding varieties. These were fully adopted by all the farmers and ranked first. These were followed by use of well decomposed FYM (rank II) which was fully adopted by 81.25 per cent of the farmers, risk management through crop insurance (rank III) was fully adopted by 81.66 per cent of the farmers, rearing of livestock/mixed crop-livestock systems (rank IV) was fully adopted by 76.25 per cent, and adoption of Direct Sown Rice (DSR) (rank V) was fully adopted by 27.91 per cent of the farmers.

Factors influencing climate change adaptation behaviour of farmers

Multiple regression analysis was done to identify the factors influencing climate change adaptation behaviour of rice cultivators. The regression analysis (Table 2) shows that education, farm income, and information-seeking behaviour have a positive effect on the adaptation behaviour of rice cultivators. Farm size, farmer-to-farmer information exchange, and change resistance were found to negatively influence the adaptive behaviour of farmers to climate change.

The model summary for the regression model used to study the factors influencing climate change adaptation behaviour of farmers is given in Table 3. The R^2 value of 0.945 shows that more than 94 percent variation in the dependent variable is explained by the independent variables included in the model. Durbin Watson

Table 1. Distribution of the respondents according to their level of adoption of adaptation practices (N=240)

S.No.	Adaptationpractices	Level of adoption			Score	Rank
		FA %	PA %	NA %		
1.	Deep summer ploughing	100	0.00	0.00	720	I
2.	Use of well decomposed FYM	81.25	18.75	0.00	675	II
3.	Green manuring	32.50	27.08	40.41	364	VII
4.	Use of suitable high-yielding variety	100.00	0.00	0.00	720	I
5.	Early sowing/planting	11.25	20.00	68.75	177	IX
6.	Adoption of Direct Sown Rice	27.91	42.50	29.58	405	V
7.	Maintenance of adequate and uniform plant stand	26.66	44.58	28.75	406	VI
8.	Rearing of livestock / mixed crop-livestock systems	76.25	0.00	23.75	549	IV
9.	Risk management through crop insurance	81.66	0.00	18.33	588	III
10.	Change in irrigation systems to manage specific stresses during crop season	10.83	19.58	69.58	172	X
11.	Use of bio-fertilizers / botanical pesticides	15.83	11.25	72.91	168	VIII
12.	Off-farm diversification	0.00	17.91	82.08	86	XI

Note: FA = Full Adoption; PA= Partial Adoption; NA= No Adoption

Table 2. Multiple linear regression analysis of the independent variables with adaptation

Independent Variables	Coefficients ^a				
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	22.811	2.979		7.657	.000
Age	-.002	.022	-.005	-.088	.930
Education	1.495	.319	.474	4.688	.000***
Size household	.122	.152	.022	.801	.424
Farm size	-.406	.178	-.083	-2.282	.023**
Farm-income	.409	.160	.086	2.562	.011**
Farming experience in rice cultivation	-.001	.022	-.002	-.036	.971
Farmer to farmer information exchange	-.061	.033	-.063	-1.839	.067*
Knowledge about local agro climate	.070	.079	.044	.882	.379
Credit and subsidy orientation	.066	.069	.043	.962	.337
Information seeking behaviour	.126	.051	.188	2.498	.013**
Preparedness for adaptation	.031	.039	.039	.796	.427
Change resistance	-.208	.066	-.152	-3.155	.002***

Table 3. Model summary for multiple regression

Model Summary ^b					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.972 ^a	.945	.942	1.190	2.153

a. Predictors: (Constant), Change resistance, Farm-income, Farming experience in rice cultivation, Size household, Farmer to Farmer Information exchange, Credit and subsidy orientation, Farm size, Knowledge about local agro climate, Preparedness for adaptation, Age, Information seeking behaviour, Education

b. Dependent Variable: Adaptation

test value of 2.153 shows that there is no autocorrelation between the variables.

Problems faced by the rice growers due to climate change and its implication on adaptation to climate change

The problems experienced by farmers were categorized into four groups and are presented in Table 4. In production-related problems, lack of quality seeds and suitable varieties to sustain the climate change was the most important problem mentioned by 86.25 per cent of the respondents. This was followed by high cost of

cultivation (77.91%), crop failure due to frequent cyclones and high incidence of pests (77.08%), and rainfed farming (74.16%).

In socio-economic problems, price fluctuation in the market was considered as the main problem by 89.58 per cent of the respondents, followed by requirement of money ahead of season for preparedness (76.66%), higher cost of labour (72.08%), preference for traditional practices of rice cultivation (70.00%), and lack of suitable farm machinery and farmers inclination to use it (64.16%). Technology can potentially play an important role in adapting to climate change. The most important problem was less

Table 4. Problems faced by the rice growers

Problems	Percentage	Rank
Production related problems		
Lack of suitable varieties and quality seeds	86.25	I
Crop failure due to frequent cyclones and high incidence of pests	77.08	III
Rainfed condition	74.16	IV
High cost of cultivation	77.91	II
Socio-economic problems		
Price fluctuation in the market	89.58	I
High cost of labour	72.08	III
Requirement of money ahead of season for preparedness	76.66	II
Lack of suitable farm machinery and farmers' inclination	64.16	V
Preference for traditional practices of rice cultivation	70.00	IV
Technology-related problems		
Lack of information concerning adaptation options	60.41	IV
Lack of information about the weather and climate	70.41	II
Lack of proper knowledge on alternative cropping systems	65.83	III
Low technical knowledge on climate resilient rice cultivation	74.16	I
Institutional problems		
Improper management of the drainage system and late release of canal water	88.33	II
Lack of proper storage capacity	74.16	V
Ineffective procurement system in the village	80.83	III
Non-availability of credit and subsidy facilities in the locality	77.50	IV
No weather-related insurance facility for rice	90.00	I

technical knowledge of climate resilient rice cultivation, which was mentioned by 74.16 per cent of the respondents, followed by lack of information about weather (70.41%), lack of proper knowledge on alternative cropping systems (65.83%) and lack of information concerning adaptation options (60.41%). Among institutional problems, no weather-related insurance option for paddy crop was considered as the major problem by 90.00 per cent of the respondents, followed by improper management of drainage system and late release of canal water (88.33%), ineffective procurement system (80.83%), non-availability of credit and subsidy facilities (77.50%) and lack of proper storage capacity (74.16%).

DISCUSSION

Irrigation management as an adaptation strategy to rice production at the farm level help offset negative impacts of climate change was also recommended by Ansari et al., (2021), in their study on adaptation to climate change in rice production in Central Java. They also observed that shifting the planting date is important for avoiding crop failure under spatially and temporally variable rainfall patterns. The other adaptation measures include maintenance of adequate and uniform plant stand, green manuring, use of bio-fertilizers/botanical pesticides to minimize chemical consumption, early sowing/planting, and change in irrigation systems to manage specific stresses during crop season.

Education enhances the adaptive capacity of the farmers by increasing awareness, knowledge, and skills. Education empowers individuals to make informed decisions, change behaviours, and develop innovative solutions to mitigate and adapt to the impacts of a changing climate. Those with higher levels of education have a higher capacity to adapt to climate change and a lower chance of suffering from its impact (O'Neill et al., 2020; Pathak et al., 2024). Similarly, high farm income also has a positive influence on the

adaptation behaviour of farmers as it offers the financial means to invest in adaptive strategies such as drought-resistant crops, irrigation infrastructure, and soil conservation methods, thereby enhancing resilience to climate variability. The information-seeking behaviour of the farmers also positively influence adaptation to climate change. The individual's intention to actively seek information about climate change would determine their knowledge and attitude towards climate change, and this would in turn influence how they act or change their behaviours in response to that risk (Choo, 2023).

Human adaptation has been defined by IPCC (Intergovernmental Panel on Climate Change) as "the process of adjusting to actual or expected climate variability and its effects to moderate harm or exploit beneficial opportunities" (Field et al., 2025). Researchers, policy makers and practitioners together agree that the adaptation to climate change is not happening at the desired pace (Salami et al., 2010; Raghuvanshi & Ansari, 2022). Farmers exhibit varying degrees of resistance to adopting new practices in response to climate change, influenced by factors like access to information, financial resources, and the perceived risks and benefits of change. Around the world, urban farmers adjust to climate change based on the support they get from local institutions and personal and environmental factors (Mensah, 2025).

Most of the farmers had small and marginal holdings. As the size of the holdings of majority of the farmers was very small, they were limited by resources and access to information on climate change adaptation. This finding aligns with a study by Daberkow & McBride (2003) in the United States, which demonstrated that due to uncertainty and fixed production and information costs, there exists a critical farm size threshold below which smallholder farmers are unable to adopt newly introduced farming technologies.

Due to lack of quality seeds in the market and non-availability of rice varieties which can withstand the adverse climatic conditions, the farmers were unable to procure seeds on time. Farmers' access to quality seed of a diverse range of adapted cultivars is still impeded by insufficient and inefficient seed production and distribution systems, poor seed quality assurance, inadequate seed policies, and seed price (Hampton et al., 2016). Increased cost of chemicals like fertilizers, fungicides, insecticides and other production inputs is also a factor. Though the use of adaptive measures can reduce the impact of extreme weather, the cost of implementation depends on the seed price and additional inputs needed. Strong cyclonic storm poses a threat to coastal agriculture in Andhra Pradesh due to heavy rainfall and high wind speed associated with the storms, leading to considerable economic losses to farmers (Ponnurangam et al., 2019). The climate in Andhra Pradesh also favours many diseases in rice, especially sheath blight. Cultivation of varieties that are susceptible to diseases is an important reason for this problem. Rising temperatures and changes in rainfall patterns have direct effects on crop yields, as well as indirect effects through changes in irrigation water availability (Nelson et al., 2009; Mishra et al., 2024). Farmers adjust to the adverse effects of climate change based on the institutional and non-institutional support they receive. While agricultural research plays an important role in developing resistant varieties, agricultural insurance takes care of farmer's fear of crop loss due to adverse weather conditions.

The defunct market committees in the state are contributing to the price fluctuation in the market. The adaptation strategy also requires some capital for preparedness to combat climate change or reduce the impacts of climate change. No adaptation strategy can be successful without ensuring that the high-vulnerability populations have the financial, technical, and institutional resources they need to adapt (World Bank, 2020). High cost of labour discourages low-income farmers from hiring necessary farm labour for adaptation to climate change. Farmers still believed that using their own traditional practices would keep the cost of cultivation lower, and traditional practices were easy to follow. For instance, Direct Seeding of Rice is a very viable alternative to traditional transplanting, offering benefits like reduced water and labour requirements. However, only 28 per cent of the sampled farmers have fully adopted this practice in the study area. Selection of appropriate machinery is important to minimize detrimental effects or to correct existing anomalies (Sundaram et al., 2019).

Even though the farmers wanted to adapt to climate change, but lack of knowledge about adaptation practices hindered their adaptation to climate change. Climate information services help farmers in finding coping strategies for managing short-term climate risks (Singh et al., 2018). Thus, a lack of such knowledge would reduce the adaptive capacity of farmers. Knowledge about plant protection is very important for a farmer in Andhra Pradesh as the climate in the state favours many diseases. Lack of such knowledge would reduce the adaptive capacity of farmers.

Crop insurance is one of the important inputs for adaptation to climate change for the farmers in the state where the adverse impact of climate change reduced the production and also sometimes resulted in total loss of the crops. Adopting insurance can affect farmers' expected utility under risk. Insurance can indeed affect the

skewness of the distribution of revenues, making farmers less prone to downside risk (Falco et al., 2014). Lack of transportation for marketing increases the transportation cost and thereby reduces the net profit of the farmers. This hinders farmers from accessing the much-needed production inputs for adaptation to climate change. Another problem faced by the farmers is the lack of efficient marketing facilities initiated by the state government in the rural areas. Farmers need money for the cultivation of crops in the next season. So, they need an efficient marketing facility for reducing transportation costs, reasonable market price of the produce, direct marketing with less involvement of middlemen, etc. Credit is an important factor in adaptation to climate change, and it should be readily available whenever needed by the farmers. The climate of Andhra Pradesh, with its varied relative humidity, is very favourable for the spoilage of rice in storage. Proper storage facilities are needed for the storage of seeds, which are to be used for sowing in the next season, and also for marketing at a later stage when the prices are favourable.

CONCLUSION

It was observed that deep summer ploughing and use of suitable high-yielding varieties were adopted by all the farmers; on the other hand, practices to minimize chemical consumption of pesticides and fertilizers, and early sowing were adopted by very few farmers. Regression analysis employed to identify the factors influencing farmers' behaviour towards adoption of adaptation practices shows that education, farm income, and information-seeking behaviour have a positive effect on the adaptation behaviour of rice cultivators in Andhra Pradesh, whereas farm size, farmer-to-farmer information exchange, and change resistance were found to negatively influence the adaptive behaviour of farmers to climate change. Various problems faced by the rice cultivators of Andhra Pradesh and their significance in the context of climate change adaptation were also discussed. It is important that the rice growers of the state adapt themselves to the changing climate so as to build resilience to extreme events.

DECLARATIONS

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

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

The authors declare that during the preparation of 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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Adoption and Compliance of AI-Enabled Pest Advisories: Evidence from the National Pest Surveillance System (NPSS) in Odisha, India

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HIGHLIGHTS

- NPSS advisories reached widely; only about half were converted into action.
- Adherence declines with increasing severity, especially for BPH and YSB in paddy.
- Simple, low-cost measures saw the highest compliance; input-intensive recommendations lagged.
- Paddy dominated sample; brinjal showed similar severity–adherence patterns.

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ABSTRACT

Artificial intelligence (AI)–enabled pest surveillance can bridge gaps between timely diagnosis and on-farm action in smallholder systems. This study assessed farmer exposure to and uptake of advisories from India’s newly launched NPSS in Odisha. An exploratory, cross-sectional inquiry was conducted during 2024–25 across 30 districts; one block and two villages per district were purposively selected based on NPSS use. Data were gathered from 1,422 participants through focus group discussions and personal interviews, and analysed. Paddy dominated the sample’s cropping pattern (66.17% of respondents), followed by brinjal (9.21%). Overall, 79.16 per cent were receiving NPSS advisories; the platform issued 851 advisories during the study, with 418 acted upon (49.11% adherence). Adherence declined as pest severity increased, especially for brown planthopper (BPH) and yellow stem borer (YSB) in paddy from 47.73 per cent (low severity) to 32.47 per cent (high severity), and YSB showed a similar drop (about 45.95% to 10%). Qualitative insights indicate lower uptake when recommendations involve costlier or more complex chemical controls, suggesting a need for clearer messaging, phased options, and enhanced last-mile support. The findings highlight substantial reach but moderate compliance, underscoring opportunities to tailor NPSS advisories to farmers’ resource realities and to strengthen capacity-building for higher-severity scenarios.

INTRODUCTION

Timely and precise pest management remains a critical constraint in Indian smallholder agriculture, where losses from

insects and diseases can undermine yields, quality, and profitability despite decades of technology diffusion (Singh & Gupta, 2016; Singh et al., 2015). Integrated Pest Management (IPM) has been

promoted as an eco-friendly framework that emphasises cultural, mechanical, and biological tactics alongside need-based chemical use. However, adoption relies on credible, timely, and context-specific advice reaching farmers at scale. Digital advisory systems offer one pathway to bridge this “last-mile” information gap by accelerating diagnosis and tailoring recommendations to local conditions (Saha et al., 2024). Emerging global evidence suggests that such digital information interventions can improve input decisions and farm outcomes. However, their effectiveness varies with design and delivery.

In this context, the Government of India launched the National Pest Surveillance System (NPSS) on 15 August 2024 to strengthen real-time surveillance and deliver AI/ML-enabled crop protection advisories (Kumar & Nandeesh, 2023; Prusty et al., 2025). NPSS integrates field scouting, geo-referenced data flows, and expert validation to issue advisories through a mobile app and web portal, aiming to reduce dependence on pesticide retailers and promote scientific pest management (Suman et al., 2024). The platform was developed by the Indian Council of Agricultural Research – National Research Centre for Integrated Pest Management (ICAR-NCIPM) in collaboration with the Directorate of Plant Protection, Quarantine and Storage (DPPQ&S) and the Ministry of Agriculture & Farmers’ Welfare (DA&FW). Early government reports indicate a phased roll-out and a growing user base, underscoring the need for independent assessments of advisory reach and farmer uptake across diverse agro-ecologies (Saha et al., 2025).

Odisha provides a relevant setting for such inquiry (Mwenda et al., 2023). Rice remains the state’s dominant crop, central to both area and livelihoods—even as diversification gains traction; public statistics and recent surveys consistently mark paddy’s prominence. In this context, rapid and credible advice on pest outbreaks—such as the brown planthopper in paddy or key pests in brinjal, can significantly influence farmers’ control choices and timing. NPSS claims to facilitate accurate and efficient diagnosis and treatment guidance, positioning it as a potential catalyst for IPM-aligned decisions at scale (Suman et al., 2025). Given the novelty of NPSS and the limited empirical evidence on compliance with AI-enabled pest advisories in India, there is a clear gap: whether, and under what conditions, farmers act on such advisories.

METHODOLOGY

An exploratory, cross-sectional study was conducted in Odisha during 2024–2025 to investigate the use of the National Pest Surveillance System (NPSS) advisories and farmers’ adoption rates. The study encompassed all 30 districts, from which one block and two villages were purposively selected based on the demonstrated use of the NPSS mobile application by farmers. The sampling frame consisted of NPSS-linked farming communities within the chosen villages, involving a total of 1,422 participants. Data collection involved focused group discussions (FGDs) and personal interviews, guided by an interview schedule aligned with the study’s objectives. Field teams documented (i) exposure to NPSS (awareness, access, and receipt of advisories), (ii) advisory content and recommended practices, (iii) whether advisories were followed or not followed, and (iv) contextual factors influencing on-farm decisions. All responses were tabulated and analysed descriptively.

To contextualise advisory uptake within the production environment, the instrument recorded prevalent crop-wise cultivation in the villages. This approach allowed results to be summarised by major crops instead of solely at an aggregate level. Recognising the operational importance of severity cues in pest management, the study also documented the severity class associated with NPSS advisories (low/medium/high) for key crops, along with the recommended management practices. For paddy, advisory–practice pairs were noted for brown planthopper and yellow stem borer across all severity levels, with similar details recorded for brinjal pests. This data facilitated the computation of advisory compliance by pest and severity tier.

Data processing involved consistency checks and tabulation of frequencies and percentages by objective. No experimental treatments or inferential statistics were utilised; instead, the interpretation focused on pattern recognition—how compliance varied by crop, pest, and severity—and its practical implications for NPSS message design and last-mile support. The choice of an exploratory design with purposive selection of NPSS-using villages was suitable for a first assessment of advisory uptake under a newly launched public digital system and for generating actionable insights for extension practice. Future research may apply inferential statistics to test links between socio-economic variables and uptake.

RESULTS

In the surveyed villages, rice was the predominant crop, influencing the types of advisories provided and the options available for farmers to act on them. Among respondents, 66.17 per cent ($n = 941$ out of 1,422) cultivated paddy, significantly more than any other crop; brinjal was a distant second at 9.21 per cent ($n = 131$). Smaller percentages reported growing tomato (4.08%), chilli (3.31%), banana (3.16%), maize (2.88%), cotton (2.74%), and black gram (1.55%), with an “others” category comprising 6.89%. These crop distributions set the stage for understanding the subsequent findings on advisory flows and adherence (Figure 1).

Of the 1,422 NPSS-linked participants across 30 districts, 1,078 (75.80%) monitored pests during the reference period. During this time, NPSS issued 851 advisories, of which 418 were followed, resulting in an overall adherence rate of 49.11 per cent. This data indicated a significant generation and distribution of advisories, yet

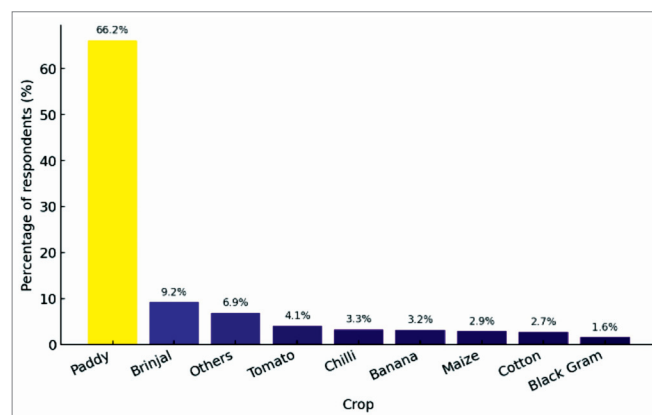


Figure 1. Distribution of major crops grown by respondents

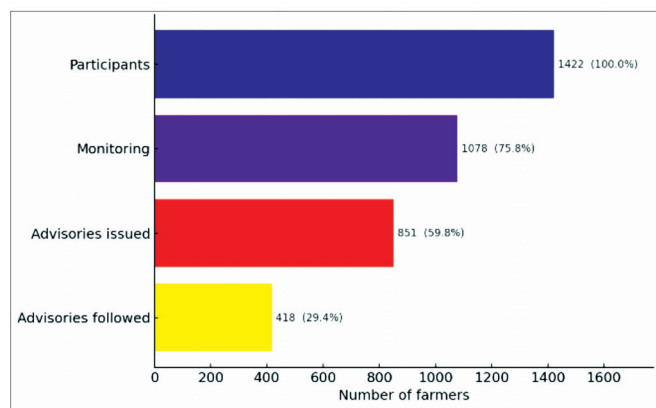


Figure 2. Advisory funnel showing participation, monitoring, dissemination, and adoption

only one out of every two advisories led to on-farm action (Figure 2). Examining the data by crop reinforced the overall findings. For paddy, 554 advisories were issued, with 251 followed (45.31%) and 303 not followed (54.69%). For brinjal, 97 advisories were issued, 42 of which were followed (43.30%), while 55 were not (56.70%). In both primary crops, fewer than half of the advisories issued resulted in action, suggesting that the complexity of the recommendations and situational constraints influenced the uptake of advice.

In paddy, adherence tended to decrease with the increasing severity of major pests, as recommended actions shifted from simple field operations to more specialised inputs. For the brown planthopper (BPH), nearly half of the advisories were followed at low severity (47.73%, 42 out of 88), but this dropped to 40.74 per cent (33 out of 81) at medium severity and further to 32.47

Table 1. Summary of pest management status of Paddy and advisory services followed by farmers

S.No.	Pest	Severity	Management practices issued by NPSS	Advisory issues by NPSS	Advisory followed farmers (%)
1	BPH	Low	Draining of water at 10-day intervals	88	47.73
		Medium	Spray neem based insecticide Azadirachtin 1500 ppm @ 5 ml/lit	81	40.74
		High	Draining of water at 10 days interval spray pymetrozine 50 WG @ 300 g/ha or flonicamid 50% WG @ 150 g/ha or dinotefuran 20% SG @ 150 g/ha	77	32.47
2	Yellow stem borer	Low	Fixing of pheromone trap @ 5 traps/ha Release of parasitoid Trichogramma Japonivum @ 1.5 lakh/ha (affixed as tricho cards)	37	45.95
		Medium	Spray neem based insecticide Azadirachtin 1500 ppm @ 5 ml/lit	34	32.35
		High	Apply chlorantraniliprole 18.5% SC 150 ml/ha or chlorantraniliprole 0.4% GR or @10 kg/ha or Bifenthrin 10% EC @ 500 ml/ha or cartap hydrochloride 4% granules @ 18.5 to 25 kg/ha or cartap hydrochloride 50% SP @ 1 kg/ha, or fipronil 5% SC @ 1000 ml/ha	10	10.00
3	Gundhi bug	Low	Fixing of Light traps	15	26.67
		Medium	Spray neem-based insecticide Azadirachtin 1500 ppm @ 5 ml/lit	14	21.43
		High	Imidacloprid 6% + Lambda-cyhalothrin 4% SL @ 300 ml/ha	5	40.00
4	False smut	Low	NA	25	100
		Medium	Spray Pseudomonas fluorescens @ 10 g/lit	36	13.89
		High	Spray Copper hydroxide 77% WP 2.5 g/litre	13	46.15
5	Bacterial leaf blight	Low	Drain water	14	100
		Medium	Drain water	12	100
		High	Spray Coper oxychloride 2 g/litre or Spray streptomycin sulphate 90% + Tetracycline hydrochloride 10% @ cycline 1 g/10 litre water. Avoid excessive use of nitrogenous fertilizer	3	0.00
6	Blast	Low	Flooding field	15	73.33
		Medium	Spray Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 500 ml/ ha or	6	33.3
		High	Kasugamycin 3% SL @ 1000-1500 ml/ha	22	54.55
7	Brown spot	Low	NA	5	100
		Medium	Spray Pseudomonas fluorescens @ 10 g/litre	17	47.06
		High	Hexaconazole 5% EC(Contaf 5 EC) @ 1000 ml/ha or Azoxystrobin 120 g/L + Tebuconazole 240 g/L SC @ 830 ml/ha or Difenoconazole 10% + Mancozeb 50% WDG @ 625 g/ha	7	71.43
8	Leaf roller	Low	Release of parasitoid Trichogramma chilonis @ 1.5 lakh/ha	11	18.18
		Medium	Spray neem-based insecticide Azadirachtin 1500 ppm @ 5 ml/lit	4	75.00
		High	Apply chlorantraniliprole 18.5% SC 150 ml/ha or chlorantraniliprole 0.4% GR or @10 kg/ha or Bifenthrin 10% EC @ 500 ml/ha or cartap hydrochloride 4% granules @ 18.5 to 25 kg/ha or cartap hydrochloride 50% SP @ 1 kg/ha, or fipronil 5% SC @ 1000 ml/ha	3	100
Overall pest management advisory services followed by farmers				554	45.31

per cent (25 out of 77) at high severity, where insecticides (e.g., pymetrozine, flonicamid, dinotefuran) were recommended alongside water management. This trend suggested that farmers preferred familiar, low-cost actions (such as periodic drainage) and were less likely to adopt chemical controls unless necessary (Table 1). A similar pattern was observed for the yellow stem borer (YSB). At low severity, adherence was 45.95 per cent (17 out of 37) with recommendations for pheromone traps and *Trichogramma* releases; this dropped to 32.35 per cent (11 out of 34) at medium severity, and fell to just 10.00 per cent (1 out of 10) at high severity, where a variety of insecticidal options (e.g., chlorantraniliprole, bifenthrin, cartap, fipronil) were suggested. The substantial decline in adherence at high severity highlighted how input-intensive recommendations were associated with the lowest uptake.

Other paddy pests exhibited mixed adherence profiles that reflected the severity–complexity relationship. For the gundhi bug, adherence was low at both low severity (26.67%, 4/15) and medium severity (21.43%, 3/14), with a slight increase at high severity (40.00%, 2/5). In contrast, all low-severity advisories for false smut were followed (100%, 25/25), but adherence dropped sharply at medium severity (13.89%, 5/36) before partially recovering at high severity (46.15%, 6/13). For bacterial leaf blight (BLB), straightforward drain-water advice achieved perfect adherence at both low (100%, 14/14) and medium severity (100%, 12/12), while high severity prescriptions involving copper oxychloride or antibiotic mixtures saw no uptake (0/3). Regarding blast, farmers adhered to low-severity nitrogen-management advice (73.33%, 11/15), but compliance fell significantly for medium flooding guidance (33.3%, 2/6) and reached 54.55 per cent (12/22) for high-severity fungicide recommendations. For brown spot, adherence was 100 per cent at low severity (5/5), 47.06 per cent at medium severity (8/17), and 71.43 per cent at high severity (5/7), with the latter coinciding with clear fungicide options. These variations indicated that simple, routine actions led to high compliance, while more complex or input-intensive recommendations faced challenges—except where farmers perceived clear, immediate benefits or had easy access to inputs.

In brinjal, the severity–adherence relationship mirrored that of paddy, with notable declines in adherence when advisories involved chemical controls or complex cultural practices. For thrips, farmers followed 45.45 per cent (20/44) of low-severity advisories focused on sticky traps and predator conservation; adherence dropped to 30.00 per cent (3/10) at medium severity and fell to 0 per cent (0/5) at high severity, where multiple insecticidal options were suggested. In the case of bacterial wilt, the low-severity recommendation of immediate rouging and destruction of infected plants achieved 91.67 per cent adherence (11/12), but adherence significantly declined at medium severity (30.43%, 7/23) and remained low at high severity (33.33%, 1/3) due to the greater effort and time needed for soil and rotation measures, along with perceived uncertainties regarding returns (Table 2). These findings suggest that, similar to paddy, the demands of the advisory—such as cost, complexity, and timing—strongly influenced uptake in brinjal.

The expanded results across crops and pests revealed three consistent empirical patterns. First, the platform demonstrated

substantial reach across districts and crops, with half of the issued advisories leading to on-farm actions. Second, adherence generally decreased as severity increased, especially when recommendations shifted from low-cost field operations to specialised chemicals or multi-step cultural practices. Third, simple, actionable guidance garnered significantly higher compliance compared to recommendations that imposed higher upfront costs, greater technical specificity, or time-intensive operations. These patterns help explain why both paddy and brinjal showed less than 50% overall adherence despite high exposure to advice, setting the stage for a focused discussion on message design, sequencing of options, and last-mile support for more demanding recommendations.

DISCUSSION

The findings revealed an advisory system with considerable reach but modest action conversion, as only about half of the issued advisories led to on-farm implementation (Sagar et al., 2022). In a rice-dominant context, this result was not surprising; the centrality of paddy to livelihoods created a strong demand for guidance. However, the content, timing, and cost of recommended practices influenced whether the advice was acted upon (Das et al., 2025). A severity–adherence gradient was observed across pests and crops (Ganai et al., 2018; Khan & Damalas, 2015). As recommendations progressed from simple field operations to input-intensive chemical controls or multi-step cultural regimes, adherence generally decreased. This trend was most evident in paddy for yellow stem borer and brown planthopper, where high-severity advisories were least likely to be implemented. In brinjal, significant drops in adherence for thrips and bacterial wilt at medium to high severity indicated that costly or complex recommendations deterred uptake. Conversely, exception cases—such as perfect adherence to low-severity guidance for false smut and bacterial leaf blight—highlighted a preference for immediately actionable, low-cost practices that farmers viewed as feasible and effective.

Three mechanisms likely explained these patterns: (i) affordability and access, (ii) complexity and timing, (iii) perceived efficacy and risk (Kabir, 2015; Baliwada et al., 2017; Baliwada et al., 2018; Nain et al., 2018). Therefore, the severity drops in adherence appeared less as a rejection of advice and more as an indication of transaction costs that escalated with the intensity of prescriptions. These insights have actionable implications for digital advisory design and last-mile support (Ashokkumar & Naik, 2021). Message architecture could be restructured to present phased, costed options—labelled “Good/Better/Best”—with clear resource footprints (cost, labour, time) and expected benefits. For high-severity situations, advisories should emphasise the minimal viable action to stabilise losses, followed by graduated chemical choices with concise instructions and safety notes. Localisation is essential: tailoring product examples to locally available actives and pack sizes could ease procurement challenges. Channel blending—using push notifications in the app alongside voice calls/SMS for time-sensitive alerts—could expand reach to less digitally engaged users. Field demonstrations and peer endorsements (through farmer facilitators/FPOs) can mitigate risks associated with complex actions like using

Table 2. Summary of pest management status of Brinjal and advisory services followed by farmers

S.No.	Pest	Severity	Management practices issued by NPSS	Issued Advisories by NPSS	Advisory followed farmers (%)
1	Thrips	Low	Set up blue traps sticky traps 15 cm. above the crop canopy for monitoring and mass trapping of Thrips @ 10-20 traps per acre. Conserve predators such as green lacewings, predatory mites, and predatory thrips	44	45.45
		Medium	Spray Broflanilide 300 g/l SC @ 42-62 ml in 500 litre of water/ha or Fluxametamide 10% w/ w EC @ 400 ml in 500 litre of water/ ha or Clothianidin 3.5% + Pyriproxyfen 8% SE @ 1250 ml in 500 litre of water/ ha or Diafenthiuron 48% + Dinotefuran 8% WG @ 625gm in 500 litre of water/ ha or Emamectin Benzoate 1.1% + Diafenthiuron 30% SC @ 1000 ml in 500 litre of water/ha or Fluxametamide 3.8% w/w + Pyridaben 9.5% w/w SC @ 1000 ml in 500 litre of water/ha	10	30.00
		High	Spray Broflanilide 300 g/l SC @ 42-62 ml in 500 litre of water/ha or Fluxametamide 10% w/ w EC @ 400 ml in 500 litre of water/ ha or Clothianidin 3.5% + Pyriproxyfen 8% SE @ 1250 ml in 500 litre of water/ ha or Diafenthiuron 48% + Dinotefuran 8% WG @ 625 g in 500 litre of water/ ha or Emamectin Benzoate 1.1% + Diafenthiuron 30% SC @ 1000 ml in 500 litre of water/ha or Fluxametamide 3.8% w/w + Pyridaben 9.5% w/w SC @ 1000 ml in 500 litre of water/ha	5	0.00
2	Bacterial wilt	Low	Collect and destroy infected plants immediately	12	91.67
		Medium	Grow resistant varieties and disease-free field. A soil pH between 5.5 and 7.0, good soil drainage and raised beds help to reduce disease pressure. Crop rotation with non-solanaceous hosts. Green manuring with Brassica sp (biofumigation). Clean field and effected parts are to be collected and burnt. Soil solarization with a transparent polyethylene sheet (125 µm thick) for 8-10 weeks during March-June in nurseries. Flooding the field for 1-3 weeks before planting will reduce bacterial wilt. Growing marigold (Tagetes spp.)	23	30.43
		High	Grow resistant varieties and disease-free field. A soil pH between 5.5 and 7.0, good soil drainage and raised beds help to reduce disease pressure. Crop rotation with non-solanaceous hosts. Green manuring with Brassica sp (biofumigation). Clean field and effected parts are to be collected and burnt. Soil solarization with a transparent polyethylene sheet (125 µm thick) for 8-10 weeks during March-June in nurseries. Flooding the field for 1-3 weeks before planting will reduce bacterial wilt. Growing marigold (Tagetes spp.)	03	33.33
Overall pest management advisory services followed by farmers				97	43.30

pheromone traps or releasing natural enemies, while KVK and Department teams can prepare critical inputs ahead of anticipated demand peaks.

The differences observed across crops suggest further targeting opportunities (Khangnbi & Priya, 2024). In paddy, where water management is frequently recommended, advisories could include micro-how-to and photo prompts within the app to clarify instructions. In brinjal, sanitation discipline and rapid rouging are crucial: short, pictorial checklists and 24–48 hours action nudges after detection could help maintain the high compliance noted at low severity. Two limitations should be acknowledged. The cross-sectional, purposive design provided an initial assessment of a newly launched public digital system; thus, causality cannot be established. Additionally, self-reported adherence may be subject to recall or social desirability bias. The evidence indicated that NPSS served as an effective signal generator, while successful implementation depended on simplifying, lowering the cost of, and clarifying high-severity advice-along with aligning digital messages with the rhythms and constraints of smallholder decision-making (Samanta et al., 2020).

CONCLUSION

The study revealed that NPSS advisories effectively reached farmers, but only led to on-farm action approximately 50 per cent of the time. Crop-specific uptake for paddy and brinjal remained below 50 per cent. Adherence generally declined with increasing severity of issues; for instance, compliance for BPH dropped from 47.73 per cent at low severity to 32.47 per cent at high severity, while adherence for YSB fell to 10 per cent at high severity. To enhance compliance, it is essential to provide phased, cost-effective options, localisation of recommendations to match locally available inputs and pack sizes, timely nudges through apps and SMS/voice messages, and pre-positioned inputs in collaboration with KVK/ Department partners. Recommend integration with input supply chains, strengthening local bio-agent availability, and analysing socio-economic predictors of compliance in future studies. Lastly, the NPSS serves as an effective signal; implementation improves when advice is simpler, more affordable, and clearer within the context of farmers' actual decision-making processes.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents 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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Crew Position-Based Assessment of Fishermen's Knowledge Needs in The Coastal Districts of Tamil Nadu

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HIGHLIGHTS

- Skippers/drivers show proficiency in navigation and modern tools, with less need for further training.
- Net haulers and helpers require more training, especially in GPS usage, sustainable fishing, and gear management.
- Tailored training programs for each crew position, especially focusing on the gaps identified for Helpers and Net Haulers.
- Policymakers, NGOs, and training institutes should focus on creating tailored training programs based on crew positions.

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ABSTRACT

The study conducted in 2025 (January to May) examined the knowledge needs of fishermen in Tamil Nadu, focusing on their roles within the fishing crew: Skippers/Drivers, Net Haulers, and Helpers. Tamil Nadu, with its extensive coastline, plays a vital role in India's marine fisheries, supporting millions of fishermen. The study identified key knowledge gaps in areas such as modern navigation technologies, sustainable fishing practices, and gear handling. A total of 150 fishermen were surveyed from coastal districts, including Nagapattinam, Ramanathapuram, Thoothukudi, and Kanyakumari, using a structured questionnaire. The findings indicate that Skippers/Drivers are generally proficient in knowledge and require less training, whereas Net Haulers and Helpers exhibit a higher need for knowledge in technology, sustainability, and gear management. Statistical analysis, including regression and correlation, reveals significant relationships between fishermen's knowledge needs and their experience, educational background, and crew position. The results highlight the necessity for tailored training programs to address the specific needs of different crew members. This study emphasises the importance of crew-specific capacity-building to enhance operational efficiency, improve sustainability practices, and foster economic resilience within the fishing communities of Tamil Nadu.

INTRODUCTION

Tamil Nadu, with its extensive coastline of 1,076 km, stands as one of India's leading marine fish-producing states Government of Tamil Nadu, 2024). It is home to a significant population whose livelihoods are intricately tied to the sea. According to the Marine Fisheries Census 2016, Tamil Nadu hosts 575 marine fishing villages

and 349 landing centres, supporting over 2 million marine fishing families and nearly 8 lakh individuals engaged in various fishing-related activities (CMFRI, 2020). The state's contribution to India's marine fishery is indispensable, underlining its vital role in both the national economy and ecological sustainability. India recorded 3.45 million tonnes of marine fish landings in 2023, with Tamil Nadu accounting for a substantial share, showcasing the state's resilience

and continued ecological and economic importance within India's marine fisheries landscape (ICAR-CMFRI, 2025).

The roles of fishermen in Tamil Nadu vary significantly, primarily based on the position they occupy within the boat crew. These positions include Skipper/Driver, Net Hauler and Helper, each with distinct responsibilities and knowledge requirements that contribute to the overall efficiency and success of fishing operations. The responsibility of skippers navigating and managing the fishing process requires advanced navigational skills and knowledge of fishing zones, especially with modern technology GPS (Byron, 1980). In contrast, other crew members, such as net haulers and helpers, while crucial in ensuring a productive catch, typically need a more specialised understanding of gear handling, the quality of the catch and maintenance procedures (Van Sittert, 2015). Their roles, though less focused on navigation, are integral to optimising operational efficiency and maintaining high standards of sustainability.

A fundamental factor influencing the sustainability and productivity of fisheries is the knowledge and expertise within the fishing communities. According to Orensanz et al., (2014), fisher knowledge (FK) encompasses a wide range of experiential insights, including an understanding of fish populations, ecosystems, fishing techniques, community dynamics, governance structures and market practices. The importance of tailored knowledge based on specific crew positions becomes evident as advancements in fishing technology, such as GPS systems and sonar, have transformed operations. Gopal (2023) underscores that more experienced roles, such as Skippers, require extensive knowledge of these technologies, while other roles may only need basic operational skills. The shift in fishing techniques, particularly in Chennai's shrimp trawl fisheries, reflects the growing complexity of fishing practices and the need for diversified knowledge across crew members to ensure sustainability and efficiency (Bavinck, 2012). This study seeks to systematically assess the specific knowledge needs of fishermen in the coastal districts of Tamil Nadu. The research aims to provide a comprehensive understanding of the knowledge gaps across different crew positions. The findings will offer evidence-based recommendations for extension services, training institutes, NGOs, and policymakers focused on equipping fisher communities with the necessary tools for enhancing their economic resilience, ensuring ecological sustainability and fostering social development. Understanding this knowledge needs will not only improve fishing operations but also contribute to the long-term viability of Tamil Nadu's marine fisheries.

METHODOLOGY

The study was carried out from January to May in 2025 to assess the knowledge needs of fishermen. Data were collected from 150 respondents using the proportionate random sampling method in the study area mentioned below. The pilot study was conducted in Indinthakari fishing village, Tirunelveli district. The sampling was carried out in the coastal districts, Nagapattinam (87,013), Ramanathapuram (1,88,915), Thoothukudi (84,987) and Kanyakumari (1,52,447) in Tamil Nadu. These districts were chosen due to the higher fisher population, and from each district, two fishing villages, such as Akkaraipettai (n=17) and Seruthur (n=8)

in Nagapattinam; Rameswaram (n=35) and Mandapam (n=20) in Ramanathapuram; Threspuram (n=14) and Thoothukudi Fishing Harbour (n=12) in Thoothukudi; and Kanyakumari (n=22) and Colachel (n=22) in Kanyakumari district were selected for the study by Proportionate random sampling. The survey was conducted for the study through personal interviews. Descriptive statistical methods, including frequency analysis, Spearman correlation, Multiple linear regression, and the Kruskal-Wallis test, were used to analyse the data through SPSS (Version 25.00). To analyse the knowledge needs, 12 statements were developed and assessed using a 5-point Likert scale with responses coded as: 5 = Most Need, 4 = More Need, 3 = Need, 2 = Less Need, 1 = Least Need (ordinal rankings without equal intervals). It is allowed for the quantitative assessment of the knowledge needs of fishermen. In order to determine how independent variables affect the dependent variable, multiple regression analysis was performed.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + e$$

Where Y = Dependent variable, β_0 = intercept, β_1 = slope, X_i , e = error term. The Kruskal-Wallis H test was used to compare crew position in the boat concerning the skill need assessment, with significant differences.

$$H = \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 3(N+1)$$

Where, K = number of groups used for comparison, N = total size of the sample, n_i = i-th group of the sample size and R_i = total of the ranks related to the i-th group. The software SPSS and Microsoft Excel were used to analyse the data. Origin Pro and Chart Expo were used to visualise the research data.

RESULTS

Role-based knowledge needs of fishing crew members

The mean score of twelve statements for skipper/driver, net hauler and helper was illustrated in Table 1. Among 150 respondents, nearly half of the respondents (43.3%) were net haulers/labourers, 34.0 per cent were skippers/drivers, and 22.7 per cent were helpers. Assuring to cover all the crew positions on a boat. The results revealed clear role-based differences in training needs, with Skippers consistently reporting the lowest scores, net haulers generally showing moderate scores, and Helpers recording the highest across most domains.

Navigation-related knowledge areas demonstrated the widest disparities. For example, the use of GPS to locate potential fishing zones was scored at 2.25 by Skippers, compared with 2.95 by Net Haulers and 4.74 by Helpers (Table 1). A similar pattern was evident for the use of modern navigation tools and techniques, where Skippers scored 2.27, Net Haulers 3.29, and Helpers 4.12. Accessing real-time weather forecasts through ICT applications such as mFish and Thoondil also followed this gradient (2.55, 3.14, and 3.71). These findings suggest that while Skippers are already highly proficient in navigation and weather monitoring, Helpers expressed a strong need for training in these areas, with Net Haulers positioned between the two.

In sustainability-related knowledge, scores were moderately high across all groups, reflecting general awareness but also

Table 1. Mean Scores for Knowledge areas among skipper/driver, net hauler, and helper

Statements	Mean scores		
	Skipper/ Driver	Net hauler	Helper
Utilising GPS technology to locate potential fishing zones	2.25	2.95	4.74
Applying sustainable fishing practices during the breeding season	3.12	3.68	3.76
Selecting appropriate fishing gear for target fish species	3.12	3.20	3.59
Understanding boat maintenance and fuel management for efficient fishing operations	3.20	3.22	3.53
Maintaining and handling fishing nets and gear for efficiency and durability	2.65	3.05	3.26
Using ice storage techniques to preserve fish quality during extended trips (6). Navigating fishing vessels efficiently using modern tools and techniques	2.96	3.24	3.49
Navigating fishing vessels efficiently using modern tools and techniques	2.27	3.29	4.12
Accessing real-time weather forecasts through ICT tools and mobile apps like mFish, Thoondil, etc	2.55	3.14	3.71
Communicating and networking through social media platforms for fish marketing and buyer connections	3.02	3.12	3.26
Adhering to Marine Protected Area (MPA) guidelines for sustainable fisheries management	2.82	3.37	3.79
Implementing responsible fishing practices to sustain commercially important fish species	2.80	3.35	3.68
Managing finances effectively by evaluating the cost-effectiveness of fishing gear and operations	3.16	3.52	3.79

highlighting specific needs. Applying sustainable fishing practices during the breeding season received mean scores of 3.12, 3.68, and 3.76 for Skippers, Net Haulers, and Helpers, respectively. Similarly, adherence to Marine Protected Area (MPA) guidelines was rated 2.82, 3.37, and 3.79, while responsible fishing practices to sustain commercially important fish species scored 2.80, 3.35, and 3.68. These results indicate that Net Haulers and Helpers identified stronger needs in sustainability practices, whereas Skippers expressed comparatively lower requirements, likely reflecting their prior experience and supervisory role.

Operational knowledge areas showed more balanced scores but still indicated role-based differences. Selecting appropriate fishing gear for target species was scored 3.12 by Skippers, 3.20 by Net Haulers, and 3.59 by Helpers. Net and gear handling, a domain central to Net Haulers, was scored 2.65, 3.05, and 3.26 across the three groups. Ice storage techniques, important for maintaining fish quality, were rated 2.96, 3.24, and 3.49, suggesting higher needs among Net Haulers and Helpers. Knowledge of boat maintenance and fuel management showed relatively similar scores across roles (3.20, 3.22, and 3.53), though Helpers again reported the highest mean.

Economic and communication competencies also reflected differentiated needs. Managing finances to evaluate gear and operational costs was scored 3.16 for Skippers, 3.52 for Net Haulers, and 3.79 for Helpers, highlighting a clear progression in training requirements. Communicating and networking through social media for fish marketing received slightly lower means overall but followed the same trend, with Skippers at 3.02, Net Haulers at 3.12, and Helpers at 3.26.

Overall, the results illustrate a consistent pattern, such as Skippers/Drivers reporting the lowest training needs, aligning with their greater experience and established responsibilities in navigation and operations. Net Haulers demonstrated moderate scores, reflecting their active role in gear handling, ice storage, and operational efficiency. Helpers consistently reported the highest mean scores across domains, particularly in navigation, sustainability, and financial literacy, signalling a substantial need for targeted training interventions to support their evolving roles in fishing operations. These findings suggest that training should

be tailored to the specific roles of crew members rather than delivered uniformly to all fishermen. A crew-specific training approach would maximise efficiency and ensure greater impact by addressing the distinct knowledge gaps of each role.

Effect of experience and education on fishermen's knowledge requirement needs

Among 150 respondents, most fishermen (52.0%) had extensive experience with over 20 years in marine fishing, 30.7 per cent with 11-20 years and 17.3 per cent with less than 10 years. The Kruskal-Wallis test was applied to examine differences in perceived knowledge needs among fishermen with varying levels of experience. The test revealed a statistically significant difference ($H = 27.175$, $p = 0.0001$; $p < 0.05$), indicating that experience plays a significant role in shaping knowledge requirements (Table 2). Fishermen with less than 10 years of experience reported the highest perceived knowledge need (mean rank = 115.75), while those with 10-20 years (67.87) and more than 20 years of experience (66.58) reported substantially lower ranks. This pattern suggests that less experienced fishermen perceive greater training needs, likely due to their limited exposure and ongoing skill development, whereas more experienced fishermen demonstrate greater confidence in their existing competencies. These findings highlight that experience level must be considered when designing training interventions, as tailoring programs according to both crew role and years of experience will ensure more effective and impactful capacity-building.

In terms of education, nearly half of the respondents (44.7%) had secondary education, 27.3 per cent had primary education, and 13.3 per cent were graduates, while 10 per cent were functionally

Table 2. Mean Rank for Experience in Fishing

	Category	Mean Rank
The knowledge need of the fishermen	Less than 10 years	115.75
	10-20 years	67.87
	Above 20 years	66.58
	Total	
Kruskal-Wallis $H=27.175$		

literate and 4.7 per cent were illiterate. The Kruskal–Wallis test was employed to examine differences in perceived knowledge needs among fishermen with varying educational backgrounds. The test yielded a statistically significant result ($H = 16.631$, $p = 0.002$; $p < 0.05$), indicating that education level significantly influences knowledge requirements (Table 3). Mean ranks revealed an inverse relationship: illiterate fishermen had the highest mean rank (108.36), followed by functionally literate (91.00), primary education (76.35), graduates (65.60), and secondary education (62.10). The slightly higher score for graduates compared with secondary-educated fishermen may reflect less practical exposure due to extended time spent in formal education. These findings suggest that fishermen with lower levels of education perceive greater training needs, likely due to limited prior learning opportunities or challenges in adapting to technical changes. Importantly, this underscores the necessity of education-sensitive training interventions, with emphasis on reaching illiterate and functionally literate individuals to bridge knowledge gaps and strengthen workforce competency.

Table 3. Mean Rank for Education Status

	Category	Mean Rank
The knowledge need of fishermen	Illiterate	108.36
	Functionally literate	91.00
	Primary education	76.35
	Secondary education	62.10
	Graduate	65.60
	Total	
Kruskal-Wallis $H = 16.631$		

Correlation between socio-demographic profile and knowledge needs of fishermen

The results from the study were used to analyse the association between the independent variables and the knowledge needs of fishermen (Table 4). Among the seventeen variables twelve variables such as age, experience in fishing, crew position in boat, average catch per trip, mass media exposure, information needs during fishing, scientific orientation, risk orientation, self-confidence, managerial behaviour, Indigenous Traditional Knowledge in fishing, and Information Communication Technology (ICT) tools usage during fishing were significant to the knowledge need of fishermen. Educational status, fishing type, fishing distance, extension agency contact, and Information sources were non-significant to the knowledge needs of fishermen.

The multiple regression analysis yielded the following model:

$$Y = 3.416 + 0.020(X1) - 0.036(X2) + 0.269(X3) + 0.269(X4) + 0.044(X5) + 0.041(X6) + 0.012(X7) - 0.029(X8) - 0.034(X9) + 0.100(X10) - 0.082(X11) - 0.106(X12) + 0.055(X13) - 0.191(X14) + 0.003(X15) - 0.052(X16) - 0.012(X17) = 0.668$$

The coefficient of determination adjusted (R^2) was 0.625, indicating that approximately 62.5 per cent of the variance in fishermen's knowledge needs is explained by the set of independent variables included in the model (Table 4). Furthermore, the regression model was found to be statistically significant, with a p -value less than 0.05, suggesting that the independent variables collectively contribute to predicting the dependent variable.

Table 4. Correlation and Regression Coefficients of independent variables and knowledge need of fishermen

Variable code	Name of the variable	Correlation coefficient (r)	Regression Coefficient (β)
X1	Age	-0.173*	0.020
X2	Educational status	-0.094 NS	-0.036
X3	Experience in fishing	-0.317**	0.269
X4	Crew position in Boat	0.787**	0.269
X5	Fishing type	0.104 NS	0.044
X6	Fishing distance	-0.076 NS	0.041
X7	Average catch per trip	-0.188*	0.012
X8	Mass media exposure	-0.199*	-0.029
X9	Extension agency contact	-0.032 NS	-0.034
X10	Information sources	0.013 NS	0.100
X11	Information needs during fishing	-0.251**	-0.082
X12	Scientific Orientation	-0.183*	-0.106
X13	Risk Orientation	-0.640**	0.055
X14	Self Confidence	-0.628**	-0.191
X15	Managerial behaviour	-0.496**	0.003
X16	Indigenous Traditional knowledge in fishing	-0.447**	-0.052
X17	ICT tools usage during fishing	-0.0162*	-0.012
R=0.817,		R ² =0.668	
Adjusted R ² = 0.625		Std error= 0.2022285	

NS = non-significant; **Significance at 0.01 level; *Significance at 0.05 level

DISCUSSION

The structure of crew positions and roles aboard fishing boats in India varies depending on the vessel type and fishing operation. In mechanised trawl fisheries, such as those in Chennai, the captain or “driver” oversees operations, while crew members take shifts to optimise fishing efforts and share profits. Larger vessels, like Sonatype boats, require larger crews, enhancing operational efficiency but increasing costs (Bavinck, 2012). Similarly, Kerala's ring seine fishery involves key positions like the Aaryakaaran (leader), with crew sizes ranging from 25 to 60. The growing size of fishing vessels has led to a shift from individual to collective ownership, influencing crew dynamics and profit distribution (Gopal, 2023).

This study confirms that fishermen's knowledge needs vary by crew role, reinforcing the importance of role-specific training. Similar patterns have been observed in agriculture, where tailored knowledge delivery improves adoption of practices (Kour et al., 2023). In fisheries, targeted dissemination through ICTs is vital, though in Tripura, limited access reduces extension effectiveness (Nirmalkar et al., 2022; Lahiri et al., 2024). Comparable knowledge gaps in aquaculture, such as fish disease and feeding practices in West Bengal (Mondal et al., 2025), highlight the broader need for structured, need-based training. Navigation knowledge was particularly limited among Net Haulers and Helpers. Viswanathan et al., (2023) also reported such gaps among support crews, emphasising risks to safety and efficiency. Training in GPS, radar, and digital mapping would address these needs, consistent with Thomas et al. (2020), who highlighted the benefits of modern navigational tools for safety and market access.

Post-harvest handling emerged as another gap, especially ice storage. Seenivasan et al. (2025) noted insufficient ice production in Tamil Nadu, reducing fish quality. Training for Net Haulers and Helpers in handling and storage could directly reduce losses. Financial literacy, particularly for Helpers, is also critical. Sajesh et al., (2021) emphasised equipping younger fishers with business and market skills to strengthen resilience. Similarly, Ismail and Khalid (2015) showed the potential of social media for marketing, which aligns with Helpers' expressed interest in digital tools. Gear selection and sustainability practices require further attention. Madhu et al. (2021) stressed the ecological impacts of gear design, while Gunakar et al., (2017) found that compliance with monsoonal bans depends on active crew participation. Awareness of Marine Protected Areas was also limited among support crews, echoing findings by Dineshbabu et al., (2022), who recommended short-duration training to improve compliance. Basic vessel maintenance and fuel efficiency training remain important for all crew roles. The FAO (2011) showed that improved engine handling reduces costs and enhances efficiency, suggesting broad benefits if such training is extended beyond Skippers.

CONCLUSION

This study shows that fishermen's knowledge needs in Tamil Nadu vary significantly by crew role. Skippers demonstrated high proficiency in navigation and vessel operation, while Net Haulers and Helpers reported greater needs in modern technologies, sustainable practices, gear handling, post-harvest techniques, and financial management. Helpers in particular revealed critical gaps in navigation tools, marketing, and compliance with Marine Protected Area guidelines. Experience and education also influenced knowledge needs, with less experienced and less educated fishermen perceiving greater training requirements than their more experienced or better-educated counterparts. These findings highlight the importance of tailoring training interventions not only by occupational role but also by socio-demographic characteristics. Such targeted programmes would maximise training impact, strengthen operational efficiency, promote sustainable practices, and enhance economic resilience. Policymakers, training institutions, and NGOs should prioritise crew-specific role- and context-specific strategies to ensure safer, more profitable, and environmentally responsible fisheries, ultimately improving the livelihoods of coastal fishing families.

DECLARATIONS

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

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Behavioural Determinants of Secondary Agriculture-based Entrepreneurs in Assam

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HIGHLIGHTS

- Younger, educated entrepreneurs with stable households show stronger entrepreneurial behaviour.
- Income and investment were positively and significantly correlated with entrepreneurial behaviour.
- Mass media exposure significantly enhanced entrepreneurial behaviour.
- Economic motivation was the strongest predictor, followed by deferred gratification and value orientation.

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Keywords: Secondary agriculture, Entrepreneurship, Entrepreneurial behaviour, Rural entrepreneurship.

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ABSTRACT

Rural India still struggles with income gaps. Secondary agriculture serves as a strategic path to promote efficient rural entrepreneurship. The study was conducted in 2024 in Assam's Dhubri district employing a mixed-method research design that examined variations in entrepreneurial attributes across secondary agricultural enterprises, based on data from 100 respondents representing five enterprises. Entrepreneurial behaviour showed positive correlations with factors like education, income, investment, media use, aspiration, motivation, gratification, and values, and a negative correlation with age. Multiple regression analysis explained 72.8 per cent of entrepreneurial behaviour (adjusted $R^2 = 0.645$). Using principal component analyses (PCA) and Varimax rotation, 23 entrepreneurial attributes were grouped and renamed into seven factors. The strategic policy advocacy to enhance entrepreneurs' holistic development should prioritize these key attributes of secondary agriculture-based entrepreneurs to improve their entrepreneurial behaviour.

INTRODUCTION

Despite India achieving self-sufficiency in food grain production, the processing of agricultural produce remains minimal, accounting for less than ten percent (Suhas & Dolli, 2023). Numerous stakeholders are now prioritizing agri-entrepreneurship as a key driver of innovation and socio-economic progress in the agricultural sector (Kademani et al., 2024). Despite constituting around 86 per cent of India's farmers and producing nearly 60 per cent of its agricultural output, small and marginal farmers face persistent financial instability, with incomes scarcely covering basic expenses and limiting opportunities for savings or better living standards (Boppana & Reddy, 2023). In India, approximately 63 per cent of the total population resides in rural areas (World Bank

Report, 2023), where agriculture and allied activities serve as the primary source of livelihood. The notion of farmer income transcends mere physical yield, emphasising the importance of returns per man-day rather than output per area. As agricultural growth and development strategies evolve, there is a need to investigate opportunities for fostering rural entrepreneurship across agriculture and allied sectors (Kharga, 2021). Hence, augmenting secondary agricultural endeavours becomes imperative to optimise resource utilisation and foster sustainable agricultural growth.

The notion of 'secondary agriculture' in India lacks a clear definition and is generally linked to agro-based manufacturing. Although the Planning Commission formed a Technical Advisory Committee on Secondary Agriculture (TACSA) in 2007, and its 2008 report highlighted the importance of the sector, the committee

did not offer a specific definition. Instead, it interpreted the term broadly to include all bio-resource-based products—both food and non-food—used for human consumption and industrial purposes.

A decade later, in 2018, a report by the Ashok Dalwai Committee recognised the growing relevance of secondary agriculture and defined it as “adding value to primary agriculture and building agricultural enterprises in rural India” through “farm-linked activities and secondary agriculture”. Secondary agriculture involves a diverse range of activities and enterprises closely tied to farming, aiming to harness and optimise financial, human, and technological resources along with organisational expertise and effective risk management strategies (Das & Ghosh, 2023). Ashok Dalwai committee’s report further categorised secondary agriculture into three different avenues, viz., Type A (Value addition to Primary Agriculture Production Systems), Type B (Alternative Enterprises) and Type C (Enterprises that use crop residues and wastes of Primary Agriculture) (Dalwai, 2018).

According to the Census of India (2011), the Northeastern region of India, despite encompassing 7.7 per cent of the nation’s land area, contributes only 1.6 per cent to the country’s industrial footprint. Assam, a central state in this region, holds strategic importance due to its abundant natural resources (Khan, 2024). However, these resources remain largely underutilised due to various constraints (Upadhyaya, 2022). Studies highlight that the off-farm ventures hold a promising avenue for boosting farmer incomes in Assam, suggesting substantial potential for the state to uplift rural livelihoods (ILRT India, n.d.). Therefore, the present investigation centres on entrepreneurs engaged in secondary agricultural enterprises. It will aid in unravelling the key attributes of these entrepreneurs, identify influential factors driving secondary agriculture and ultimately facilitate robust policy formulation.

METHODOLOGY

The study was conducted in Assam. Dhubri District was purposively selected out of 35 districts of Assam known for its cultural diversity and linguistic plurality, reflecting the composite heritage of the region (Tiwarei, 2024). The rich cultural tapestry of a region would aid in fostering and promoting rural entrepreneurship through secondary agriculture (Singh et al., 2017). From Dhubri’s 12 blocks, two blocks—Rupshi and Dharmasala—were randomly selected for the research. Five distinct rural enterprises involved in secondary agricultural activities were randomly chosen across three avenues of secondary agriculture. The selected enterprises included *Mora* (Bamboo cane stool) Making (Enterprise 1) Bamboo Basket Weaving (Enterprise 2), Thread Processing (Enterprise 3), *Gamucha* (a handwoven, rectangular piece of cloth, typically made of cotton, and is a significant cultural symbol of Assam) Weaving (Enterprise 4), and Shola craft products using discarded fish packing box made with Thermocols (Enterprise 5). From each enterprise, 20 entrepreneurs were randomly selected to participate in the study, bringing the total number of respondents engaged in secondary agriculture to 100.

A pilot study was conducted in the chosen district, using informal discussions to capture essential insights into entrepreneurs’ socio-economic contexts, types of enterprises, and operational challenges. These findings helped shape the final research design.

Key study variables were identified and broadly categorised into four aspects, viz., socio-personal, socio-economic, communicational and psychological attributes, through a thorough literature review and expert consultations, aligning with the investigation’s core objectives. The assessment of entrepreneurial behaviour in this study is based on six core dimensions: innovativeness, achievement motivation, decision-making ability, risk-taking ability, planning ability, and self-confidence. These components were selected through a triangulated approach combining theoretical grounding and empirical precedent. Theoretically, the framework draws from McClelland’s Achievement Motivation Theory (McClelland, 2015), which identifies achievement orientation and risk propensity as foundational traits of entrepreneurs. Empirically, studies such as Shirur et al., (2019) have operationalised these six dimensions in agricultural contexts, demonstrating their relevance and measurability among rural entrepreneurs. The Entrepreneurial behaviour was quantified using a composite index approach, where the index of individual components was assessed separately and then aggregated to derive an overall score. Data collection was executed using a structured interview schedule tailored to the research objectives. Respondents were interviewed over a span from October 2023 to February 2024. The gathered data were processed and analysed utilising Microsoft Excel and SPSS version 23.0.

Statistical tools like mean, standard deviation, frequency & percentage were employed to understand the distribution pattern of the respondents in different categories of variables. Enter multiple regression analysis was carried out considering entrepreneurial behaviour as the dependent variable and selected attributes as the independent variables. Factor analysis was used to analyse the interrelationships among the set of various attributes and represent latent dimensions that account for the shared variance.

RESULTS

Entrepreneurial behaviour represents a specific dimension of entrepreneurial activity that focuses on analysing, anticipating, and shaping individual actions within entrepreneurial contexts. Figure 1 reveals that the six key aspects of entrepreneurial behaviour differ across the five enterprises engaged in secondary agricultural activities. Among the assessed traits, achievement motivation was most pronounced, with a majority of entrepreneurs scoring above 80 per cent, and the highest reaching 92 per cent. Notably, entrepreneurs from Enterprise 1 exhibit the highest degree of achievement motivation. The trait of innovativeness also ranks relatively high, with more than 70 per cent of participants showing significant creative initiative. However, the capacity for risk-taking appears to be the weakest among the six behavioural dimensions.

As evidenced in Table 1, a range of socio-economic and psychological variables demonstrated a statistically significant positive correlation with entrepreneurial behaviour at the 1% significance level. These include education, household status, economic status, average annual income, level of enterprise investment, resource position, and frequency of mass media engagement. In addition, key psychological constructs—such as aspirational level, economic motivation, deferred gratification, and value orientation—were also positively associated with entrepreneurial engagement. Conversely, the variable of age revealed

Table 1. Correlation between attributes of entrepreneurs based on secondary agriculture and entrepreneurial behaviour

Correlation Coefficient (r)	
Attributes of the Entrepreneur	Entrepreneurial Behaviour
Age (X1)	-.358**
Education (X2)	.464**
Family type (X3)	0.030
Family size (X4)	-0.038
Male earning member (X5)	0.103
Female earning member (X6)	0.024
Earning member of family (X7)	0.118
Organization participation (X8)	0.144
Household status (X9)	.498**
Economic status (X10)	.365**
Average annual income (X11)	.379**
Enterprise investment (X12)	.354**
Experience (X13)	-0.020
Resource position (X14)	.338**
Credit orientation (X15)	0.180
Market orientation (X16)	0.064
Mass media use (X17)	.499**
Personal cosmopolite information use (X18)	-0.051
Personal localite information use (X19)	-0.086
Level of aspiration (X20)	.529**
Economic motivation (X21)	.669**
Deferred gratification (X22)	.608**
Value orientation (X23)	.359**

*significant at 5% level of significance, **significant at 1% level of significance

a significant negative correlation, suggesting that younger individuals may be more inclined toward entrepreneurial activities compared to their older counterparts. This pattern underscores the multifaceted nature of entrepreneurial behaviour, shaped by both structural conditions and individual-level psychological drivers.

Table 2 reveals that all 23 independent variables have an R-squared value of 0.728, and the adjusted R-squared value is 0.645, which means that the 23 variables have contributed 72.8 per cent of the total variation in entrepreneurial behaviour. Entrepreneurs

with relatively high educational qualifications, organisational participation, household status and mass media usage have showcased greater entrepreneurial behaviour than others. It also revealed that entrepreneurs with greater economic motivation and deferred gratification have significantly high entrepreneurial behaviour. Organisational participation has depicted negative effects on entrepreneurial behaviour.

In Table 3, it was observed that the 23 attributes (variables) of the entrepreneurs were categorized into seven components. Component 1 is most significant and comprises seven attributes viz., average annual income, economic status, level of aspiration, household status, enterprise investment, resource position, economic motivation with eigenvalue of 5.250, a per cent of the variance of 22.828 and the cumulative per cent of 22.828 is explained. This component was renamed as “Entrepreneurial economy”. Component two had an eigenvalue of 3.304 and the variance explained was 14.365 per cent with cumulative per cent of 37.193. This component was made up of five items, namely age, education, value orientation, mass media and deferred gratification, and it was renamed as “Entrepreneurial personality”. The third component comprised four attributes, which were male earning member, family size, family type and earning member of family that had an eigenvalue of 2.724, and a per cent of the variance of 11.843 and the cumulative per cent of 49.036 was explained. This component was renamed as “Entrepreneurial family pattern”. The fourth component was renamed as “Gender dynamics” which had an eigenvalue of 1.736, the variance explained was 7.55 percent and the cumulative per cent was 56.586. The two attributes under this component that were female earning members and experience. The fifth component comprised of two attributes viz., market orientation and personal localite, with an eigenvalue of 1.471, a percent of the variance of 6.397 was explained and the cumulative percent was 62.983. This component was renamed as “Entrepreneurial marketing”. Personal cosmopolite and organization participation together constituted the sixth component with an eigenvalue of 1.255, the variance explained was 5.458 per cent and the cumulative per cent was 68.440 and was renamed as

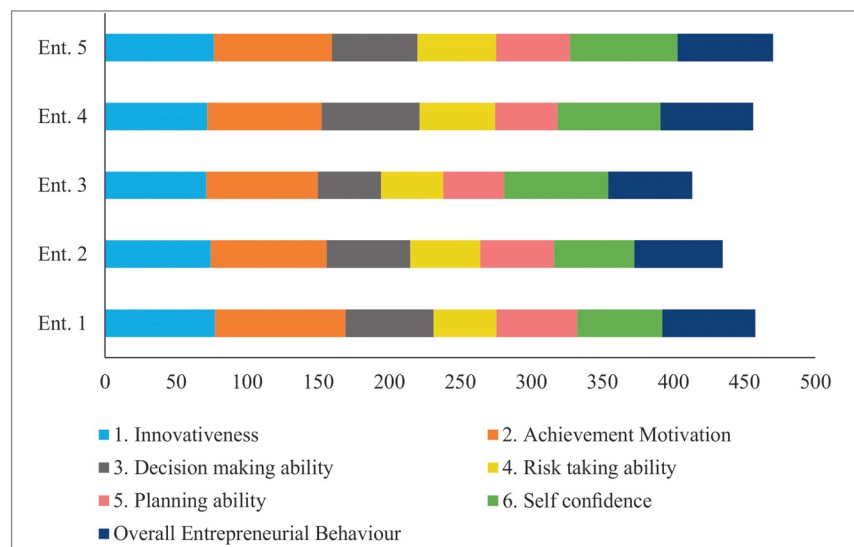
**Figure 1.** Differential entrepreneurial behaviour of various secondary agriculture-based entrepreneurs

Table 2. Multiple regression between entrepreneurial behaviour (dependent variable) and attributes of entrepreneurs

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	
1	.853	.728	.645	4.218	
Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.549	11.341		.048	.962
Age (X1)	.070	.067	.133	1.041	.301
Education (X2)	1.309	.591	.216	2.214	.030
Family type (X3)	1.826	1.698	.118	1.076	.285
Family size (X4)	-1.561	1.587	-.120	-.984	.328
Male earning member (X5)	1.017	5.312	.093	.191	.849
Female earning member (X6)	2.656	4.815	.208	.552	.583
Earning member of family (X7)	-1.705	5.050	-.183	-.338	.737
Organization participation (X8)	-1.568	.611	-.199	-2.564	.012
Household status (X9)	2.577	1.064	.239	2.421	.018
Economic status (X10)	-1.680	1.745	-.108	-.963	.339
Average annual income (X11)	2.448E-05	.000	.243	1.704	.092
Enterprise investment (X12)	.000	.001	-.021	-.184	.854
Experience (X13)	.108	.092	.151	1.174	.244
Resource position (X14)	.046	.137	.026	.333	.740
Credit orientation (X15)	.228	.325	.056	.703	.484
Market orientation (X16)	1.519	2.677	.042	.567	.572
Mass media use (X17)	.465	.227	.188	2.053	.043
Personal cosmopolite information use (X18)	1.005	.671	.120	1.498	.138
Personal localite information use (X19)	-.207	.181	-.082	-1.145	.256
Level of aspiration (X20)	-.071	.255	-.036	-.277	.782
Economic motivation (X21)	1.423	.501	.310	2.843	.006
Deferred gratification (X22)	.769	.262	.297	2.937	.004
Value orientation (X23)	.894	.477	.156	1.873	.065

“Organisational interaction”. The last component had an eigenvalue of 1.077 with a per cent of variance 4.683, along with a cumulative per cent of 73.124. This component had only one variable i.e., credit orientation, and thus it is named as “Credit orientation”.

DISCUSSION

The present study reveals that a majority of respondents exhibit a moderate level of entrepreneurial behaviour, which aligns with earlier findings by Mudoi et al., (2020) and Shivacharan et al., (2015), who reported similar behavioural distributions among rural agri-entrepreneurs in Assam and Telangana, respectively. However, the study also highlights relatively low levels of risk-taking behaviour, which may be attributed to socio-cultural norms that discourage financial risk, economic insecurity, and limited access to safety nets. This finding resonates with Keshari et al., (2024), who noted that farmers often exhibit risk-averse tendencies due to uncertain market conditions and lack of institutional support. Moreover, Shivacharan et al., (2015) observed that despite high economic motivation, many rural entrepreneurs refrain from taking bold financial decisions, preferring incremental growth strategies. Interestingly, the current study finds that younger entrepreneurs tend to display higher levels of entrepreneurial behaviour,

particularly in domains such as planning ability and self-confidence. This observation aligns with Kobba et al., (2020), who reported that younger individuals in both farm and non-farm sectors are more adaptive, tech-savvy, and open to innovation. However, Sahu (2022) observed that older farmers in Chhattisgarh demonstrated higher persistence and manageability, contradicting the assumption that youth always correlate with stronger entrepreneurial behaviour. Additionally, entrepreneurs with strong economic and resource positions—such as access to capital, land, and market linkages—exhibit significantly higher entrepreneurial behaviour. This supports the findings of Gupta et al., (2019) & Nain et al., (2024) who emphasized the role of financial stability and resource availability in enhancing entrepreneurial performance. Entrepreneurs having greater mass media usage tend to show significant entrepreneurial behaviour as compared to others (Gupta et al., 2019). However, Deepa (2022) found that excessive reliance on media discouraged risk-taking among rural entrepreneurs, who became more cautious after exposure to negative case studies. In the current research, the psychological attributes namely level of aspiration, economic motivation, deferred gratification and value orientation displays positively strong correlation with the entrepreneurial behaviour and thus it is evident that entrepreneurs pursuing strong psychological

Table 3. Factor analysis of the attributes of entrepreneurs

Factor No.	Variables	Eigenvalue	Variance explained (%)	Cumulative (%)	Factor loading value	Factor renamed
1	Average annual income (X11)	5.250	22.828	22.828	.821	Entrepreneurial economy
	Economic status (X10)				.813	
	Level of aspiration (X20)				.797	
	Household status (X9)				.687	
	Enterprise investment (X12)				.644	
	Resource position (X14)				.596	
	Economic motivation (X21)				.508	
2	Age (X1)	3.304	14.365	37.193	.835	Entrepreneurial personality
	Education (X2)				.738	
	Value orientation (X23)				.686	
	Mass media (X17)				.673	
	Deferred gratification (X22)				.559	
3	Male earning member (X5)	2.724	11.843	49.036	.899	Entrepreneurial family pattern
	Family size (X4)				.898	
	Family type (X3)				.866	
	Earning member of family (X7)				.769	
4	Female earning member (X6)	1.736	7.550	56.586	.888	Gender dynamics
	Experience (X13)				.628	
5	Market orientation (X16)	1.471	6.397	62.983	.785	Entrepreneurial marketing
	Personal localite (X19)				.429	
6	Personal cosmopolite (X18)	1.255	5.458	68.440	.845	Organizationalinteraction
	Organization participation (X8)				.573	
7	Credit orientation (X15)	1.077	4.683	73.124	.851	Credit orientation

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.643; Bartlett's Test of Sphericity = 1536.178

attributes establishes good entrepreneurial climate (Kumari et al., 2025; Gupta et al., 2023). Enter regression model displayed significant role in analysing the functional relationship between attributes of entrepreneurs and entrepreneurial behaviour, where the difference between R square and adjusted R square is 0.083. The attributes of the entrepreneurs, i.e., 23 variables, have been organized into seven distinct groups. This is achieved through factor analysis, employing Principal Component Analysis (PCA) for extraction and Varimax rotation, alongside the Kaiser-Meyer-Olkin Measure of Sampling Adequacy, which stands at 0.643. The extraction method determined the initial factors based on the variance of the data and interpreted the factors where all the components had eigenvalue greater than one aligning with the findings of Shirur et al., (2019) who applied PCA and Varimax rotation to assess entrepreneurial traits among mushroom growers, identifying distinct behavioural dimensions that were both statistically and contextually coherent. Similarly, Keshari et al., (2024) emphasized the utility of factor analysis in isolating psychological and socio-economic determinants of entrepreneurial behaviour in rural India, reinforcing the methodological relevance of this approach.

CONCLUSION

Rural entrepreneurship is vital for India's economic growth, given its large rural population. Despite post-independence government initiatives, many efforts have failed to meet their goals, highlighting the need for more effective support strategies. Secondary agricultural activities offer significant potential to enhance rural incomes and improve living standards. To maximize their impact, rural entrepreneurial development programs must be

critically evaluated and realigned to better integrate these activities, ensuring more effective outcomes in rural communities. The study reveals that while entrepreneurs often exhibit strong achievement motivation and a flair for innovation, they may lack sufficient risk tolerance and strategic foresight. To bridge this gap, policymakers and development agencies should prioritize context-sensitive initiatives that reflect the unique challenges and opportunities of local entrepreneurial ecosystems. Hence, emphasizing targeted entrepreneurial traits is therefore crucial for formulating and enacting policies that can effectively advance secondary agricultural enterprises and foster comprehensive rural development.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents 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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Determinants of Consumer Perceptions towards Value-added Millet Products in Kerala, India

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HIGHLIGHTS

- This study examines determinants of consumption of value-added millet products.
- Study findings show that consumer perception varied according to demographic features.
- The SEM model states that the determinants have a significant impact on the perception of consumers, except price.

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Keywords: Kerala, Millet, Perception, Structural Equation Model, Value-added product.

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ABSTRACT

The paper examines determinants affecting the consumption of value-added millet products among consumers in Kerala, India. Using multi-stage sampling, 326 samples were collected from three districts of Kerala state in India, namely, Trivandrum, Palakkad, and Malappuram in December 2023. The study employed t-tests and one-way ANOVA to investigate the potential impact of socio-economic characteristics on consumer perception of value-added millet products. The structural equation model (SEM) was employed to analyse the determinants, like nutritional value, price, package quality, flavour, and media exposure, on consumer behaviour to buying millet products. Consumer perceptions vary according to demographic features such as gender, age, marital status, area of residence, and income. The SEM model states that all five determinants have a significant impact on the perception of consumers except price. With an unstandardized coefficient of 0.59, the “nutritional benefit” determinant had the strongest positive influence on consumer perception, while with an unstandardized coefficient of -0.023, price had a negative influence on the perception of consumers. The results imply that to increase the acceptance of value-added millet products, initiatives to promote millet consumption should concentrate on enhancing nutritional knowledge, taste, flavour, quality of production, and cost reduction.

INTRODUCTION

Millets are essential plant genetic sources capable of helping underprivileged farmers in dry, barren, marginal, and impoverished lands, particularly in Asia and Africa, achieve food security (Gupta et al., 2017; Zehra et al., 2025). It is a viable and promising crop for ensuring the food and nutritional security of the future

generation, given its broad tolerance to diverse agro-ecological contexts, superior nutritional characteristics, and exceptional agronomic qualities as a staple food (Gyawali, 2021). Millets have the following health benefits: (i) Lowering the chances of hypertension and cancer, and (2) The high concentration of antioxidant content lowers oxidation stress, prevents obesity, and lowers the probability of getting diabetes (Prajapati et al., 2023).

At the global level, India ranks first in millet production by producing more than 170 lakh tonnes (GoI, 2021). This accounts for 80 per cent of Asia's overall production and around 20 per cent of global production. Though the production area of millets decreased by 56 per cent between 1950–55 and 2015–20, the productivity of millet rose by 228 per cent due to the adoption of high-yielding varieties of seeds (GoI, 2021).

Due to these health and nutritional advantages, consumers widely prefer millets (Platel, 2013). For instance, calcium content is highest in finger millet (348 mg/100 g), which prevents osteoporosis. Because of a higher iron concentration, pearl millet and barnyard millet can help pregnant women with anaemia satisfy their iron requirements. Fox millet, on the other hand, has the most significant concentrations of zinc (4.1/100 g) and iron (2.7/100 g) (Platel, 2013). pearl millet contains free lipid content with a typical range of 5.6–7.1 per cent and bound lipids ranging from 0.57–0.90 per cent. Adding bajra flour in bakery products is a useful strategy to increase the consumption of carbohydrates and iron in the human diet (Singh et al., 2020). Sensory attributes of breakfast cereal (made up of pearl millets) were highly acceptable and had a bowl life of 3 min (Kumari et al., 2019).

As far as Kerala government's initiatives for millet consumption and production encouragement are concerned, the Kerala government implemented a campaign known as the "millet village" scheme to boost millet cultivation in 2017–18 (Government of Kerala, 2017). Similar initiatives are also intended to be implemented in other districts (Mohan et al., 2021). Kerala is actively expanding its millet production. Kerala exported 364.57 Metric Tonnes of millets to the world in the fiscal year 2021–2022, placing it tenth among Indian states. In addition to producing millets, such schemes aimed to start sourcing, packaging, labelling, distribution, and promotion of value-added millet products (APEDA, 2022; Yadav & Usha, 2022).

Despite the importance given to millet by the government of Kerala, there is a lack of understanding among the customers, mainly due to significant discrepancies among millet cultivators, customers, suppliers, and researchers. Hence, it is important to educate consumers about the benefits of switching to millet over staples like wheat and rice (Sreeni, 2023). In this context, it is necessary to examine those components that affect consumer behaviour towards millet products.

METHODOLOGY

The area of the present investigation is Kerala. This descriptive study is qualitative, cross-sectional, correlational, and non-experimental. The research population consists of all the consumers

of millet products in Kerala. A multi-stage random sampling approach was employed to choose a sample of consumers. For this, Kerala was split into the north, central, and south zones. In the second phase, a district is randomly chosen from each zone, such as Trivandrum from the south zone, Malappuram from the north zone, and Palakkad from the central zone. Data has been collected from 326 respondents in December 2023.

The questionnaire consists of two sections. The first part focused on the demographic details of the consumers, whereas the second section consisted of 27 statements under the six sub-sections, such as "nutritional benefit", "price", "packaging and quality", "taste", "media exposure", and "perception of the consumer". A descriptive examination was carried out to explain the demographic features of the respondents. In order to investigate whether the demographic features of the consumers affect the attitude of respondents towards millet consumption, a t-test and a one-way ANOVA were employed. SEM was employed to examine the influence and impact of five primary elements on respondents' perceptions of value-added millet products. SEM is a multivariate data analysis method for analysing complex relationship among constructs and indicators. To check the sufficiency of the sample chosen, the Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity (BTS) were conducted before factor analysis. The results are shown in Table 1. The KMO value for the current investigation is 0.889. "To test the hypothesis that the correlation matrix is an identity matrix," one applies BTS (Tucker & LaFleur, 1991). With 64.24 per cent of the total variance retrieved, the Bartlett's test of sphericity was significant ($\chi^2 = 4534.209$, $p < 0.000$). The Kolmogorov-Smirnov test (K-S test) and the Shapiro-Wilk test (S-W test) were applied to check whether the sample data is normally distributed or not. Using the traditional Cronbach Alpha (CA) model developed by Cronbach (1951), an effort was made to assess its reliability. Commonly, an Alpha score that ranges from 0.7 to 0.8 is suitable; more than 0.8 is desirable. It can be inferred that Cronbach Alpha for all the variables is greater than 0.8, which means items in each group are consistent.

RESULT

Variations in the consumer perceptions based on demographic characteristics

To determine whether there is any difference in the perception of consumers towards value-added millet products based on gender, a t-test was employed. Table 1 shows the findings of the 't' test. As the p-value obtained is greater than 0.05, we accept the null hypothesis (H_0). As a result, the perception of consumers towards millet products is not affected by gender.

Table 1. Independent Samples Test

Variables	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Gender (independent variables) Equal variance assumed	0.948	0.331	-0.459	324	0.647	-0.10531	0.22955
Perception (Dependent variable) Equal variance not assumed	-	-	-0.462	322	0.644	-0.10531	0.22785

Source: Field Survey Data, 2023

A one-way ANOVA was employed to determine the variations in the perceptions of consumers based on their “age”, “place of residence”, “marital status”, “educational level”, and “level of income”. The results of the analysis are displayed in Table 2. From the Table 2, we can infer that there are significant variations or significant differences in the perception of consumers towards the value-added products of the millet based on the five demographic factors discussed above, since the p-value is less than 0.01. This was in line with the findings of other studies such as Meng et al., (2021); Reddy & Patel (2023); Ojha et al., (2025); Pradhan et al., (2025).

Effects of factors on consumer perception towards value-added millet products

In order to examine the effect of variables such as “nutritional benefit”, “price”, “packaging quality”, “taste”, and “media exposure” on the perception of consumers towards value-added millet products, an SEM utilising AMOS was conducted. Confirmatory factor analysis (CFA) has been undertaken before SEM. The result of CFA shows the model is properly fitted, as indicated by the CMIN/DF value of 2.002 (Figure 1). In this case, the CFI value is 0.927, which is higher than 0.90 indicating a perfect fit. In addition, it is determined that the root mean square residuals (RMR) have a value of 0.0252 and the root mean square error of approximation (RMSEA) has a value of 0.0396, which is below the threshold limit of 0.08 as considered adequate by Hair et al., (2006). Figure 1 shows the CFA model.

Structural equation model results

Table 3 demonstrates the model fit summary of SEM, which indicates that the computed p-value is 0.013, which is below the threshold limit of 0.05, but the issue has been resolved by the CMIN/DF value of 4.684, which denotes an acceptable fit. With a chi-square value of 26.964 (df = 14), the construct measurements showed acceptable model fit statistics. The current dataset shows

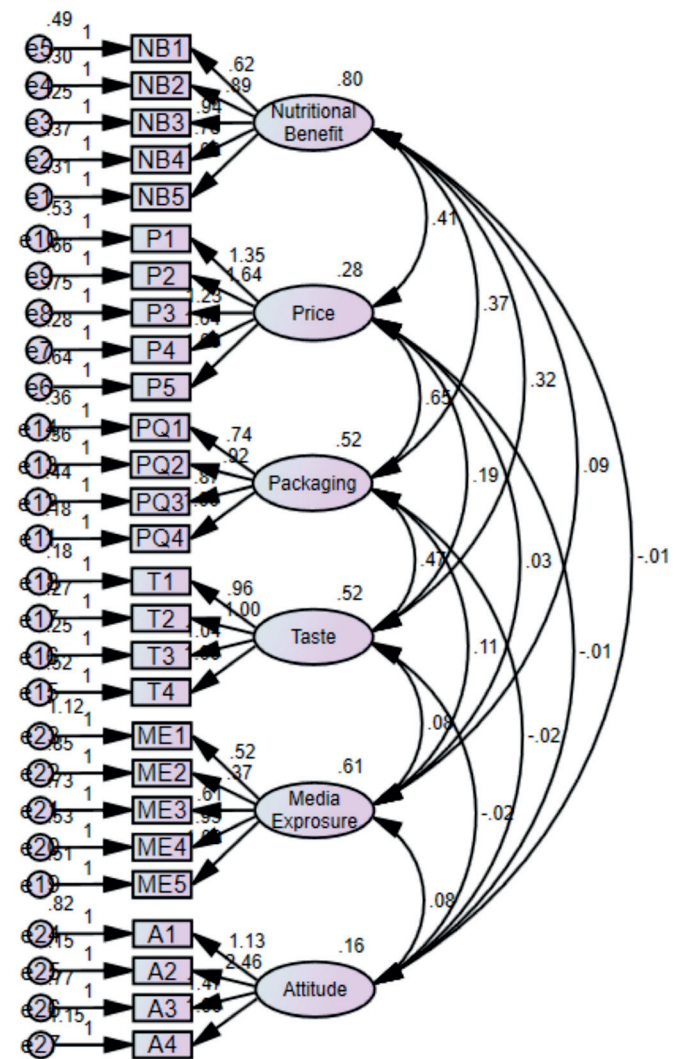


Figure 1. Confirmatory factor analysis
Source: Field Survey Data, 2023

Table 2. Result of ANOVA

Source	Perception (Dependent Variable)	Sum of Squares	df	Mean Square	F	Sig.	Hypothesis and Results
Age	Between Groups	95.359	17	5.609	8.634	0.000	Reject H_{0b}
	Within Groups	200.757	309	0.650			Age does influence the consumer perceptions.
	Total	296.116	326				
Area of residence	Between Groups	147.509	17	8.677	7.823	0.000	Reject H_{0c}
	Within Groups	342.736	309	1.109			Area of residence does influence the consumer perceptions.
	Total	490.245	326				
Academic qualification	Between Groups	174.489	17	10.264	9.408	0.000	Reject H_{0d}
	Within Groups	337.114	309	1.091			Educational qualification does influence the consumer perceptions.
	Total	511.602	326				
Marital Status	Between Groups	159.884	17	9.405	8.571	0.000	Reject H_{0e}
	Within Groups	339.052	309	1.097			Marital Status does influence the consumer perceptions.
	Total	498.936	326				
Income	Between Groups	116.406	17	6.847	5.004	0.000	Reject H_{0f}
	Within Groups	422.867	309	1.369			Income does influence the consumer perceptions.
	Total	539.272	326				

Source: Primary Data, 2023

Table 3. Summary of SEM fit

Indices	Value
Chi-square value	26.964
Degree of Freedom	14.000
P value	0.013
Chi-square value/DF	4.684
Goodness of Fit Index	0.936
Adjusted Goodness of Fit Index	0.961
NFI	0.976
CFI	0.945
Root Mean Square Residuals	0.006
Root Mean Square Error of Approximation	0.076
TLI	0.971
PNFI	0.658
PCFI	0.530

Source: Field Survey Data, 2023

an acceptable model fit as per Hair et al., (2010); Hu & Bentler (1999) perfect fit because the trucker-lewis index (TLI) value is 0.971, the adjusted goodness of fit index (AGFI) value is 0.961, and the goodness of fit index (GFI) value is 0.936, all of which have a value greater than 0.90 as suggested by Byrne (1994) & Hair et al., (2006). Further, the values of the root mean square residuals and root mean square error of approximation (RMSEA) are 0.006 and 0.076, respectively, both of which are less than the cutoff of 0.08 (Hair et al., 2006), indicating a perfect fit.

DISCUSSION

The t-test results revealed that both genders shared similar perceptions and awareness levels regarding their nutritional benefits, price, quality, and availability. This is due to shared cultural food habits and equal exposure to media and health campaigns. A higher level of education is also a reason, as most respondents (96.32%) qualify for graduation or more. This aligned with the investigation findings of Jayawardana et al., (2020) & Mohan et al., (2021). Mohan et al., (2021) conducted the study to identify the variables influencing millet purchasing behaviour. Their findings indicated that there is no variation in the perception of consumers towards millet consumption based on gender, as they analysed factors such as “perceived value”, “essential nutrients”, and “healthy life”. Meanwhile, Jayawardana et al., (2020) found no variations in perceptions of consuming millet among genders. However, there were significant variations in the awareness between males and females about finger millet as a source of nutrients.

The one-way ANOVA result revealed that the perception of respondents varies based on the demographic variables such as “age”, “place of residence”, “marital status”, “level of education”, and “level of income”. In the case of “age”, there is significant variation in the perception of millet products, as younger consumers may prefer modern, ready-to-eat products. At the same time, middle-aged groups were often more health-conscious and adopt millets for their nutritional benefits. On the other hand, older consumers may have stronger traditional linkages and familiarity with millet-based foods. These generational differences in perception, lifestyle, and consumption priorities explain the variation in perceptions toward millet products. According to Meng et al., (2021), older people consume millet more than others, mainly due

to millet’s higher nutritional quality and health benefits. Furthermore, the study was conducted by Jayawardana et al., (2020) to assess the knowledge and perception towards finger millet products in Sri Lanka. They found that all the respondents in the age groups 71–80 and 81–90 preferred consuming finger millet. It indicated that the age-wise variation towards millet products and the higher preference of older people towards them. At the same time, in terms of “educational qualification” and “residing place”, there was no significant variation in the preference towards finger millet (Jayawardana et al., 2020), which was contradictory to our findings. This finding of Jayawardana et al., (2020) was rejected by Kebakile et al., (2003). Kebakile et al., (2003), in their research on people’s consumption behaviour towards sorghum, a type of millet in Botswana, revealed that respondents with higher levels of education often correlated with reduced daily sorghum intake. One possible explanation for the decrease in sorghum preference as educational attainment increases is the various meal programmes offered at various school levels (Kebakile et al., 2003).

CONCLUSION

The study discovered that all five elements under study had a considerable impact on customers’ perceptions, with “nutritional benefits” having the strongest and most positive influence. The present study has identified some future directions as expansion of the sample consumer, and undertaking research in other regions of India can give more generalisability and more understanding about the perception of consumers towards millet products. Long-term studies can be undertaken to have a more comprehensive idea of the attitude of consumers towards millet products. As perception is more of a qualitative phenomenon, new insights can be generated by complementing both quantitative and qualitative data through focus group discussions or interviews, which provide a deeper understanding.

DECLARATIONS

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

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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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Determining the Knowledge Level and Accessibility of Major ICT Tools by Farmers in Madhya Pradesh

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HIGHLIGHTS

- ICTs use convenes the agricultural practices, economic improvement, and decision-making.
- Majority of farmers possessed a medium level of ICT knowledge (68.45%), Mobile as the most used tool.
- Digital literacy of farmers needed to be improved through campaigns and training.
- Futuristic agricultural solution in remote areas will be possible by both farmers and extension functionaries.

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ABSTRACT

Information Communication Technologies are vibrant ways to significantly boost the agricultural sector by providing farmers with access to vital information, input availability, and online financial transactional services like DBT covering PM-KISAN Samman Nidhi, agri-input subsidies, and domestic gas subsidies. The study was conducted in 2024 to find out the major ICTs tools' use, accessibility, knowledge level, and major barriers faced in use by collecting data from 150 randomly sampled farmers of Harda district of Madhya Pradesh. Data were collected by using a pre-tested structured interview schedule and analyzed with appropriate statistical tools. The majority of respondent farmers (68.45%) had a medium knowledge level about ICT tools. Education, annual income, social participation, mass media exposure, and extension contact expressed significant positive correlation with accessibility of major ICT tools among farmers. The major barriers were observed with Garrett's ranking techniques. The farmers, especially young farmers, possessed the ICT tool like a smart mobile only for personal entertainment and interconnectivity, rarely using it to access agricultural knowledge for improvement. The backstopping of farmers to boost digital literacy for agricultural development and ICT adoption could be augmented by organizing educational campaigns and training.

INTRODUCTION

Information and Communication Technology (ICT) tools are very important to obtain the information for decision making in crop planning by farmers. The farmers seek information from ICTs related to weather forecasts, market prices, agricultural advice, e-learning, e-commerce platforms for mobile banking and micro-financing options generally allowing farmers to secure loans and manage transactions easily, supply chain management, social media groups to share experiences, solve problems collectively and

support each other for ensuring food gain production in the country. Innovative agriculture and rural development may be attained by ICT use as it improves communication among agricultural research, extension, farmers and other stakeholders (FAO, 2025). The emerging knowledge-based economy and information revolution is due to ICTs interventions. The timely reliable information provides decision support to farmers through ICTs (Shukla et al., 2024a). The quick delivery of the farm information to faraway regions is possible by ICTs well use (Mishra et al., 2021; Joshy, 2018; Mishra et al., 2020). The telecommunication and Internet services over the

past twenty- five years created an environment for people for greater access around the world. The agricultural development is seen faster with ICT interventions (Patra et al., 2020). Transfer of technology nowadays is being supported by ICTs and blends with field personnel (Lahiri et al., 2017; Panda et al., 2019; Kavaskar & Sharmila, 2020). Farmers benefit from ICT-based information access during critical times (Ravikumar et al., 2015; Kale et al., 2016). ICTs may provide cost cost-effective solution to farmers in remote areas (Lahiri et al., 2020). ICT has benefitted the livestock extension (Chandra et al., 2023). The mobile tools were used more than other mass communication tools in farming like TV, radio etc. (Gangil & Verma, 2018). Tripura state has big scope of ICT in fisheries extension (Nirmalkar et al., 2022). The farmer enhanced their family's educational status and economic by better use of ICT technologies (Anand et al., 2022). ICTs based Kisan mobile advisory services found very fruitful in changing farmers' technical information, crop production and crop diversification planning in Harda district of M.P. (Kumar et al., 2015.) The farmers have exploited the social media platforms for the adoption of best agricultural practices (Nain et al., 2019; Sandeep et al., 2022). Farmers received confidence by using an based app for KVK's activities for the dissemination of information and advisory service in Punjab (Singh et al., 2023). The financial benefits were reaped by farmers utilizing ICTs information in agricultural activities and fertilizer dose management in Madhya Pradesh (Kumar, 2025).

METHODOLOGY

A random sample of 150 farmers as respondents, representing all three blocks, namely Harda, Khirkiya, Timarani and ten villages in each block, with five farmers from each village of Harda district, was selected. The independent variables were social participation, education, mass media exposure, family type, extension contact, age, and annual income. The ICT tool used by farmers, their availability, the knowledge level of farmers, and barriers in ICT tool use and knowledge were assessed as dependent variables. Knowledge scores were obtained on yes/no (yes, score-1, no, score-0) on a pre-tested scale having set of 32 questions on the knowledge level on the usage of different ICT tools. The data were collected in a pre-tested semi-structured interview schedule during January to June 2024. The ownership of particular ICT tools was reflected as accessibility to ICT. The data were compiled, analyzed and interpreted by utilizing statistical tools like percentage, arithmetic means, standard deviation, correlation coefficient, regression coefficient and Garrett's ranking technique for making the findings more rational. The Garrett ranking formula, used to convert ranks into percentages for analysis.

RESULTS

The accessibility to major ICT tools by the farmers under study is represented in Figure 1 in ascending order. The data reflects the majority of respondents accessed the major ICT tool i.e. mobile phone (86.5%) for information sharing in agriculture field through messaging app like WhatsApp, social media platforms such as Facebook & YouTube, followed by television (78%) for watching DD kisan, radio (22.5%) specially in tribal locality, computer (21%), kisan help line (19%) including kisan sarathi toll free number

1551 and least accessed was e-newsletter/literature (13%) in the study area. Farmers used these major ICT tools for improving their agricultural knowledge, innovative ideation, improved variety sharing, new technology, and methodology and practice exchange among each other as part of farmer-to-farmer communication. Farmers exploited these tools to update them regarding weather, marketing, commodity prices, input information, insect-pest management, new varieties, crop diversification, and weed management related information at priority.

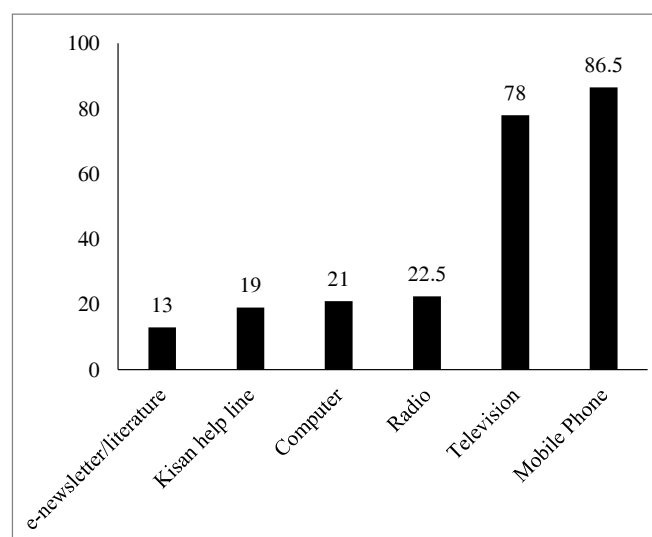


Figure 1. Accessibility of respondent farmers towards major ICT tools

The findings are in line with those by Kumar et al., (2015); Nain et al., (2019); Shashidhara (2020); Anand et al., (2022). These studies reported mobile as the highest accessible tool followed by television in Meghalaya, Haryana, Maharashtra, Karnataka, Rajasthan & Bihar respectively.

Table 1. Knowledge level of practicing farmers on the usage of major ICT tools

Categories	Percentage	Mean	Standard deviation
Low (<14.81)	11.52		
Medium (14.82- to 77.77)	68.45	46.62	32.51
High (>77.77)	20.03		
Total	100		

The mean knowledge score of the respondents was 46.62 ± 32.51 . More respondents (68.45%) had medium knowledge on the use of ICT tools, followed by high knowledge (20.03%) and low knowledge (11.52%). It shows that the farmers would need to be backstopped through training on the use of ICTs and the retrieval skill for needed information online from authentic sources and research institutions. These noble efforts can boost trust and use of ICT tools to a great extent among farmers and other stakeholders. Findings of the present study are in line with the findings of Sharmila & Kavaskar (2017); Lahari et al., (2017); Nirmalkar et al., (2022).

Table 2. Correlation between independent variables and respondents' accessibility to major ICT tools

Independent variable	Correlation coefficient @
Age	-0.153
Education	0.762**
Annual income	0.598**
Social participation	0.384**
Mass media exposure	0.789**
Extension contacts	0.676**

*Significant at 1% level

Age of respondents was found to be negatively and not significantly correlated. The variables under study, like education, annual income, social participation, mass media exposure and extension contact were found to be significantly correlated with accessibility of major ICT tools (Table 2). It reflects that by strengthening these independent variables, the accessibility to major ICT tools among farmers may also be increased or vice versa. Now the positive temperament of farmers towards social media platforms made them keener to exploit major ICT tools in study area. The economically strong farmers found more capable of using major ICT tools and cultivate a good attitude toward ICT use for knowledge and information sharing. Similar findings are reported by Anand et al., (2022); Mukharjee & Jha (2024) in Bihar and West Bengal states, respectively.

Table 3. Multiple regressions between independent variables and accessibility to major ICT tools

Independent variable	Regression coefficient (r)	t value
Age	0.017	-0.276
Education	0.675	4.504**
Annual income	0.022	0.756
Social participation	0.011	0.690
Mass media exposure	0.045	4.218**
Extension contact	0.058	4.957**

R square=0.912; F value=19.785, **Significant at 1% level

Table 3 shows the multiple regressions to test the potency of the linear relationship between the given independent variables with a single dependent variable. The functional relationship between independent variables and their accessibility to major ICT tools among respondents was calculated by using multiple regression analysis. The variables as age, education, annual income, social participation, mass media exposure, and extension contacts, together determined about 91 per cent variation in farmers' accessibility to major ICT tools as evident from R-squared value of 0.912. The regression coefficients found to be positively significant at 1% level of significance for attributes like education, mass media exposure & extension contacts. This implies that by enhancing these three elements, the farmers' access and use of these major ICT tools for agricultural practices would improve or vice versa. The youth engaged in agriculture were seen efficient in handling ICT tools than the aged ones (Kumar et al., 2015). Similar finding was reported by Panda et al., (2019); Anand et al., (2022); Singh & Mathur (2024) with respect to the farmers in West Bengal, Bihar and Rajasthan states of India.

Table 4. Garrett's ranking of the different barriers for ICT tools use in agriculture

Different Barriers	Garrett's ranking score	Percentage	Rank
Possession of ICT tools only for personal entertainment and communication	8703	16.83	1
Difficulty to understand non-speaking language and low retrieval skill	8446	14.16	2
Low digital literacy and awareness	8350	12.32	3
Data privacy and trust issue on online information	8350	11.65	4
Socio-economic aspects	8301	9.32	5
Poor internet connectivity	8029	9.08	6
Lack of motivation to acquire the required ICT tool handling skills	7954	7.94	7
Lack of confidence to use ICT	7682	6.42	8
High cost of good ICT tools as barriers	5924	6.56	9
Unavailability of ICTs device	5348	5.72	10

Barriers connected with the use of major ICT tools by the farmers

The foremost barriers faced by farmers under study are presented in Table 4 in ascending order. The possession of ICT tools only for personal entertainment and interconnectivity (rank-1), difficulty to understand non-speaking language and low retrieval skill (rank-2), low digital literacy and awareness (rank-2), data privacy and trust issue on online information (rank-4), and socio-economic aspects (rank-5) were the barriers found in this study. Similar barriers were reported by Patra et al., (2020); Nirmalkar et al., (2022); Lalthlamuanpuui et al., (2024). Thus, the backstopping on these barriers may streamline the farmer's skill and the enough exploitation of available ICT tools. The regular training and awareness creation among farmers by line departments followed by a meticulous strategy development for organizing virtual farmer's capacity building and training programme to save the time of farmers, ICT for creating mass awareness on crop insurance awareness programmes, FPOs development, organic and natural farming awareness, e-NAM, climate smart agriculture awareness, agri-apps and social media initiatives etc. can improve the situation of ICT tools utility for economic development and motivation of farmers to engage them in agriculture with confidence and trust building.

DISCUSSION

A large number of farmers (68.45%) had medium knowledge about ICT tools for modern agricultural practices. This shows that farmers were aware and keen to learn new technologies for economic progress and crop management in a holistic manner. Young farmers having formal education had higher handling ICT tools literacy. The mobile phone was the most used ICT tool in Harda district of Madhya Pradesh. Mobile phones were used as they can be used to get a wide range of information by making use of different applications. The farmers also revealed a few avoidable barriers in the smooth exploitation of ICT tools for agricultural upliftment, such as weak internet connectivity and, lack of local language content

in ICT platforms. The ICT tools for agricultural use may be increased by organizing education campaigns to boost digital literacy and ICT adoption among farmers.

Education, mass media exposure and extension contacts were correlated significantly and positively at 1% level. This indicates that by enhancing these three attributes, the farmers' access and use of major ICT tools would improve or vice versa. The major challenge was that the farmers, especially young farmers, possessed the ICT tools only for personal entertainment and interconnectivity, thereby using it meagerly to access relevant information for agricultural knowledge improvement and awareness. They were quite reluctant to search for modern farm techniques and information related to the cropping pattern followed for their livelihoods.

CONCLUSION

This study highlights the significance of ICT tools in agricultural development, particularly in Madhya Pradesh. The findings reveal that most farmers possess medium knowledge of ICT tools, with mobile phones being the most widely used tool. Education, mass media exposure, and extension contacts significantly influence farmers' accessibility to ICT tools. However, major barriers include using ICT tools for personal entertainment, difficulty understanding non-speaking languages, and low digital literacy. To overcome these challenges, regular training and awareness programs can be implemented to boost digital literacy and ICT adoption among farmers. Policymakers can promote ICT-based initiatives, develop local language content, and improve internet connectivity to enhance agricultural development. Practically, farmers can benefit from targeted capacity-building programs, enabling them to utilize ICT tools effectively for informed decision-making and improved livelihoods. By addressing these challenges, ICT tools can play a vital role in transforming agriculture in Madhya Pradesh.

DECLARATIONS

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

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Modeling of Farmers' Preferences towards Climate-Smart Agriculture Using Conjoint Analysis

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HIGHLIGHTS

- Farmers preferred CSA practices with high adaptation potential.
- Adoption of expert-recommended CSA practices remains low.
- The conjoint model showed high reliability with Pearson's R and Tau of 0.934 and 0.856, respectively.

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Keywords: Conjoint analysis, Farmer's preferences, Climate smart agriculture (CSA), Adaptation, Sustainable agriculture.

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ABSTRACT

Climate change poses a significant threat to agricultural productivity, particularly for smallholder farmers in India. The study utilized a mixed-method approach, which involved 150 farmers and expert consultations from Punjab and Uttar Pradesh states related to the domain in the year 2024-25. Farmers' preferences were studied using CSA attributes: productivity, adaptation, and mitigation, deploying the conjoint analysis. It was found that the farmers are continuously affected by the dynamic weather conditions, causing irregular rainfall to impact crop health and eventually crop yield. Although awareness related to CSA was present but its adoption was very low due to the absence of infrastructure and technology. A gap was found between the recommendation of the experts related to integrated and efficient nutrient management and the farmers' adoption level. As a result of the conjoint analysis, it was found that the adaptation attribute was highly favoured by the farmers, followed by the other two, i.e., mitigation and productivity. The reliability of the model was supported by Pearson's R (0.934) and Kendall's tau (0.856), which revealed a strong connection between the prediction and the actual preferences.

INTRODUCTION

Indian agriculture contributes significantly to rural households. The sector still faces continuous challenges due to unpredictability in the climatic occurrences (Raghuvashi & Ansari, 2020). Unpredictable weather dynamics have threatened the stability in the income of millions of farmers (Shanabhoga et al., 2023; Meena et al., 2023). These continuously growing vulnerabilities highlight

the immediate need for the adoption of more resilient and sustainable farming methodologies (Rampa et al., 2020; Ashoka et al., 2022). Climate-Smart Agriculture (CSA) has emerged as an efficient answer focused on reshaping and redirecting agricultural growth in the context of the current challenges brought by climate change (Ravindera & Singh, 2019; Mosso et al., 2022; Shitu & Nain, 2024). CSA can fulfill several major objectives, such as boosting agricultural productivity, improving adaptive resilience (Sodhi et

al., 2023), and decreasing greenhouse gas emissions (Das & Paul, 2021). It holds practices like crop diversification, agroforestry, conservation agriculture, efficient irrigation, and the utilization of enhanced seed varieties, which are the prominent ones (Bhatnagar et al., 2024). Despite its enhancing global significance and favourable policies in India, the understanding and adoption of CSA practices at the root level remain inconsistent and poor (Djufry et al., 2022). It is sought that there is a significant gap between the recommendations of experts and the practices adopted by farmers (Ndue & Pal, 2022). Although the agricultural bodies defend for technologically sound and environmentally sustainable walkovers (Sharma et al., 2021), farmers confront financial, infrastructural, and informational hurdles that retard their ability to incorporate innovations (Mo et al., 2023). Similarly, it is very important to understand farmers' thoughts, patterns of preferences, and awareness of CSA to design acceptable and feasible interventions for them (Mahto et al., 2021).

This document puts a thrust towards the existing gap by exploring the level of preferences and awareness among the farmers concerning different CSA practices in the selected Indian states, viz., Punjab and Uttar Pradesh. These areas were chosen to illustrate a range of CSA practice levels and awareness, from those with advanced adoption to those that are less informed. Simultaneously, this study collects deep insights from expert faculty and researchers from prominent agricultural universities selected from the two states, Punjab and Uttar Pradesh, to establish a framework for scientific recommendations.

Conjoint analysis as a statistical tool is utilized to quantitatively evaluate farmers' preferences for specific selected CSA properties: productivity, adaptability, and mitigation impacts (Andati et al., 2023). This proposition facilitates the calculation of part-worth utilities and relative importance scores, providing deep insights into what farmers keep into priority when selecting among various CSA alternatives (Malarkodi et al., 2023). By orienting these empirical insights perceived from the farmer respondents along with the expert's advice, the present study seeks to guide towards policy development and extension initiatives that could encourage the widespread adoption of climate-resilient agricultural methodologies in Indian agriculture (Sarker et al., 2025). The results are directly coinciding with the significance towards India's obligations under Sustainable Development Goals (SDGs) 2 and 13, which concentrate on Zero Hunger and Climate Action, respectively (Vatsa et al., 2023).

METHODOLOGY

This research was conducted in three selected districts within the states of Punjab and Uttar Pradesh (U.P.), India. The three selected districts were Kapurthala in Punjab (under the jurisdiction of PAU), Sant Kabir Nagar in Uttar Pradesh (under ANDUA&T), and Kanpur in Uttar Pradesh (under CSAUA&T). The districts were purposefully chosen based on their differing levels of Climate-Smart Agriculture (CSA) adoption. Kapurthala, Kanpur, and Sant Kabir Nagar, all three districts, were identified as being advanced, moderate, and relatively low in awareness and adopting CSA practices, respectively, illustrating a gamut from least to significant practice levels. The layout enabled a comparative study of CSA

awareness and preference inclination across various agro-climatic and institutional borders. The chosen agricultural experts were identified and selected on the basis of their professional experience in climate-resilient agriculture, active participation in CSA extension and research initiatives. Total 15 experts were consulted, five from each university, to get professional insights on important CSA attributes and their relevance in farmer's decision processes. A population sample of 150 farmers was selected for study, with 50 respondents from each selected district using Slovin formula (Asenahabi & Ikoha, 2023). The selection criteria were such that they must be actively involved in farming for a minimum time period of five years, have experienced climate-related happening at least in the past five years, and must be intended to take part in a structured interview. A well-structured questionnaire was developed to collect information on awareness of CSA practices, adoption level, and preferences related to CSA attributes. The preference evaluation employed a conjoint analysis statistical tool, pointing up three primary CSA attributes; Productivity, Adaptation, and Mitigation in three scales i.e., Low, Medium, and High. An orthogonal exhibition was used to develop CSA practice profiles, which were then ranked by the selected respondents. The experts were contacted additionally using a Delphi-approach to validate and allocate weights to the CSA attributes. Data collection with the respondents involved direct interviews and online consultations (calls, emails, and structured Google forms) with experts. The data collection process was performed within six months, from July to June in 2024-25. The data was analysed using descriptive statistics to assess awareness variables. Conjoint analysis was engaged for the estimation of part-worth utility magnitudes and relative relevance scores. The model validation used Pearson's correlation coefficient and Kendall's Tau towards observed and predicted preferences. Additionally, a comparative examination was done between expert preferences and farmer practices to highlight the adoption gaps.

RESULTS

Effects of dynamic climatic conditions on agriculture

The farmers surveyed across the three selected districts, Kapurthala of Punjab and U.P., reported a wide range of challenges imputable to unpredictable dynamic climatic conditions. As shown in Table 1, the most common effect was an increase in pest infestation and disease incidence, cited by 93 per cent of farmers. This is particularly significant, as it not only reduce yields but also

Table 1. Impact of fluctuating and unpredictable climate on Farming Methods

Effects of dynamic climatic conditions	Observations Recorded (%)
Yield decline	89
Erratic Rainfall/ Droughts	90
Temperatures rise	88
Growing Diseases & Pests	93
Post-harvest losses	68
Boosted Input costs	64
Impact on Livestock's	61

increases the dependency on chemical approaches, hence raising input costs and affecting sustainability of the environment. Similarly, 90 per cent of respondents reported irregular rainfall and droughts, which is prevalent in Sant Kabir Nagar and parts of Kanpur, is particularly vulnerable. Respondents in these areas revealed their inability to forecast the sowing and harvesting periods, leading to mismatches in crop cycles. This has also contributed to 89 per cent of the yield decline, a statistic that match with national-level data linking reduced productivity to unexpected off time rainfall, extreme weather conditions, and delayed monsoons. Further another significant concern was raised by 88 per cent of respondents, was the rise in temperature. This has a direct impact on both physiology of the crop and health of the livestock. Shortened crop growth, and reduced grain fillings, especially in cereals like wheat and paddy, was reported due to increased temperature. Additionally, to these primary impacts, 68 per cent of farmers reported post-harvest losses, highlighting that a lack of storage facilities and infrastructural bottlenecks hiked the climatic effects. In the same pathway, 64 per cent of respondents faced increasing costs of inputs, which could be linked to the demanding need for fertilizers, irrigation, and pesticides to overcome climatic stress. Notably, the impact on livestock, including reduced milk yield, stress of heat, and fodder unavailability, especially in dry periods, was reported by about 61 per cent of farmers. There was a significant impact of climate change, requiring immediate steps for adaptation strategies and interventions related to infrastructure for the sustainability of agricultural livelihoods.

Awareness and adoption of CSA practices

Table 2 shows the levels of awareness and adoption of 18 CSA practices selected and identified among the surveyed farmers. The data shows a lacunae which is found significant between awareness and actual implementation, identifying the difference between behavioural adoption and propagation of knowledge. The most widely known CSA practice is CIS, which was found with awareness of 85 per cent and adoption of 60 per cent. This high level of apprehension can be attributed to large-scale government defends and increasing farmer exposure to climatic risks. However, concerns by respondents about transparency lacunae, delays in processing, and lesser compensation amounts, which insignificantly explains the 25 per cent decline between awareness and adoption. Governance of Soil Health is another practice with a relatively high adoption rate of 80 per cent awareness, 55 per cent of adoption, due to ongoing initiatives like the scheme of Soil Health Card and targeted awareness acts by KVKs and other organisations. Similarly, Crop Diversification holds a 75 per cent of awareness and 60 per cent of adoption, particularly in Kapurthala, where water-intensive crops are being substituted by lesser water-consuming crops. In contrary the awareness and adoption levels in Use of Solar Energy showed 25 per cent, 10 per cent, Agroforestry of 30 per cent and 10 per cent, and Protected Cultivation of 35 per cent and 12 per cent have significantly low levels of both awareness and acquisition. These practices, although having the potential for boosting resilience, suffer from poor outreach, limited demonstrations, and greater primary investment costs. The Digital and ICT-based tools, which have unlimited ability for real-time agro-advisory, show 50

Table 2. Farmers response frequencies towards CSA Awareness and Adopted Practices

CSA Practice	Awareness (%)	Practices (%)
Crop Diversification	75	60
Drought-Resistant and Climate-Resilient Varieties	60	35
Conservation Agriculture	40	20
Agroforestry	30	10
Organized and effective irrigation systems	65	30
Rainwater Harvesting	50	25
IFS	55	30
IPDM	45	20
Enhanced Animal Husbandry Practices	60	40
SHM	80	55
Agro-Advisories Based on Weather	70	40
No Tillage or Reduced Tillage	30	15
Utilization of Solar Power in Agriculture	25	10
Cultivation Under Protection	35	12
Infrastructure That Withstands Climate Challenges	40	20
CIS	85	60
Digital and ICT-Driven Instruments	50	25
Community-Driven Resource Management	30	15

(IFS = Integrated Farming System, IPDM = Integrated Pest & Disease Management, SHM = Soil Health Management, CIS = Crop Insurance Scheme)

per cent awareness but only 25 per cent adoption, showing a digital divide exaggerated by low accessibility to smartphones, poor network connectivity, and lack of training.

Surprisingly, Weather-Based Agro-advisories have a relatively good awareness level of 70 per cent but only 40 per cent of the adoption, as many farmers still depend on traditional knowledge or informal networks for weather knowledge.

The results show that awareness does not guarantee the adoption, and targeted interventions are required to alter knowledge into action. Factors such as access to resources, extension services, economic feasibility, and ascertain reliability play a significant role in moulding the behaviour of the farmer.

Expert preferences vs. farmer adoption of CSA practices

A significant component of the study included capturing the preferences of agricultural experts from the organisations viz., PAU, ANDUA&T, and CSAUA&T and comparing them with adoption behaviour of the farmer. Table 3 illustrates this comparison and highlights some critical lacunae that must be considered. Experts gave priority preference to efficient irrigation systems up to 95 per cent, drought-resilient varieties up to 90 per cent, soil health management up to 95 per cent, and integrated farming systems up to 90 per cent. These practices are considered complete resolutions that denotes both sustainability and productivity under climatic stress. Although, the level of adoption among farmers for the practices mentioned above is much lower i.e., between 30 per cent and 60 per cent. For instance, while experts strongly advocate for efficient methods of irrigation, only 30 percent of farmers revealed that they used systems such as sprinkler and drip irrigation. Factors which were identified for it included, high initial costs, lack of

Table 3. CSA Practices recommendations and their adoption by the farmers

CSA Practice	Expert Preference (%)	Farmer Adoption (%)
Structured Efficient Irrigation Systems	95	30
Drought-Resistant & Climate-Resilient Varieties	90	35
SHM	95	55
IFS	90	30
CIS	90	60
Agroforestry	70	10
Digital & ICT-Based Tools	85	25
Protected Cultivation	80	12

technical knowledge, and inadequate subsidy programs. In the same way, although 70 per cent of experts favour Agroforestry, only 10 per cent of farmers have adopted this practice. Despite its long-term advantages, like carbon sequestration and diversification of income, it faces challenges due to the lack of short-term incentives and tangled land tenure systems. ICT and Digital Tools were support by 85 per cent of experts, yet only 25 per cent of farmers reported employing them. This difference can be linked to issues with digital infrastructure, digital literacy levels, and a lack of trust in technological advices. This adversity highlights a mismatch between expert recommendations and the ground realities. Bridging these lacunae necessitates participatory methods that indulge farmers in both planning and technological choices, along with efforts to build their capacity and improved accessibility.

Utility estimates and model fitness

To measure farmer's preferences quantitatively for CSA characteristics, a conjoint analysis was utilised. The results, shown in Table 4, detailed the utility scores and relative importance for three primary CSA attributes: Adaptation, Productivity, and Mitigation, each at Low, Medium, and High levels.

Utility magnitudes

The highest positive utility score was recorded for High Adaptation which was found 1.030, followed by High Productivity of 0.360 and Medium Mitigation of 0.490 units. These preferences shows that farmers are more bended towards CSA practices that strengthen their resilience against variability in climate rather than those that prioritize only yield or environmental perks. Antagonistically, Low Adaptation of -0.620 and Low Mitigation of -0.520 units received the lowest utility scores, reflecting the farmer's strong disinclination to practices that lack climate risk protection.

Relative weights

Adaptation was observed as the most significant attribute, holding a relative importance of 49.76 per cent, which was followed by Mitigation at 33.39 per cent and Productivity at 16.84 per cent. This shows a clear view for prioritization of climate-resilient approaches towards production enhancement. Respondents preferences for adaptation align directly with their actual challenges,

like unpredictable rainfall and hiked pest pressure. Resolution strategies that can mitigate these risks are viewed as more precious than those that merely boost output.

Credibility of the model

The validation of the conjoint model revealed the fitness of the model through Pearson's R value of 0.934, Kendall's Tau of 0.856, and a p-value of less than 0.01. The results indicate that the model exhibits a high level of internal consistency and predictive validity, suggesting that respondents' stated preferences closely reflect their actual decision-making behavior. Overall, the conjoint analysis provides a rigorous, quantitative framework for understanding how farmer respondents perceive different features of CSA practices, providing actionable insights for policymakers and extension personnel.

Table 4. Utility Coefficients Estimated Using Part-Worth Model and the fitness of the model

Attribute	Attribute Level	Utility Estimate	Std. Error	Relative Importance (%)
Productivity	Low	-0.285	0.395	16.842
	Medium	-0.075	0.395	
	High	0.360	0.395	
Adaptation	Low	-0.620	0.395	49.764
	Medium	0.410	0.395	
	High	1.030	0.395	
Mitigation	Low	-0.520	0.395	33.394
	Medium	0.490	0.395	
	High	0.030	0.395	
(Constant)		4.620	0.290	
Model estimation		Value (r or τ)	p-Value	-
Pearson's R		0.934	0.000**	
Kendall's tau (τ)		0.856	0.000**	

(**significant at 1 per cent level)

DISCUSSION

The results highlight insights into the awareness, preferences, and adoption of CSA practices of farmers in selected districts. The data reveal that the effects of climate change are widely seen across all districts, demonstrating an increased prevalence of pests and diseases, irregular rainfall, and decreasing crop yields. These show that small farmers are particularly vulnerable to climatic variability due to their limited capacity for adaptation. Despite a significant level of awareness about the CSA practices, a significant gap persists between the knowledge and implementation. Farmers revealed high awareness of exercises such as soil health management, crop insurance, and crop diversification. However, adoption was found moderate or low, particularly for technical or capital-intensive exercises such as protected cultivation, agroforestry, or solar energy use. This proposes that while awareness campaigns and extension services have created information flow, economic, institutional, and infrastructural problems continue to hinder the adoption.

The contrast between expert preference and farmer adoption is particularly noticeable. Experts from leading agricultural

universities unanimously emphasized practices such as integrated farming systems, efficient structured irrigation systems, and drought-resilient crop varieties as important for shaping resilience. However, these attempts are either partially adopted or significantly underutilized at the root level. This shows a mismatch between scientific recommendations and ground, possibly due to differences in technical understanding, risk perception, and access to assets among producers. Further, the conjoint analysis deepens this understanding by measuring the relative importance of CSA attributes. Respondents showed the strongest preference for attributes connected to adaptation, suggesting an immediate concern with surviving the impacts of climate rather than long-term mitigation or even productivity perks. This is reflected in the highest utility score for high adaptation and the negative utility associated with low adaptation. Mitigation and productivity features followed in significance, proposing that farmers prioritize resilience over environmental goals or yield perks, especially in erratic climatic conditions. The high reliability of the conjoint model with Pearson's R of 0.934, Kendall's Tau with a 0.856 value, and p-value of less than 0.01 adds statistical robustness to these results. It confirms that the preferences stated by farmers are linked with predicted choices, which makes the results valuable for policy design. Additionally, the findings highlight the need for a multi-pronged approach to gauge CSA adoption. Beyond awareness developments, there is an immediate requirement for financial perks, grass-root level training, infrastructure support, and participatory extension structures to amplify CSA knowledge into sustained practice. Filling the lacunae between expert opinions and farmer ascendancies will be important for amplifying the adoption of climate-resilient technologies in India's diverse farming landscapes.

CONCLUSION

Information perceived from this study reveals that awareness of CSA practices is increasing among farmers, but root level implementation is still low, particularly for technically complex or require significant resources. The findings from conjoint analysis reveal that farmers place a higher magnitude on CSA features that grow their ability to adapt to climate fluctuations rather than those that aid productivity or mitigation efforts. This show there is immediate need to protect their livelihoods from unpredictable rainfall, temperature hikes, and pest occurrences. A significant disparity is found between the CSA methods recommended by experts and those that farmers are found with. Experts advocate for integrated and resource-efficient approaches, such as enhanced livestock management, efficient irrigation systems, whereas farmers frequently encounter barriers to adopting these practices due to costs, insufficient institutional support, or limited knowledge. Filling this void is crucial for effective adaptation and resilience at the community level.

DECLARATIONS

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

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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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Impact Assessment of Floating and Alternative Feeds (*Wolffia globosa*) for Fish Rearing Technologies in Tripura, India

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HIGHLIGHTS

- Floating feed and *Wolffia*-based technologies improved aquaculture's social, economic, and environmental outcomes.
- Floating feed increased fish production, efficiency, and livelihoods but faced high costs and supplier dependence.
- Wolffia*-based feed offered a sustainable alternative, enhancing profitability, efficiency, and household welfare.
- Major constraints included high feed costs for floating feed and flood-induced feed loss for *Wolffia* technology.

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ABSTRACT

The study assessed the social, economic, and environmental impacts of floating feed– and *Wolffia*-based fish rearing technologies disseminated by the College of Fisheries, CAU (Imphal), Lembucherra, Tripura. An after-only design was employed with 140 respondents: 100 floating feed adopters chosen through simple random sampling and 40 *Wolffia* adopters through complete enumeration. Impact indicators across social, economic, and environmental domains were developed using Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) criteria, expert-validated, and analysed with the Wilcoxon Signed-Rank Test, paired t-tests, and Spearman's correlation. Floating feed adoption improved production (+16.75 kg cycle⁻¹), net returns (+Rs. 6,644.26), and feed efficiency [Apparent feed conversion ratio (AFCR) –0.23], raising the Economic Impact Score from 32.93 to 40.23 ($p = 0.000$). Social participation, awareness, and income increased, while the Environmental Impact Score fell from 23.996 to 19.146, reflecting improved water quality. *Wolffia* adoption also enhanced production (+18.48 kg cycle⁻¹), returns (+Rs. 4,804.35), and AFCR (–0.25), contributing to livelihoods, nutrition, and climate-resilient aquaculture. Major constraints included high floating feed price, supplier dependence, flood-induced losses, and weak extension support. Overall, both technologies boosted aquaculture productivity, profitability, and sustainability, highlighting the need for technical services, training, and institutional support.

INTRODUCTION

India, like many developing countries, faces challenges of food insecurity, unemployment, migration, and malnutrition, exacerbated by population growth (Noor et al., 2018). Like many regions of

India, fisheries contribute to Tripura's economy by ensuring income, employment, and nutritional security significantly (Das, 2012). The state records the fastest growth in fish production among the Northeastern states (Debnath, 2011). In 2010, culture fisheries accounted for 97.01% of total production (DoF, 2011). Presently,

38,594.69 hectare (ha) of water are available, of which 30,715.93 ha are under culture fisheries and 7,878.76 ha under capture fisheries. Pisciculture occupies 29,390.62 ha, including seed production (DES, Govt. of Tripura, 2024). In 2009–10, production was 37,000 tonnes (t) against demand of 41,000 t (DoF, 2011), while recent figures report 85,805.68 t with per capita consumption of 27.73 kg in 2023–24 (DES, Govt. of Tripura, 2024). Despite progress, imports from West Bengal, Andhra Pradesh, and Bangladesh continue.

Aquaculture is crucial for both economic contribution and human nutrition (Sajeev et al., 2023). Feed approaches such as floating feed and Wolffia-based feed play a vital role in enhancing production and profitability. Floating feed reduces wastage and improves water quality (Abdelhamid et al., 2019). Wolffia, with 30–40% protein and rapid growth, offers a low-cost, sustainable feed source. It enhances the growth of species such as *Labeo rohita*, improves water quality by recycling nutrients, and reduces the risk of eutrophication (Nath et al., 2021; Said et al., 2022).

The College of Fisheries, CAU (Imphal), Lembucherra, has promoted these technologies to meet rising demand. Floating feed was standardised using rice bran, mustard oil cake, corn, wheat, and fish meal to ensure floatability, nutrition, and cost efficiency. Adoption has extended to ICAR, the Department of Fisheries, Tripura, KVKs, and institutions in Assam, Arunachal Pradesh, and Mizoram. Production requires feed mills, ingredients, labour, and electricity (Saha et al., 2020). Floating feed is applied in fertilised ponds or tanks at an apparent feed conversion ratio (AFCR) of 1.8–2.2, with a six-month culture period and stocking density of 15,000 ha⁻¹. Feeding is adjusted from 3–4% of biomass twice daily, reducing to 0.5–1.0% in cloudy weather and winter (Das et al., 2016). The College also developed Wolffia-based fry rearing for Rohu (*Labeo rohita*) fingerlings in 2020 and disseminated it from 2020 to 2023. Live Wolffia (*W. globosa*), rich in protein, low in fibre, and highly digestible, addresses both feed cost and water quality challenges (Seephua et al., 2025). Experimental trials showed higher survival, growth, and fingerling quality in Rohu fry fed with Wolffia compared with artificial feed (Yadav et al., 2025).

Impact assessment of floating and Wolffia-based feeds is essential to evaluate their effectiveness, efficiency, and sustainability. These technologies enhance growth, survival, productivity, and profitability while minimising feed wastage and mitigating environmental stress. Assessment also considers scalability, economic viability, and farmer adaptability, supporting broader dissemination (Das et al., 2014).

Against this backdrop, this study aims to assess the social, economic, and environmental impacts of floating feed and Wolffia-based fish rearing technologies disseminated by the College of Fisheries, CAU (Imphal), Lembucherra, Tripura and to understand the related challenges to farming communities in continuing to use the technologies.

METHODOLOGY

The study was conducted in Tripura during 2024–2025. Tripura, located in the north eastern region of India, covers a territorial area of 10,492 km² between 22°56'–24°32' N latitudes

and 90°09'–92°10' E longitudes. Floating feed and Wolffia-based fish rearing technologies have been disseminated by the College of Fisheries, CAU (Imphal), Lembucherra, in different districts of Tripura. For the study, districts were selected based on farmer adoption of these technologies, with the highest adoption recorded in West Tripura, followed by Sepahijala, North Tripura, Dhalai, and South Tripura (DoF, 2023). In total, 238 farmers were identified as adopters of floating feed-based technology and 40 as Wolffia adopters. Wolffia-based technology adoption was found to be lower because a farmer needs an extra pond to produce Wolffia for harvesting Wolffia on a continuous basis. Most of the fish farmers in the region are smallholders possessing a single pond of a smaller size. They cannot afford the water area to produce Wolffia continuously, which reduces the adoption of Wolffia-based fish rearing technology by the fish farmers in the region. Owing to their small number, all Wolffia farmers were included through complete enumeration, while 100 floating feed farmers were selected using simple random sampling from 238 identified farmers. Thus, the final sample comprised 140 respondents.

An *ex-post facto* research design was used, as the technologies were already adopted by farmers. Specifically, an after-only design was applied, which relies on post-adoption data to assess effects without prior manipulation (Reed et al., 2021). Impact indicators covering social, economic, and environmental domains (Garlock et al., 2024) were developed using the Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) criteria (Doran, 1981). Preliminary focused group discussions (FGDs) generated indicators, which were validated through expert consultation using a Google Forms survey. Thirty-two experts, including scientists, extension personnel, and officials, rated indicators on a five-point Likert scale (1 = not relevant to 5 = highly relevant). Qualitative feedback helped refine, merge, or drop indicators, ensuring contextual relevance. From the literature review and field consultations, 139 indicators were initially identified. Experts rated them on a five-point Likert scale, while qualitative feedback helped refine, merge, or remove items. Items were computed, and items scoring less than 3.5 of the weighted mean score were eliminated. The final set comprised 81 indicators: for floating feed, 16 social, 16 economic, and 10 environmental; for Wolffia feed, 14 social, 14 economic, and 10 environmental. These validated indicators provided a reliable framework for a comprehensive assessment of the technologies' social, economic, and environmental impacts. The impact assessment was done in an After-only design with perceived responses of the farmers before and after adoption of the technology on a five-point Likert scale (1 = very low to 5 = very high) on the combinations of positive and negative selected and validated indicators for floating and Wolffia-based technologies as mentioned above.

The Wilcoxon Signed-Rank Test was applied to ordinal data to capture perceptual changes in social and environmental impacts, while the paired t-test assessed parametric economic variables, including feed cost, production, returns, and feed conversion ratio. Constraints were grouped into technological, economic, social, and extension domains, rated on a five-point severity scale (Most severe = 5 to Least severe = 1). These were ranked using weighted mean scores, and their relationships with impact scores were analysed through Spearman's rank correlation coefficient.

RESULTS

Impact of floating feed-based fish rearing technology

Table 1 shows that the Wilcoxon Signed-Rank Test, to evaluate the impact of floating feed-based fish rearing technology. The technology had a significant positive social impact ($p < .001$), enhancing participation, awareness, income, consumption, and education, while improving efficiency through reduced labour requirements. Gains were also noted in knowledge, training, extension access, and social status. Economically, despite higher

Table 1. Social, economic and environmental Impact of floating feed-based fish rearing technology

Parameters	Before	After	p-value	Impact
<i>Social Impact</i>				
Farmer group participation	1.43	2.43	0.000	+ve
Labour need	2.43	1.43	0.000	+ve
Household income	1.43	2.43	0.000	+ve
Prophylaxis use	1.00	1.43	0.000	+ve
Fish consumption	2.43	3.43	0.000	+ve
Training effectiveness	1.43	2.43	0.000	+ve
Aquaculture dependence	1.43	2.43	0.000	+ve
Education investment	1.43	2.43	0.000	+ve
Peer knowledge-sharing	1.43	2.43	0.000	+ve
Market risk	2.43	3.43	0.000	-ve
Social status	1.43	2.43	0.000	+ve
Ease of use satisfaction	2.43	3.43	0.000	+ve
Knowledge on feed management	1.43	2.43	0.000	+ve
Extension access	2.00	3.43	0.000	+ve
Farm sustainability perception	2.43	3.43	0.000	+ve
<i>Overall</i>	<i>26.54</i>	<i>39.39</i>	<i>0.000</i>	<i>+ve</i>
<i>Economic Impact</i>				
Feed cost/cycle	2.44	3.39	0.000	-ve
Fish production	2.21	2.72	0.000	+ve
Total return	2.13	3.18	0.000	+ve
Avg. fish weight	1.98	2.41	0.000	+ve
Feed wastage	2.80	1.74	0.000	+ve
Market distance	2.89	1.90	0.000	+ve
Feed storage/handling	2.38	3.48	0.000	+ve
Fish mortality	2.72	1.87	0.000	+ve
Feed enterprises	2.52	3.39	0.000	+ve
Profitability perception	2.43	3.43	0.000	+ve
Feed price variation	2.26	3.33	0.000	-ve
Market dependency	2.30	3.34	0.000	-ve
Farmer knowledge transfer	1.43	2.48	0.000	+ve
Feed availability	2.44	3.57	0.000	+ve
<i>Overall</i>	<i>32.93</i>	<i>40.23</i>	<i>0.000</i>	<i>+ve</i>
<i>Environmental impact</i>				
Water clarity	2.41	3.43	0.000	+ve
Dissolved Oxygen	2.41	3.49	0.000	+ve
Algal bloom	2.59	1.61	0.000	+ve
Water odour	2.61	1.57	0.000	+ve
Fish disease	2.57	1.57	0.000	+ve
Disease treatment	2.00	1.00	0.000	+ve
Leftover feed	2.02	1.02	0.000	+ve
Soil texture	2.60	2.60	1.000	Neutral
Sediment buildup	2.41	1.43	0.000	+ve
Feed wastage	2.38	1.43	0.000	+ve
<i>Overall</i>	<i>23.99</i>	<i>19.15</i>	<i>0.000</i>	<i>+ve</i>

perceived market risks from feed costs, the impact score rose from 26.54 to 39.39, reflecting improved livelihoods and sustainability. Production, returns, fish weight, feed handling, and efficiency increased, while wastage, mortality, and market distance declined. Overall, the Economic Impact Score improved from 2.93 to 40.23 ($p < .001$), confirming significant benefits. The Environmental Impact Score decreased from 23.996 to 19.146 ($p < .001$), indicating better pond conditions. Improvements included higher water clarity and dissolved oxygen, alongside reduced algal blooms, odour, disease incidence, leftover feed, sediment buildup, and wastage. Soil texture, however, showed no change.

Table 2. Social, Economic, and Environmental Impact of Wolffia-Based Fish Rearing Technology

Parameters	Before	After	p-value	Impact
<i>Social score</i>				
Farmer group participation	1.48	2.43	0.000	+ve
Household fish consumption	1.52	2.45	0.000	+ve
Labour requirement	1.48	1.48	1.000	Neutral
Prophylaxis treatment applied	1.48	2.48	0.000	+ve
Household income	1.48	2.48	0.000	+ve
Training effectiveness	2.48	3.48	0.000	+ve
Satisfaction with Wolffia feed	2.48	3.48	0.000	+ve
Risk of market fluctuations	2.00	2.00	1.000	Neutral
Social status	1.48	2.48	0.000	+ve
Commercial feed dependency	1.48	1.52	0.835	Neutral
Education investment	1.48	2.00	0.001	+ve
Farmer-to-farmer knowledge	2.48	3.48	0.000	+ve
Access to extension services	1.48	2.00	0.001	+ve
Farm sustainability perception	1.48	2.48	0.000	+ve
<i>Overall</i>	<i>24.26</i>	<i>34.26</i>	<i>0.000</i>	<i>+ve</i>
<i>Economic score</i>				
Feed used	1.70	2.48	0.000	+ve
Feed cost	2.00	2.00	1.000	Neutral
Fish production	1.30	2.00	0.000	+ve
Return	1.22	2.13	0.000	+ve
Avg. fish weight	1.22	2.22	0.000	+ve
Feed wastage	2.61	2.04	0.000	+ve
Storage loss (monsoon)	2.00	2.61	0.000	+ve
Shift to Wolffia feed	1.48	2.61	0.000	+ve
Fish mortality	2.26	1.52	0.000	+ve
Feed the enterprise's need	2.00	2.00	1.000	Neutral
Feed price variation	2.00	2.00	1.000	Neutral
Market dependency	1.48	1.48	1.000	Neutral
Yield improvement perception	1.22	1.87	0.001	+ve
<i>Overall</i>	<i>22.48</i>	<i>26.30</i>	<i>0.003</i>	<i>+ve</i>
<i>Environmental score</i>				
Water clarity	1.48	2.48	0.000	+ve
Dissolved oxygen	2.48	3.48	0.000	+ve
Algal bloom presence	2.48	1.48	0.000	+ve
Water odour	2.00	1.48	0.001	+ve
Fish disease occurrence	2.52	1.52	0.000	+ve
Disease treatment applied	2.52	1.52	0.000	+ve
Leftover feed in the pond	1.48	1.00	0.001	+ve
Soil texture change	1.48	1.48	1.000	Neutral
Sediment buildup from the feed	2.00	1.00	0.000	+ve
Feed wastage	1.48	1.48	1.000	Neutral
<i>Overall</i>	<i>19.91</i>	<i>16.91</i>	<i>0.000</i>	<i>+ve</i>

Impact of Wolffia feed-based fish rearing technology

Table 2 shows that the impact of Wolffia-based fish rearing reveals significant gains across social, economic, and environmental dimensions. Socially, the Overall Score rose from 24.26 to 34.26 ($p < .001$), with improvements in participation, income, consumption, training, satisfaction, extension access, social status, and education, while labour, market risk, and feed dependency remained unchanged. Economically, the score increased from 22.48 to 26.30 ($p < 0.003$), driven by higher production, returns, fish weight, and lower mortality and wastage, though feed cost, market dependency, and storage loss persisted. Environmentally, the score declined from 19.91 to 16.91 ($p < .001$), reflecting better pond health through improved water clarity and dissolved oxygen and reduced algal blooms, odour, disease, and sediment, with no change in soil texture or feed wastage. Overall, Wolffia technology strengthened livelihoods, pond ecology, and farmer confidence.

Comparative economic performance of Wolffia and floating feed technologies

Paired t-test results (Table 3) showed significant improvements ($p < .001$) in economic performance for both floating feed and Wolffia technologies separately. In floating feed, feed cost rose by Rs. 2,206.56 per cycle (6-month cycle), yet fish production (+16.75 kg) and returns (+Rs. 6,644.26) increased, with AFCR improving by 0.23, reflecting higher efficiency. Similarly, Wolffia adoption led to higher feed use (+11.21 kg), increased production (+18.48 kg), and greater returns (+Rs. 4,804.35), with AFCR improving by 0.25. Overall, both technologies enhanced efficiency, productivity, and profitability despite higher input costs.

Perceived constraints of using floating feed-based fish farming

The perceived constraints to floating fish feed adoption were identified across four domains: technological, economic, social, and extension-related (Table 4). Technological issues included limited quality testing facilities (Mean = 4.57) and inadequate access to aerators and pumps (Mean = 3.95). Economically, the high cost of feed (Mean = 4.72) was the most severe constraint, along with poor access to credit and subsidies. Social barriers such as resistance to change (Mean = 3.44) and weak farmer networking (Mean = 2.43) were noted, while extension constraints included inadequate

Table 4. Perceived constraints associated with using floating feed-based technology

Constraints	Mean	Rank
<i>Technological</i>		
Lack of access to quality testing facilities	4.573	1
Lack of access to basic technologies	3.950	2
Limited technical knowledge	2.573	3
Poor water quality management	2.311	4
Incompatibility of floating feed with the traditional pond	1.459	5
Complexity in using floating feed	1.163	6
Difficulty in storing feed	1.098	7
<i>Economic</i>		
High cost of floating feed	4.721	1
Limited access to credit or subsidies	4.262	2
Low profitability in small-scale farms	3.623	3
Fluctuating market prices for fish	3.361	4
High wages & labour cost	1.329	5
High transportation cost of feed	1.295	6
<i>Social</i>		
Resistance to change	3.442	1
Poor networking among fish farmers	2.426	2
Illiteracy	2.000	3
Lack of awareness about the floating feed	1.443	4
Mistrust in new feed brands or products	1.409	5
<i>Extension</i>		
Poor dissemination of success stories	4.213	1
Irregular monitoring and feedback mechanisms	3.885	2
Lack of regular training or demonstration programs	3.852	3
Inadequate number of fisheries extension workers	3.786	4
Limited availability of locally relevant training materials	3.131	5

dissemination of success stories (Mean = 4.21) and irregular monitoring. Overall, economic and extension constraints were most critical, followed by technological and social factors.

Perceived constraints of using Wolffia feed-based fish rearing

The perceived constraints in adopting Wolffia-based feed technology were observed across technological, economic, social, and extension domains (Table 5). Technologically, flood-induced feed loss (Mean = 4.43), weather dependency, and poor growth

Table 3. Economic performance in Wolffia and floating feed

Parameter	Mean Difference (After-Before)	Std. Deviation	95% Confidence Interval of the Difference		Paired Difference	
			Lower	Upper	t-value	p-value
<i>Wolffia-based fish rearing technology</i>						
Feed used	-11.213	5.29462	-13.503	-8.923	-10.157	.000
Fish production	-18.478	13.26605	-24.215	-12.742	-6.680	.000
Total return	-4804.348	2363.256	-5826.296	-3782.399	-9.750	.000
AFCR	.2547	0.182	0.176	0.333	6.718	.000
<i>Floating feed-based fish rearing</i>						
Feed cost	-2206.558	744.842	-2397.320	-2015.794	-23.137	.000
Fish production	-16.754	12.643	-19.992	-13.516	-10.350	.000
Total return	-6644.262	3110.092	-7440.794	-5847.731	-16.685	.000
AFCR	0.232	0.131	0.199	0.266	13.864	.000

Table 5. Perceived constraints associated with using Wolffia (alternative) feed

Constraints	Mean	Rank
<i>Technological</i>		
Flood-induced feed loss	4.435	1
Weather Dependency	2.652	2
Poor growth of Wolffia due to insufficient nutrients	2.565	3
Contamination by other aquatic weeds (Azolla, Spirogyra, Lemna, etc.)	2.261	4
Lack of storage technique	1.783	5
Unsuited for certain fish species	1.739	6
Complexity of the technology/Difficulty in maintaining	1.565	7
Potential for overfeeding and water quality issues	1.435	8
Technology is not suited to the existing environment	1.304	9
<i>Economic</i>		
Lack of financial support/non-availability of credit	4.174	1
Low profitability in small-scale farms	3.174	2
Dependency on external suppliers	1.435	3
High transportation cost of feed	1.174	4
High wages & labour costs	1.087	5
High cost of Wolffia	1.043	6
<i>Social</i>		
Poor networking among fish farmers	2.739	1
Resistance to change	1.739	2
Lack of awareness among farmers about the Wolffia feed	1.174	3
Illiteracy	1.000	4
<i>Extension</i>		
Lack of regular training or demonstration programs	3.739	1
Poor dissemination of success stories or research findings	3.696	2
Irregular monitoring and feedback mechanisms	3.304	3
Inadequate number of fisheries extension workers	2.261	4
Ineffective communication	1.870	5
Limited availability of locally relevant training materials	1.435	6

from nutrient deficiency were major issues. Economically, lack of financial support or credit (Mean = 4.17) and low profitability in small-scale farms limited adoption. Socially, weak farmer networking (Mean = 2.74) hindered collaboration, while extension-related challenges included inadequate training, demonstrations, and dissemination of research. Overall, financial insecurity, environmental vulnerability, poor networks, and weak extension support were identified as critical barriers to adoption.

Relationship between constraints and impacts of adopting floating feed and Wolffia-based fish rearing technologies

Spearman's correlation analysis (Table 6) reveals that for floating feed, technical ($\rho = -0.676$, $p < 0.01$) and extension constraints ($\rho = -0.716$, $p < 0.01$) significantly reduce effectiveness, while economic factors show no effect ($\rho = 0.04$, $p = 0.757$) and social constraints show a weak positive link ($\rho = 0.255$, $p < 0.05$), possibly due to adaptive practices. For Wolffia, social constraints have a moderate negative impact ($\rho = -0.522$, $p = 0.011$), technical barriers are moderately negative but marginal ($\rho = -0.399$, $p = 0.059$), while economic and extension factors remain negligible. Overall, technical and extension barriers are critical for floating feed, while social and technical barriers weigh more for Wolffia adoption.

DISCUSSION

This research assesses that floating feed and Wolffia-based fish aquaculture technologies are highly impactful on social, economic, and environmental domains, mirroring trends documented in previous studies. The introduction of floating feed enhanced awareness, involvement, and community actions among farmers, whereas Wolffia-based feed secured social bonding and farmers-to-farmers (F2F) learning. This highlights the capacity of easy and straightforward technology to promote social networks, in agreement with Joffre et al. (2017).

Table 6. Correlation between constraints and impacts of floating feed and Wolffia (alternative) feed

Pair	Spearman's ρ	p-value Sign. at 0.05	Interpretation
TC vs F	-0.676	0.0 (S)	Strong negative correlation → As technical constraints increase, the impact of floating feed significantly decreases.
EC vs F	0.04	0.757 (NS)	No meaningful relationship
SC vs F	0.255	0.047 (S)	Weak but positive correlation → as social constraints increase, impact may slightly increase or vice versa (could be due to contextual factors or farmer adaptation).
ExC vs F	-0.716	0.0 (S)	Very strong negative correlation → Higher extension/communication-related constraints are strongly associated with lower impact.
TC vs W	-0.399	0.059 (S)	Moderate negative correlation → More technical constraints are associated with reduced impact, but not statistically significant at the 0.05 level.
EC vs W	0.288	0.182 (NS)	Weak positive correlation → economic constraints may have a minor influence on impact.
SC vs W	-0.522*	0.011 (S)	Moderate negative correlation → higher social constraints significantly reduce the impact of Wolffia feed.
ExC vs W	-0.185	0.397 (NS)	Very weak negative correlation → communication issues have little/no relationship with impact score.

TC= Technological, EC=Economic, SC=Social, ExC=Extension, Impact of Floating Feed= F, Impact of Wolffia= W. Significant = S, Non-Significant = NS

Economic gains were observed in both technologies. Increased fish production, household income, profitability, and enhanced feed conversion ratios were reported by farmers. Results are in line with Belton & Little (2011), who attributed income increases to improved education investment and noted improvements in nutrition through increased consumption of fish (Kawarazaka & Béné, 2011; Munkit et al., 2025). As well, gains in fish yield, mean weight, lowered mortality, and feed utilisation concur with Ng & Romano (2013) to illustrate how efficient feed management contributes to the productivity and sustainability of ponds. Valladão et al. (2018) also showed the importance of feeding management in aquaculture in South American countries. However, the adoption of floating feed had economic issues, such as increased feed price and market dependence, regarding the negativity of commercial feeds (Kumar et al., 2018; Ansah & Frimpong, 2015). Conversely, Wolffia feed remained inexpensive, providing smallholders with a low-input option. Environmental impacts were also greatly enhanced. Both technologies promoted clearer water, increased dissolved oxygen, and minimised sedimentation and algal growth, in favour of Edwards (2015) on sustainable intensification. Minimised wastage of feeds and better pond conditions, in line with Ng & Romano (2013), further emphasise the beneficial ecological impact of these technologies.

In spite of these advantages, the constraint faced by the fish farmers restricted adoption. For floating feed, technological constraints—such as absence of aerators, pumps, quality analysis, and technical information—had a sharp decline in effectiveness ($\rho = -0.676$, $p < 0.01$), which confirms Kumar et al. (2018). Extension gaps came out as the most important challenge ($\rho = -0.716$, $p < 0.01$), indicating the necessity for more intense institutional support (Nirmalkar et al., 2022). These economic factors, like high cost of feeds, limited access to credit, and unstable prices, were noted but did not impact perceived influence considerably ($\rho = 0.04$, $p = 0.757$). Notably, social constraints showed a weak positive association with influence ($\rho = 0.255$, $p < 0.05$), meaning that farmers who were motivated used networks and resilience practices to adapt to challenges. For Wolffia-based feed, technological limitations like flood-induced losses of feed, environmental sensitivity, and limited growth under conditions of nutrient deficiencies moderately limited adoption ($\rho = -0.399$, $p = 0.059$), as reported by Appenroth et al. (2017). Economic limitations were weak and non-significant ($\rho = 0.288$, $p = 0.182$), highlighting the cost-effectiveness of Wolffia relative to commercial feed.

These results are consistent with Raj et al. (2025), who stated that poor technical support and high input prices constrain the development of improved aquaculture practices. Biswas et al. (2025) & Meinam et al. (2025) also highlighted the importance of stakeholder identification, resource conservation, and sustainable utilisation of water in the development of fisheries. Higher income and better information access were also seen to stimulate demand for upgraded fisheries training (Niangti et al., 2025). In addition, providing the timely delivery of quality seed, feed, and fertilisers by connecting farmers with certified vendors, and the promotion of financial knowledge have been identified as critical to building resource access and planning (Lahiri et al., 2024). Overall, the research shows that there are clear social, economic, and environmental gains of utilising floating feed and Wolffia-based feed.

Yet, technology and extension-related constraints have to be addressed by means of precision policy interventions, capacity development, and institutional support in order to ensure optimal adoption, impact, and long-term sustainability, as appreciated by Little et al. (2016) & Munguti et al. (2024) in their study in African countries.

CONCLUSION

The research concludes that floating feed and Wolffia-based fish rearing technologies greatly increase aquaculture productivity, profitability, and sustainability in Tripura. Floating feed enhances market returns, pond water quality, fish growth, and feed efficiency, while Wolffia feed encourages farmer livelihoods, nutrition, and small-scale, climate-smart aquaculture with reduced negative environmental impacts. Social advantages are greater participation, extension service access, knowledge sharing, income, education investment, training effectiveness, and increased income. Major adoption constraints were high feed prices, reliance on off-farm suppliers, flood losses, technical and extension constraints, and poor farmer networking. These need to be addressed through focused interventions like timely training, demonstrations, exposure visits, better storage of feeds, credit facilities, ICT-based advisories, knowledge sharing within the community, and scientific support services like water analysis and feed quality assurance. Subsequent studies should concentrate on trials and long-term evaluations to inform scalable take-up and build resilient aquaculture, livelihoods, and food security in the region.

DECLARATIONS

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

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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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Climate Resilient Farming: Influence of Livelihood Assets on Agrochemical vs Organic Input Use in Coastal India

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HIGHLIGHTS

- Livelihood assets strongly influence farmers' adaptation choices between an increase in agrochemical and organic input usage in farming.
- Physical capital encourages the use of organic inputs and reduces reliance on agrochemicals, whereas human capital reduces reliance on agrochemicals.
- Social capital enhances organic inputs use; however, it might also promote use of agrochemicals without targeted interventions.

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ABSTRACT

Climate change poses immense pressure on global agriculture, particularly in coastal regions. Several adaptation strategies to climate change were taken by farmers, though not all are aligned with long-term sustainability. Through logistic regression, the study assesses the role of livelihood assets in farmers' choices between agrochemical intensification and organic farming, where livelihood assets were measured using the Department for International Development's (DFID) framework. The study covered five coastal states and one coastal union territory of India. Using a stratified random sampling method, 520 agricultural households were surveyed during 2024–2025. Villages were selected based on proximity to the sea and the implementation of the National Innovation on Climate Resilient Agriculture (NICRA) and Project on Climate Resilient Agriculture (PoCRA) programmes. Findings indicate physical capital as a pivotal factor encouraging organic farming and curbing agrochemical intensification, while human capital reduces reliance on agrochemicals. Natural and financial capital enhance agrochemical use. The dual positive influence of social capital on organic farming and agrochemical intensification underscores the need for tailored guidance, as affirmed by sustainability-oriented initiatives, proven effective in limiting agrochemical intensification as NICRA and PoCRA. Inclusion in such programmes and enhancing human and physical capital may reinforce farmers' orientation with sustainable adaptation trajectories.

INTRODUCTION

The multifaceted effect of climate change (CC) poses immense pressure on the agricultural systems across the globe. Over the past few decades, significant economic disruption to the agricultural sector in least developed countries has been caused by the increasing

frequency and severity of wildfires, storms, floods, and droughts, which have placed substantial pressure on food production systems and rural livelihoods (FAO, 2021). The direct impacts of CC include changes in crop growth cycles and yield fluctuations, while indirect impacts manifest themselves through increased frequency and intensity of extreme climatic events, changes in soil fertility, erratic

in rainfall patterns, and changes in the distribution and prevalence of pests and diseases, which adversely affect overall agricultural productivity (Yuan et al., 2024). Despite a global concern, coastal areas are more susceptible to climate change-induced sea level rise; it is mentioned that 21st-century sea-level rise may exceed the projection of the Intergovernmental Panel on Climate Change (IPCC), i.e., 0.61 to 1.10 meters compared to the 1950s (Siebert et al., 2020).

Climate variability poses a serious threat to food security (Pradhan et al., 2025). Increasing temperatures, erratic rainfall, and intensified cyclonic storms are crumbling up the livelihood of the densely populated coastline of India (Dasgupta et al., 2020). The impact of CC on reducing crop productivity in coastal regions jeopardises food security and lowers the income and livelihood stability of coastal populations (Gopalakrishnan et al., 2019). Subsequently, increased reliance on agrochemicals, referred to as agrochemical intensification (Pelinson et al., 2023), in order to maintain agricultural productivity has been driven by rising temperatures (Quan et al., 2024) and rainfall shocks (Guo & Chen, 2022), inadvertently exacerbating environmental degradation (Sharma et al., 2020). In contrast, organic farming, as an adaptive measure, provides greater sustainability, care for biodiversity, and augments carbon sequestration relative to conventional practices with more reliance on agrochemicals, thereby supporting CC mitigation (Murry, 2019). From the standpoint of smallholding farmers, organic farming promotes comprehensive growth by reducing input costs and improving profit (Sahu & Tiwari, 2024). Das et al. (2024) advocated that farmers' resiliency is not only shaped by the factors related to agriculture, but also by their livelihood assets. As highlighted by Ren et al. (2022), such livelihood assets play a crucial role in reducing the reliance on agrochemicals and advancing sustainable agricultural practices. Also, organic farming contributes to the pursuit of sustainable livelihoods by strengthening livelihood assets (Sibarani & Somboonsuke, 2024). In this backdrop, present study examines the role of various livelihood assets, that include human, natural, financial, physical, and social capital, in influencing farmers' decisions to use organic inputs or agrochemical intensification in India's climate-vulnerable coastal regions. It further examines how sustainability-focused initiatives, such as NICRA and PoCRA, shape both agrochemical intensification and sustainable agricultural practices.

METHODOLOGY

This study is based on primary data collected between October 2024 and March 2025 across five coastal states—West Bengal, Odisha, Tamil Nadu, Kerala, and Maharashtra—and one UT, Andaman & Nicobar Islands. Districts, blocks, and villages were selected considering coastal proximity and the implementation of NICRA/PoCRA programme. One district was selected from each State/UT, except Maharashtra, where three districts were included to capture coastal proximity and presence of both NICRA and PoCRA programme. From each district two blocks—one with NICRA/PoCRA intervention and one without—except in Maharashtra, where one block from each district represented interventions under NICRA, PoCRA and no intervention. Accordingly, 13 selected blocks were: Kultali and Gosaba (South 24 Parganas, West Bengal); Marshaghai and Mahakalpara

(Kendrapara, Odisha); Thirupulani and Ramanathapuram (Ramanathapuram, Tamil Nadu); Kunnummal and Panthalayani (Kozhikode, Kerala); Ferrargunj and Port Blair (South Andaman, Andaman & Nicobar Islands); Ambajogai (Beed), Kankavli (Sindhudurg), and Risod (Washim) in Maharashtra. Two villages per block were chosen, where 20 farm-households per village were selected through stratified random sampling based on net cultivated area. Thus in total, from 26 villages a sample of 520 agricultural households were surveyed.

The “Balanced Weighted Average Approach” (Namgyal et al., 2025) was used to construct the index values of livelihood assets, i.e., human, natural, financial, physical, and social capital, after normalizing the subcomponents (listed in Table 1) through “Linear Scaling Technique” (De & Das, 2021). For, subcomponent (x_i) positively associated with livelihood assets, Eq. 1 and for the negatively associated subcomponent (x_i) Eq. 2 was applied.

$$X_i = \frac{x_i - \text{Min}(x)}{\text{Max}(x) - \text{Min}(x)} \quad \dots (\text{Eq. 1})$$

$$X_i = \frac{\text{Max}(x) - x_i}{\text{Max}(x) - \text{Min}(x)} \quad \dots (\text{Eq. 2})$$

Where, $\text{Max}(x)$ and $\text{Min}(x)$ are the maximum and minimum values of x_i respectively. The transformed variable (X_i) is positively associated with the index and lies between intervals (0,1).

Let, x_{ji} ($j=1,2,\dots,k$) denote the values of the j^{th} subcomponent of the d^{th} asset for the i^{th} observation ($i=1,2,\dots,n$), and X_{ji} represent the corresponding normalized value. Composite index of the d^{th} asset, comprising k subcomponents, is derived using (Eq. 3).

$$I_i^d = \frac{\sum_{j=1}^k X_{ji}}{k} \quad \dots (\text{Eq. 3})$$

Further, the logistic regression technique is used to explain the dummy variable Y with values 0 and 1. Considering, $z = XB + u$ as the regressor, the probability of $Y=1$ is defined as,

$$P(Y=1) = \frac{1}{1 + e^{-z}} \quad \dots (\text{Eq. 4})$$

The ‘odds ratio’ is

$$\frac{P}{1-P} = \frac{1}{e^{-z}} = e^z \quad \dots (\text{Eq. 5})$$

So, regressand Y (0,1) can be represented as the logarithm of the odds ratio as:

$$L = \ln\left(\frac{p}{1-p}\right) = z = XB + u \quad \dots (\text{Eq. 6})$$

Parameter B is estimated using maximum likelihood method. Estimated coefficients provide the marginal effects of change in X on the likelihood function (i.e., $\partial L / \partial X$).

RESULTS

The study examines the influence of livelihood assets on farmers' decision-making regarding agrochemical intensification (AGROCHEMICAL) versus the adoption of organic input usage (ORGANIC), both of which are important for sustaining agricultural productivity. Livelihood assets, operationalised as a composite

Table 1. Description of the sub-components of the livelihood assets

Asset	Subcomponents	Description of Sub-components	Unit	Effect
Human Capital	Dependency Ratio	% of non-working household (HH) members	%	-ve
	Head's Education	Education level of HH head	Years	+ve
	Average Education	HH's average education level	Years	+ve
	Maximum Education	Highest education level in the HH	Years	+ve
	Illness Ratio	% of HH members with health challenges	%	-ve
Natural Capital	Agricultural Land	Net sown area of the HH	Acres	+ve
	Natural Fuel	Access to natural cooking fuel	Binary	+ve
	Surface Water	Access to surface water irrigation	Binary	+ve
	Ground Water	Access to groundwater irrigation	Binary	+ve
Financial Capital	Livestock	Estimated HH livestock worth	Rupees	+ve
	Health Insurance	% of health-insured HH members	%	+ve
	Govt. Assistance	HH Govt. financial aid sources count (Central/State)	Count (0,1, 2)	+ve
	Kisan Credit Card	Possession of a Kisan Credit Card	Binary	+ve
	Institutional Loan	Access to institutional loans	Binary	+ve
Physical Capital	Pucca Dwelling	Ownership of a pucca dwelling	Binary	+ve
	Dwelling Distance	Distance of the dwelling from an all-weather road	Kilometres	-ve
	Agricultural Land Distance	Distance of agricultural land from an all-weather road	Kilometres	-ve
	Drinking Water	Access to drinking water facilities within the dwelling premises	Binary	+ve
	Latrine	Possession of a sanitation facility meeting hygienic standards	Binary	+ve
Social Capital	SHG Participation	% of adult female HH members engaged in Self-Help Groups	%	+ve
	Membership	Association with a Farmers' Producers Organization or Cooperative Society	Binary	+ve
	Media Access	Number of media sources (Print & Social) accessed by the HH	Count(0,1, 2)	+ve

index comprising multiple subcomponents (Table 1), exert statistically significant effects on farmers' choices. The socio-economic profile of sample households across selected states and UT (Table 2) reveals notable variation in agricultural land holdings, major crops grown, irrigation sources, and livelihood asset endowments. Furthermore, the household-level responses presented in Table 3 highlight region-specific exposure to climatic stressors.

Regional variations in the distribution of agricultural land size among sample households can be seen from Table 2. In West Bengal, 70% of households have less than 1 acre of agricultural land, highlighting the prevalence of marginal farming and land fragmentation. Kerala also has a high number of smallholders, with 75% of people owning less than 2 acres of land, although this is slightly more balanced than in West Bengal. In contrast, Maharashtra and Odisha show a more equitable distribution, with more than 30% of households in each state owning 3 acres or more of land, indicating better access to cultivable land. Tamil Nadu is skewed to medium-sized agricultural land, with more than 50% of sample households in the 1-2 acre category, whereas only 13.75% of households have 3 acres or more of land. Andaman and Nicobar Islands show a unique scenario, with a relatively high proportion (33.75%) of households owning 3 acres or more of land, and a comparatively even distribution across all size categories.

Like agricultural land holding, regional disparities can also be seen in the irrigation patterns. In Kerala, 82.5% of sample households are completely dependent on rainwater, indicating limited irrigation availability. Similarly, Tamil Nadu has a rain-fed dependency rate of 51.25%, although 41.25% of farmers have access to both groundwater and surface water, reflecting higher diversity

than others. In West Bengal, 76.25% depend only on surface water, with no reported use of groundwater. Odisha presents a balanced profile, with 35% sample respondents using both ground as well as surface water and 27.5% dependent on rainfall, indicating moderate irrigation benefits. In Maharashtra, where 40.83% of the sample households depend primarily on rainwater for agriculture, a significant proportion rely solely on groundwater (22.5%) or surface water (20%). Additionally, 16.67% of households reported access to both groundwater and surface water sources, indicating a degree of hydrological diversity within the region. A mixed pattern is observed in the Andaman and Nicobar Islands, with 47.5% using only surface water and 33.75% relying on rainfall, due to island-specific hydrology and limited groundwater availability.

The distribution of livelihood resources of the selected farm households clearly reveals regional strengths and weaknesses. Kerala and the Andaman & Nicobar Islands topped the list in physical capital with scores of 0.949 and 0.925, respectively, indicating strong infrastructure and access to basic services. Odisha and Kerala also exhibit strong social capital (0.601 and 0.649), indicating better community networks and institutional support. In contrast, West Bengal has relatively low scores in financial (0.288) and social capital (0.305), although it maintains moderate levels of natural (0.446) and physical capital (0.724). Maharashtra shows balanced performance in most categories, with significant strengths in physical (0.792) and social capital (0.609). Tamil Nadu shows high human capital (0.640) but limited natural capital (0.251), indicating strong education and skills but limited environmental resources. Odisha stands out for its financial capital (0.552), perhaps due to better access to credit or income diversification. Kerala (0.594) and

Table 2. Selected states and UT-wise socio-economic profile of sample households

	West Bengal	Odisha	Tamil Nadu	Kerala	Maharashtra	Andaman & Nicobar Islands
Number of sample households	80	80	80	80	120	80
<i>Agricultural land holding (% of sample households)</i>						
Less than 1 acre	70.00	5.00	10.00	33.75	2.50	20.00
1 to less than 2 acre	25.00	36.25	53.75	41.25	44.17	32.50
2 to less than 3 acre	2.50	28.75	22.50	18.75	12.50	13.75
3 acre and more	2.50	30.00	13.75	6.25	40.83	33.75
<i>Major field crops Grown</i>						
Kharif	Paddy, Jute	Paddy, Jute	Cotton, Groundnut, Black gram	Paddy	Millet, Paddy, Soybean	Paddy, Sugarcane
Rabi	Paddy, Potato, Sunflower	Paddy, Green gram, Black gram, Groundnut	Paddy, Cotton	Paddy	Sorghum, Gram	Maize, Green gram, Black gram
Summer	Paddy	Paddy	Paddy	Paddy	-	-
<i>Sources of Irrigation (% of sample households)</i>						
Only groundwater	0.00	3.75	7.50	6.25	22.50	1.25
Only surface water	76.25	33.75	0.00	0.00	20.00	47.50
Both ground and surface water	0.00	35.00	41.25	11.25	16.67	17.50
Fully dependent on rainwater	23.75	27.50	51.25	82.50	40.83	33.75
<i>Livelihood Asset (Average index value)</i>						
Human Capital	0.510	0.671	0.640	0.632	0.595	0.612
Natural Capital	0.446	0.328	0.251	0.086	0.351	0.429
Financial Capital	0.288	0.552	0.279	0.572	0.424	0.220
Physical Capital	0.724	0.723	0.625	0.949	0.792	0.925
Social Capital	0.305	0.601	0.338	0.649	0.609	0.313
Composite Asset Index	0.469	0.584	0.443	0.594	0.558	0.520

Table 3. Comparative vulnerability to climatic stressors across selected states and UT

Climatic stressors	% of sample households					
	West Bengal	Odisha	Tamil Nadu	Kerala	Maharashtra	Andaman & Nicobar Islands
Frequent occurrence of storm surges	83.75	100.00	42.50	53.75	46.67	42.50
Frequent occurrence of drought	8.75	47.50	17.50	53.75	56.67	20.00
Frequent occurrence of floods	63.75	98.75	0.00	3.75	50.83	12.50
Change in rainfall pattern	63.75	78.75	52.50	92.50	90.83	65.00
Water scarcity in surface water bodies	45.00	71.25	17.50	63.75	63.33	16.25
Decline in groundwater level	31.25	72.50	17.50	61.25	76.67	6.25
Increase soil erosion	15.00	78.75	35.00	23.75	37.50	8.75
Increase in soil salinity	27.50	67.50	0.00	3.75	14.17	10.00
Degradation of soil fertility	75.00	100.00	35.00	52.50	37.50	63.75
Increase in pests and disease outbreaks	77.50	100.00	17.50	75.00	68.33	58.75
Decrease in crop productivity	62.50	85.00	52.50	91.25	50.00	58.75
Increasing incidence of crop loss	47.50	100.00	52.50	83.75	69.17	28.75

Odisha (0.584) top the composite asset index, indicating overall livelihood resilience, while West Bengal (0.469) and Tamil Nadu (0.443) lag behind, indicating multidimensional asset gaps that may require targeted interventions.

The challenges faced by the agricultural households due to climate change show stark differences among the selected states and UT. Based on the reported suffering of the sample households, Table 3 reveals that Odisha is facing the most severe and multifaceted impacts; 100% of sample households reported windstorms, soil

erosion, insect outbreaks, and crop damage, as well as widespread flooding and groundwater depletion. West Bengal has high storm surge (83.75%) and flood (63.75%), but limited drought impact, indicating dependence on monsoon and salinity risks. Intense rainfall variability (over 90%), combined with drought and groundwater depletion, in Kerala and Maharashtra, indicates severe hydrological stress. Kerala's risk is further reflected by high insect infestations (75%) and crop damage (83.75%), although flood risk is low. Tamil Nadu has moderate climate stress, with more than half of households

Table 4. Binary logistic regression related to agrochemical intensification and organic farming

Regressor	Regressand: [AGROCHEMICAL]		Regressand: [ORGANIC]	
	Model 1.1 Marginal effect	Model 1.2 Marginal effect	Model 2.1 Marginal effect	Model 2.2 Marginal effect
HUMAN_CAP	-0.649*** (0.165)	-0.745*** (0.171)	0.152 (0.156)	0.154 (0.156)
NATURAL_CAP	0.191* (0.105)	0.240** (0.107)	0.014 (0.101)	0.012 (0.101)
FINANCIAL_CAP	0.330*** (0.117)	0.463*** (0.124)	0.077 (0.107)	0.071 (0.110)
PHYSICAL_CAP	-0.416*** (0.126)	-0.403*** (0.128)	1.278*** (0.136)	1.278*** (0.136)
SOCIAL_CAP	0.214** (0.103)	0.207* (0.105)	0.197** (0.099)	0.197** (0.099)
NICRA_PO CRA	-	-0.213*** (0.047)	-	0.010 (0.044)
Chi ²	40.87	61.22	115.39	115.45
Prob > Chi ²	0.00	0.00	0.00	0.00
Pseudo R ²	0.057	0.086	0.172	0.172
Log likelihood	-336.29	-326.12	-277.72	-277.69
Akaike crit. (AIC)	684.59	666.244	567.442	569.389
Bayesian crit. (BIC)	710.113	696.021	592.965	599.166
Number of observations	520	520	520	520

Note: *** p<.01, ** p<.05, * p<.1. Values in parentheses are standard errors.

affected by rainfall variability and crop damage, but the risk of salinity and storm surge is relatively low. Under stress, rainfall variability, groundwater depletion, and soil degradation emerge as widespread threats, with Odisha and Maharashtra particularly affected. Andaman and Nicobar Islands, although less exposed overall, still report significant soil fertility decline (63.75%) and pest outbreaks (58.75%), emphasizing ecological fragility.

As evident from Table 4, Model 1.1 estimates the likelihood of agrochemical intensification, where the regressand AGROCHEMICAL takes the value 1 if any household reported increased use of chemical fertilisers or pesticides, and 0 otherwise. The regressors include five dimensions of livelihood assets: human capital (HUMAN_CAP), natural capital (NATURAL_CAP), financial capital (FINANCIAL_CAP), physical capital (PHYSICAL_CAP), and social capital (SOCIAL_CAP). Model 1.2 builds on this by incorporating an additional regressor, NICRA_PO CRA, which takes the value 1 if the household is a beneficiary of either the NICRA or PoCRA programme, and 0 otherwise. As explanatory variables, Model 2.1 uses the same set of livelihood asset variables as Model 1.1, but considers ORGANIC as the regressand, which takes the value 1 if any household reported use of organic inputs, and 0 otherwise. Model 2.2 mirrors Model 2.1, with the inclusion of NICRA_PO CRA as an additional regressand. All four models are based on a consistent sample of 520 households. This uniform sample size ensures comparability across model specifications and allows for a comprehensible understanding of the effects of livelihood assets and the impact of NICRA & PoCRA on both agrochemical intensification and organic farming adoption.

Findings from Model 1.1 and Model 2.1 demonstrate that livelihood assets, human (HUMAN_CAP), natural

(NATURAL_CAP), financial (FINANCIAL_CAP), physical (PHYSICAL_CAP), and social capital (SOCIAL_CAP) significantly shape the choice between agrochemical and organic input use, respectively, albeit with varied directional effects. Increased access to natural resources (natural capital) and stronger household financial capacity (financial capital) are positively associated with the likelihood of increased application of chemical fertilisers and pesticides, showing marginal effects of 0.191 and 0.330, with statistical significance at the 90 and 99 per cent levels, respectively. However, neither natural nor financial capital appears to significantly encourage the adoption of organic input use. Conversely, enhanced human capital, encompassing education, health status, and labour availability, demonstrates a restrictive effect on increased agrochemical use, reflected by the most pronounced marginal effect (-0.649) and significance at the 99 per cent level, though it does not exert a statistically significant influence on organic input uptake. Physical capital, indicating access to infrastructural amenities such as pucca housing, potable water, sanitation, and all-weather roads, contributes positively to organic farming. It is associated with a reduction in agrochemical intensification (marginal effect: 0.416) and simultaneously fosters organic input adoption (marginal effect: 1.278), both with significance at the 99 per cent level. Notably, social capital, measured through household association with various organisations and access to print and social media, emerges as a dual influencer. It positively correlates with both agrochemical intensification and organic input usage, registering marginal effects of 0.214 and 0.197, respectively, with 95 per cent confidence, indicating that organisational affiliations may currently lack a coherent sustainability agenda, thereby facilitating divergent farming behaviours.

To further examine the role of organisational alignment with sustainability goals, Models 1.2 and 2.2 incorporate two government-led initiatives, NICRA and POCRA (NICRA_PO CRA), as additional explanatory variables. The National Innovations in Climate Resilient Agriculture (NICRA), implemented by the Indian Council of Agricultural Research (ICAR), has played a significant role in promoting the use of sustainable inputs and facilitating organic farm inputs usage. NICRA has shown a set of climate-resilient technologies, including zero-till sowing, green manuring, integrated pest and nutrient management, and region-specific organic farming packages, across diverse agro-climatic zones (Ministry of Agriculture and Farmers Welfare, 2025). Complementing this, the Project on Climate Resilient Agriculture (PoCRA), implemented by the Government of Maharashtra in partnership with the World Bank, has demonstrated a comprehensive approach to enhance climate-resilient farming and reduce environmental degradation with a strong focus on reducing agrochemical dependency. It promotes organic farming, integrated nutrient and pest management, and farmer-led capacity building to enhance ecological sustainability and input efficiency (Leena, 2017).

The result reveals that the presence of NICRA and POCRA interventions is significantly associated with a reduction in the likelihood of agrochemical intensification among beneficiary households, with a marginal effect of 0.213 and statistical significance at the 99 per cent level (Model 1.2). This underscores the potential of structured policy interventions in reducing reliance on agrochemicals through capacity building, awareness campaigns, and access to alternative technologies. However, while these initiatives are effective in curbing agrochemical intensification, it is evident from Model 2.2 that they do not exert a statistically significant influence on the adoption of organic input use, indicating the limitations in the emphasis of programmes on organic cultivation or barriers faced by beneficiaries in transitioning to organic methods, such as challenges regarding certification, access to the market, or availability of inputs.

DISCUSSION

The role of agrochemicals in order to enhance agricultural yield, particularly in the context of increasing challenges from CC, is undeniable. However, the upsurge in use of chemical inputs has led to higher production costs and increasing environmental problems, which undermine the broader objectives of sustainable agriculture. Chen et al. (2024) highlighted that farmers' access to livelihood assets has a strong influence on their decisions to either increase agrochemical use or to come up with sustainable organic farming practices. The findings of the present study are partially in line with those of Chen et al. (2024), particularly in showing that improvements in human and physical capital help reduce the overuse of agrochemicals. Similarly, Yang & Cui (2025) stated that natural, human, financial, and social capital significantly affect farmers' environment-friendly production behaviour, although they do not find an obvious connection between physical capital and green production practices. In contrast, the present study finds that physical capital plays a key role in encouraging farmers to adopt organic farming. The importance of infrastructure is also highlighted by Maksimovich et al. (2023), who noted that reduced

transportation and transaction costs support organic farming. Mishra et al. (2015) also emphasised the role of better road connectivity in enabling the smooth transport of organic products. On the other hand, Karki et al. (2012) noted that poor road connectivity affects both conventional and organic farming. While it limits access to agrochemicals in remote areas, it also makes it difficult for government agencies to provide support for organic farming in remote areas.

The financial capital that is essential for maintaining inputs and productivity was found here to be positively associated with intense use of agrochemicals. This supports the argument made by Combarry (2022) that farmers with more financial resources tend to apply more chemical inputs. Interestingly, this study does not find any significant relationship between financial capital and the use of organic inputs. This differs from the findings of Zhang et al. (2025), who claimed that, depending on the situation of organizational and market structure, access to credit can support both conventional as well as organic input use. Similarly, the present study finds that access to natural capital increases the likelihood of higher agrochemical use. This aligns with Xie et al. (2020), who described a non-linear relationship where chemical input use first decreases with larger farm size but then increases after a certain threshold.

Social capital shows a mixed influence on both the intensification of agrochemicals and the adoption of alternative organic practices, which is also noted by Ren & Jiang (2022). While Hu (2020) linked social capital with higher agrochemical use, another study by Ma et al. (2022) associated it with increased participation in organic farming. Drawing from evidence in the climate-vulnerable state of Odisha, Das et al. (2020) found that institutional arrangements notably impact the adaptation decisions of farm households. In this line, the present study finds that the Institutional program NICRA, which promotes climate-resilient agriculture (Yadav et al., 2025) and also organic farming across India, alongside the region-specific program PoCRA in Maharashtra, contributed significantly to reducing chemical input use. However, the limited impact of these programmes on farmers' willingness to adopt organic methods suggests that deeper structural and behavioural issues need to be explored. Targeted interventions are required to enhance climate resilience and promote climate-smart agricultural practices. The key livelihood indicators (such as infrastructure, connectivity, community network, landholding, irrigation access, and income) are reported as determinants of the resilience of the farmers in Odisha (Das et al., 2025). Therefore, policy interventions that strengthen human and physical capital, along with institutional support need to be specifically designed to ease the transition to organic farming, paving the way to the achievements of both productivity and sustainability goals.

CONCLUSION

The differences in livelihood assets and climatic stressors highlight the need for region-specific policy frameworks that align resource growth with climate adaptation goals. The study validates the critical role of livelihood assets in farmers' decision-making under coastal climate stress in India. While natural and financial capital influence the agrochemical intensification, human and physical capital

evidently restrict the reliance on such practices. Physical capital was found to promote sustainable organic input use in agriculture. Social capital exerted a double-edged influence in supporting agrochemical intensification as well as organic input use, directing towards institutional alignment. NICRA and POCRA, with their alignment with climate-resilient and organic agriculture, play a significant role in curbing increased agrochemical use, yet fall short in facilitating transitions to the use of organic inputs. Targeted policies, enhancing physical and human capital, and integrating sustainability requirements within grassroots organizations can promote more comprehensive and resilient pathways for agricultural adaptation.

DECLARATIONS

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

Conflict of interest: The author declares that there is no conflict of interest related to the publication of this article. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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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Time Management and Procrastination Patterns Among Undergraduate Agriculture Students

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HIGHLIGHTS

- The assessment of time management and procrastination focuses on students' planning, prioritization, goal setting, use of time-saving techniques, and avoidance of procrastination behaviors.
- Task prioritization and personal time management were the strongest aspects of time management behavior among students across the three cohorts.
- Students from the 2022 and 2023 cohorts showed a strong positive correlation in their time management behavioural patterns.

ARTICLE INFO

Keywords: Time management, Procrastination, Undergraduate students, Agricultural education, Behavioral study, Academic cohorts.

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ABSTRACT

Academic and personal success among students is achieved when they can manage their time effectively without procrastination. The present study was conducted in 2025 to examine time management behaviors and procrastination tendencies among 101 undergraduate students across three batches: 2021 (N = 28), 2022 (N = 33), and 2023 (N = 40) from the College of Agriculture, Vellayani. A 20-item standardized questionnaire, rated on a 5-point Likert scale, revealed a gradual decline in batch-wise mean scores: 2.238 (2021), 2.199 (2022), and 2.014 (2023). Students consistently scored highest in task prioritization (Mean = 3.17) and personal time management, while daily task listing (Mean = 1.48) and short task scheduling (Mean = 1.11) were persistent weaknesses. Heatmap and Spearman correlation analyses indicated behavioral consistency between the 2022 and 2023 cohorts ($r = 0.818$) and divergence with the 2021 batch. The results of the one-way ANOVA and paired t-tests indicate that there are no statistically significant differences in time management scores among the batches. The results highlight the need for early interventions that strengthen micro-level planning behaviours, thereby reducing procrastination tendencies, enhancing academic self-regulation, and improving undergraduate learning outcomes.

INTRODUCTION

In higher education and research environments, the ability to prioritize tasks, plan systematically, and manage activities efficiently is essential for achieving academic goals while maintaining relevance and integrity (Velamuri & Mallappa, 2025). Time management is widely recognized as a cornerstone of academic achievement,

enabling students to efficiently allocate cognitive and emotional resources across academic, personal, and professional domains (Claessens et al., 2007; Cyril, 2014; Galaviz et al., 2025). In higher education, especially in academically rigorous and interdisciplinary environments such as agricultural universities, the ability to prioritize tasks, create schedules, and self-regulate time is essential. These skills are crucial for successfully managing coursework,

fieldwork, and assignments, as well as planning for the future (Kearns & Gardiner, 2007). Capacity building of students to improve their time management skills is essential to ensure their academic success, strengthen institutional effectiveness, and prepare a more competent, professionally equipped society (Alyami et al., 2021; Wilson et al., 2021; Fu et al., 2025). Studies have demonstrated the positive impact of effective time use on academic performance. Galaviz et al. (2025) highlight the benefits of planning and goal-setting for improving both Grade Point Average (GPA) and self-efficacy. This foundational insight was further developed by Cyril (2014), whose Time Management Behavior Scale (TMBS) introduced a structured framework for assessing goal-setting, planning, prioritization, and perceived control over time.

More recent research (Eilam & Aharon, 2003; Kearns & Gardiner, 2007; Zhou et al., 2022) underscores how metacognitive skills, self-monitoring, and resistance to digital distractions enhance time management and reduce academic stress. Conversely, procrastination is a self-regulatory failure that stems from impulsivity and an aversion to tasks. It has been shown to reduce time efficiency, lower performance, and increase psychological distress (Steel, 2007; Sirois, 2014; Sirois, 2023). Procrastination along with poor time management, can result in delays, increased stress, and reduced performance (Häfner et al., 2014). Procrastination tends to decline during high-stakes academic transitions, indicating that contextual factors can influence student behavior, and is negatively correlated with self-regulation among college students (Tuckman, 2002; Bommareddy et al., 2022). By adopting a holistic approach to time management, institutions can significantly improve both individual performance and broader academic and research outcomes. When combined with the proactive involvement of government and academic institutions in promoting more equitable, efficient, and effective practices, this approach can further enhance student engagement in learning (Sabu & Roy, 2025).

Despite a robust body of literature on time management and procrastination, research remains limited in the context of agricultural education, where students encounter unique temporal challenges due to the integration of theoretical learning and intensive fieldwork (Yien et al., 2014; Alghamdi, 2022). Additionally, studies by Safiya et al. (2024) and Ahmady et al. (2021) have revealed a negative correlation between time management and stress levels among undergraduate students. Addressing this gap, the present study explores time management behavior and procrastination tendencies among undergraduate students from three consecutive batches (2021 to 2023) at College of Agriculture, Vellayani, guided by the research question: 'How do students manage their time during their undergraduate period, and how does it affect the procrastination patterns influencing their learning outcomes?'

METHODOLOGY

This study employed a quantitative, descriptive research design to assess and compare time management behaviors among undergraduate students enrolled in the College of Agriculture, Vellayani. A total of 101 students participated in the study, drawn from three consecutive academic batches: 2021 (N=28), 2022 (N=33), and 2023 (N=40). The sample was purposively selected

to capture variability in academic maturity, exposure to institutional routines, and proximity to career transitions.

Data were collected using a standardized 20-item Time Management Questionnaire developed to assess key behavioral domains such as planning, prioritization, goal setting, application of time-saving techniques, and avoidance of procrastination. Each item was rated on a 5-point Likert scale (Never = 0, Seldom = 1, Sometimes = 2, Often = 3, Always = 4), enabling the quantification of behavioral frequencies. Prior to administration, the instrument was piloted on a non-respondent sample, and reliability analysis produced a coefficient exceeding 0.8, confirming strong internal consistency. In addition, content validity assessment verified that the items accurately captured students' time management and procrastination tendencies. The tool, widely employed in earlier studies, thus provided a robust and reliable framework for examining self-regulatory time use in academic contexts.

The responses were processed to generate batch-wise mean scores for each item, which formed the basis of the statistical analyses. Descriptive statistics were first applied to identify patterns and trends, followed by comparative analysis across batches through ranking of items and graphical interpretation using line charts and heatmaps.

To examine whether differences existed across the three cohorts, a one-way ANOVA was applied to batch-wise mean scores, which appropriately captured variation at the group level. To complement this, paired t-tests were employed to explore pairwise differences between batches, and a dot-and-whisker plot was generated to visualize mean differences with confidence intervals. Further, Spearman's rank correlation was used to assess the consistency of time management behaviors across cohorts, providing additional insight into monotonic relationships.

RESULTS

The analysis of student responses revealed insightful patterns in time management behaviors across the three batches studied. The line chart in Figure 1 shows the mean scores per time management items across the three batches. The overall mean scores indicate a modest but notable decline in effective time management from senior to junior cohorts: 2.238 for the 2021 batch, 2.199 for the 2022 batch, and 2.014 for the 2023 batch. When individual items were ranked based on average scores, certain strengths emerged consistently across batches. Task Prioritization was the highest-rated behavior, with an impressive average score of 3.17, followed closely by Focused and Multitasking and Personal Time Management. These results reflect a commendable ability among students to recognize and manage high-priority tasks, and to carve out intentional time for reflection, planning, or rest. In contrast, several areas were identified as weak points in students' time management routines. The lowest-scoring behaviors included Short Task List creation (1.11), Daily Review (1.18), and Daily Task List usage (1.48). These findings indicate a lack of micro-level planning practices, such as breaking large tasks into manageable parts or reviewing progress regularly—skills that are essential for consistent academic performance and long-term goal attainment. These patterns underscore the need for structured interventions aimed at fostering granular time management habits, especially among students in their early years.

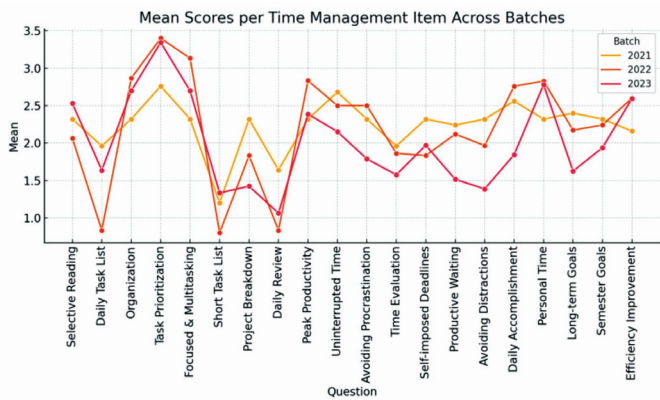


Figure 1. Line chart of mean scores per time management items across batches

Figure 2 presents a heatmap of time management scores by batch and provides a clear, comparative view of time management behaviors across the three batches, highlighting both strengths and weaknesses at a glance. Darker shades indicated higher average scores, revealing that skills such as Task Prioritization, Focused and Multitasking, and Personal Time were consistently stronger across all cohorts—particularly evident in the 2021 and 2022 batches. Conversely, lighter shades clustered around items like Short Task List, Daily Review, and Daily Task List, signifying persistent underperformance in these areas. This visual pattern confirmed that

while students may excel at high-level goal-setting and prioritization, they struggle with the finer, routine-based aspects of time management. The heatmap also reflected batch-wise consistency in both strengths and shortcomings, reinforcing the need for targeted training on micro-planning strategies, especially for underclassmen. Such visual tools are valuable not only for diagnostic analysis but also for communicating areas of concern to academic support teams and curriculum designers.

A Spearman rank-order correlation was conducted to assess the consistency and relational patterns in time management behaviors across different academic cohorts, based on the mean scores of all 20 items. This non-parametric method measures monotonic relationships without requiring the assumption of a normal distribution. The results revealed a strong positive correlation ($r = 0.818$) between the 2022 and 2023 batches, suggesting that these two cohorts share highly similar behavioral patterns—possibly influenced by similar institutional exposures, academic calendar routines, or shared post-pandemic classroom dynamics. A moderate correlation was observed between the 2021 and 2022 batches ($r = 0.617$), while the weakest, yet still statistically significant, correlation existed between the 2021 and 2023 cohorts ($r = 0.494$). These findings suggest a gradual behavioral shift over time, with seniors (2021) potentially having diverged due to increased academic maturity, goal orientation, or proximity to career transitions. The correlation heatmap visually underscores these trends, with warmer tones between 2022 and 2023 denoting tighter

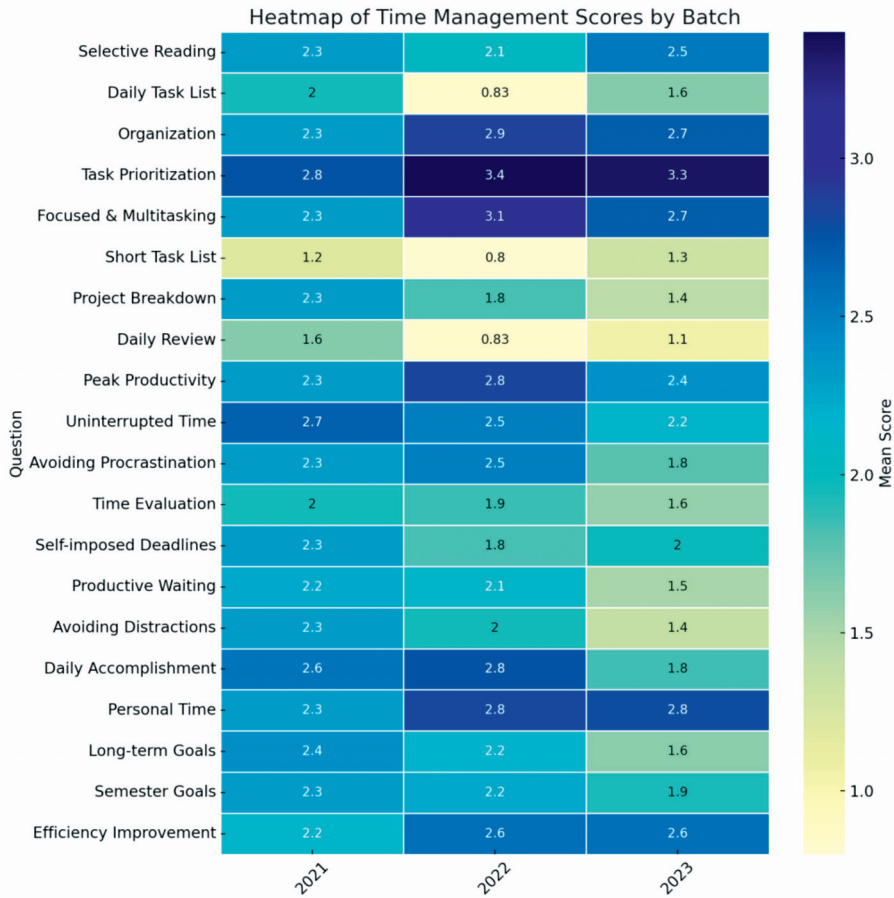


Figure 2. Heatmap of time management scores by batch

alignment, while cooler tones with 2021 indicate moderate divergence.

A one-way ANOVA was conducted to examine whether there were statistically significant differences in time management scores among the three batches across all the selected parameters, and the results are displayed in Table 1. The results indicate that the differences in time management scores across batches are not statistically significant ($p > 0.05$). This suggests that the overall patterns of time management behavior among students remain largely similar over the years.

Although ANOVA showed no significant differences across batches ($F = 0.85$; $p = 0.435$), variations in p-values reveal useful insights. Selective Reading ($p = 0.86$), Task Prioritization ($p = 0.69$), and Peak Productivity ($p = 0.72$) were identified as highly stable behaviors with relatively high p-values, indicating uniformity and reflecting a shared academic culture among students. Project Breakdown ($p = 0.26$), Daily Review ($p = 0.41$), and Time Evaluation ($p = 0.44$) can be considered moderately variable behaviors of students across the three batches, indicating small fluctuations that may respond to targeted interventions. Daily Accomplishment ($p = 0.09$), Personal Time ($p = 0.08$), and Avoiding Distractions ($p = 0.13$) were identified as borderline sensitive behaviors, with p-values approaching significance. Emerging differences in these borderline sensitive areas may become more evident with larger sample sizes or well-designed training interventions. The findings reveal that time management behaviors are largely uniform across cohorts, indicating underlying systemic factors, while minor differences point to specific areas where institutions can intervene effectively.

Paired t-tests were also conducted between the batch-wise scores to further explore pairwise differences, and the results are

Table 1. One-way ANOVA of Time Management Scores Among the Three Batches

Parameter	F-Statistic	p-Value
Selective Reading	0.16	0.86
Daily Task List	2.47	0.15
Organization	0.57	0.58
Task Prioritization	0.39	0.69
Focused & Multitasking	1.04	0.42
Short Task List	1.05	0.42
Project Breakdown	1.67	0.26
Daily Review	1.1	0.41
Peak Productivity	0.34	0.72
Uninterrupted Time	0.78	0.48
Avoiding Procrastination	1.14	0.4
Time Evaluation	1.00	0.44
Self-imposed Deadlines	0.4	0.68
Productive Waiting	1.85	0.23
Avoiding Distractions	2.82	0.13
Daily Accomplishment	3.51	0.09
Personal Time	3.71	0.08
Long-term Goals	2.4	0.15
Semester Goals	0.91	0.46
Efficiency Improvement	1.16	0.39

F-statistic: 0.85; p-value: 0.435, *Significant if $p < 0.05$

Note: These figures are illustrative estimates derived using R; minor rounding differences may apply.

Table 2. Paired t-test between batches

Comparison	t-statistic	p-value
2021 vs 2022	0.32	0.749
2022 vs 2023	1.89	0.075
2021 vs 2023	2.02	0.058

presented in Table 2. None of the paired comparisons showed statistically significant differences (all $p > 0.05$), which is consistent with the ANOVA results. This suggests that regardless of batch, students tend to struggle similarly with time management issues such as inconsistent daily routines, underutilized planning tools, and lack of strategic goal setting.

The Dot-and-Whisker plot in Figure 3 visualizes the mean differences in time management scores between batches along with their 95% confidence intervals. The red vertical line at zero indicates no difference.

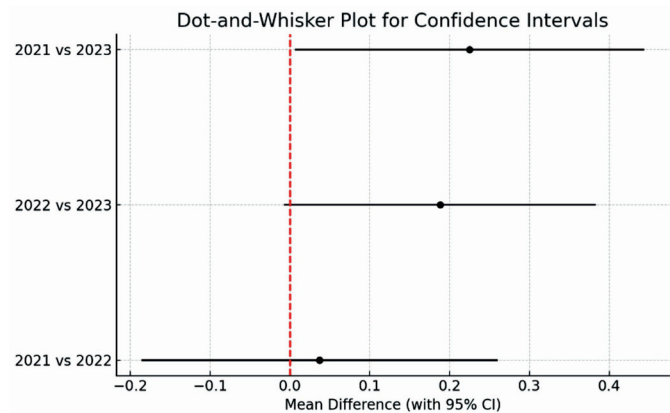


Figure 3. Dot and Whisker plot of time management scores across batches

Since all confidence intervals cross this line, we can conclude that there is no significant mean difference between any pair of batches. These observations reinforce the hypothesis that despite interventions or academic evolution, the fundamental time management behavior among undergraduate students remains similar across years.

DISCUSSION

The declining trend in time management from the 2021 to 2023 batches suggests a reduction in structured behaviors among younger cohorts, possibly reflecting a maturity effect in which students in more advanced stages of their academic programs demonstrate slightly better self-regulation and time use. This supports the developmental model of self-regulation, where time management skills improve with academic progression (Galaviz et al., 2025). The 2021 cohort's stronger performance may reflect their focus on placements or further studies, aligning with Claessens et al. (2007). In contrast, the 2022 and 2023 cohorts, still adjusting academically and socially, appear more prone to distractions and reactive planning, consistent with findings by Steel (2007); Kearns and Gardiner (2007). Students across all cohorts performed well in higher-order skills like Task Prioritization and Personal Time Management, aligning with Zhou et al. (2022), who noted students'

cognitive awareness often exceeds their behavioral follow-through. This “knowing–doing” gap reflects a disconnect between planning and execution. Low scores in micro-level behaviors such as Short Task Listing and Daily Review suggest weak procedural habits, critical for translating goals into action. These findings support Cyril (2014) and Kearns and Gardiner (2007), who emphasized that poor task breakdown and self-monitoring contribute to procrastination and reduced time control.

The heatmap highlighted both consistencies and differences in time management traits across cohorts. Common strengths in prioritization and weaknesses in review-based behaviors suggest systemic skill gaps. This aligns with Nonis and Hudson (2010), who emphasized the need for explicit instruction in time structuring. High Spearman correlation between the 2022 and 2023 batches ($r = 0.818$) indicates stable behavioral patterns, while the 2021 batch showed moderate alignment, possibly due to post-pandemic transitions and increased career focus. These trends, consistent with Tuckman (2002), point to evolving behaviors under academic pressure and highlight the value of visual analytics in educational assessment. The absence of statistically significant differences in time management scores across batches, as confirmed by ANOVA and paired t-tests, indicates a consistent behavioral pattern rather than cohort-specific variation. This suggests that common tendencies such as procrastination, reactive planning, and fragmented attention may be pervasive among students, regardless of academic year. The stability of these patterns may also reflect minimal changes in institutional routines or academic environments during the observed period.

In social science research, statistical non-significance does not mean irrelevance. In behavioural studies like time management, consistent patterns across groups can uncover underlying structural, cultural, or psychological influences. This study’s lack of significant differences in time management scores across batches suggests persistent habits shaped by institutional or generational norms. Recognizing these patterns provides valuable insights into the deeper dynamics of student behavior, moving beyond a solely significance-focused approach. Similarly, Mehler et al. (2019) and Edelsbrunner et al. (2024) in their studies highlighted the importance of non-significant findings in psychology and educational research, respectively.

This study reinforces the hypothesis that fundamental time management behaviors among undergraduate students in agricultural education remain largely unchanged across batches, despite evolving curricula, technological tools, and academic interventions. The observed stability in behavioral patterns is attributed to several interrelated factors. These include developmental traits such as procrastination and inconsistent scheduling common in early academic stages; persistent digital distractions; and static institutional cultures that fail to adapt pedagogical and mentoring approaches. Additionally, peer influence perpetuates informal time-use norms, while the lack of sustained, personalized interventions limits long-term behavioral change. Ambiguous academic demands and minimal variation in student demographics further contribute to the persistence of time management inefficiencies. These findings highlight the need for continuous, context-sensitive strategies and curriculum adaptations to deeply embedded behavioral patterns in

academic settings and meet students’ evolving needs (Yadav & Vatta, 2025). The findings of this study provide insights into the time management behaviors of undergraduate students in an agricultural academic setting. By analyzing behavioral patterns across three academic cohorts, the results not only highlight recurring strengths and weaknesses but also reveal batch-wise variations influenced by academic maturity.

CONCLUSION

Persistent time management inefficiencies among undergraduate students in agricultural education, with no significant differences across batches, indicate systemic behavioral patterns and provide compelling empirical evidence for the urgent need to implement targeted time management interventions within the undergraduate agricultural curriculum. Consistently low scores in short task scheduling, daily review, and task list usage reveal structurally ingrained behavioral gaps across cohorts. These overlooked micro-level inefficiencies can accumulate over time, leading to procrastination, poor planning, academic stress, and reduced long-term career readiness. Strategic training in time blocking, goal breakdown, and self-monitoring has been shown to reduce procrastination and improve student effectiveness. Embedding time management modules early in the curriculum, through short courses, project-based learning, digital tools, and peer mentorship, can promote proactive self-regulation with lasting academic and professional benefits. Faculty-led mentoring, supportive learning environments, and regular monitoring of task prioritization and workload can further strengthen students’ time management behaviors and reduce procrastination tendencies.

DECLARATIONS

Ethics approval and informed consent: The research was conducted in accordance with institutional guidelines and approved by all the authors. Ethical approval was obtained from all the participants, and informed consent was obtained from all participants before the study commenced.

Conflict of interest: The authors declare that there are no conflicts of interest in conducting this research study. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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.

Authors’ contribution: This work was carried out in collaboration between all the authors. Authors 1 and 2 collected the data, and Authors 3 and 4 performed the statistical analysis. The study was conceptualized, tabulated, interpreted, and the final draft of the manuscript was prepared by Authors 5, 6, and 7. All authors read and approved the final manuscript.

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

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Communication and Marketing Behaviour of Tomato Growers in Southern Odisha, India

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HIGHLIGHTS

- Mobile phones and TV were the most used agricultural information; newspapers, radio, and extension publications were rarely used.
- Over half of the respondents showed medium planning and marketing; education, farm size, and extension contact positively influenced performance.
- Strengthening digital extension services and providing marketing training can enhance decision-making and profitability for tomato growers.

ARTICLE INFO

Keywords: Communication behaviour, Marketing behaviour, Mass media, Digital extension, Extension services.

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ABSTRACT

The study investigated the communication and marketing behaviour of tomato growers in southern Odisha during the 2023–24 cropping season. The study employed a multi-stage random sampling technique to select 120 farmers from twelve villages in Gajapati and Rayagada districts. Data were collected using a structured interview schedule, focusing on mass media exposure, information seeking, information sharing, planning, decision making, and post-marketing review. Descriptive statistics, Pearson's correlation and multiple regression analyses were used to analyse the data. The results revealed that 55.8 per cent of growers had medium planning ability and 64.2 per cent displayed medium overall marketing behaviour. Mobile phones and television were always used by about three-quarters of respondents, while newspapers, radio, farm magazines and extension publications were seldom consulted. Extension officials and local leaders were important but infrequently contacted sources of information. Positive correlations were found between communication behaviour and marketing behaviour, and variables such as education, farm size and participation in extension activities significantly influenced both. Enhancing digital extension services, improving farmer training on market planning and expanding market infrastructure could substantially improve tomato growers' decision-making and profitability.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is among the world's most important vegetable crops, widely cultivated for its nutritional value and economic significance (Kumar et al., 2020). India ranks second in tomato production, yet productivity remains below the world average due to myriad constraints, including limited access to quality

seed, inadequate market infrastructure, high post-harvest losses and insufficient extension support (Emana et al., 2017). Southern Odisha, comprising districts like Gajapati and Rayagada, has favourable agro climatic conditions for tomato cultivation, but farmers often face low yields and poor market realisation (Kumar, 2024). One critical factor influencing the adoption of improved technologies and market participation is farmers' communication

behaviour—how they seek, process and disseminate information (Anamika et al., 2024). Against this backdrop of favourable conditions but suboptimal outcomes in South Odisha, understanding how farmers communicate and market becomes pivotal. These behavioural dimensions often determine whether improved technologies are noticed, trusted, adopted, and translated into better prices.

Communication behaviour encompasses information input, processing and output. Effective communication enables farmers to access technical knowledge, perceive innovations accurately, and make informed decisions about management practices. Likewise, marketing behaviour refers to the planning, decision making, implementation and post marketing review associated with producing, packaging and selling agricultural products. According to Kotler and Armstrong (2010), marketing involves a social and managerial process through which individuals and groups obtain what they need and want by creating and exchanging products and value. These marketing behaviour can be mapped (Gupta et al., 2021). When farmers possess strong communication skills and sound marketing strategies, they are better positioned to adopt new technologies, access markets efficiently and secure higher returns (Chandra et al., 2023).

Previous research has underscored the importance of communication and marketing behaviours in agricultural development. Leagans (1961) defined behaviour as a composite of knowledge, mental and physical abilities and attitudes. Kumar and Mishra (2018) emphasised that farmers' communication behaviour is shaped by their exposure to mass media, interpersonal channels and extension systems. Sonare et al. (2020) highlighted how the adoption of improved tomato varieties and technologies narrows productivity gaps. Studies have found that marketing behaviour among vegetable growers is influenced by market access, infrastructure, and information availability (Samajder et al., 2016; Kowsalya et al., 2021). However, there is limited empirical evidence about how tomato growers in southern Odisha use communication channels and plan their marketing activities. Such knowledge is vital for designing effective extension programmes and market interventions (Godara et al., 2024a; Godara et al., 2024b).

The present study aimed at assessing the communication and marketing behaviour of tomato growers in selected districts of southern Odisha with specific objectives to identify the mass media and interpersonal channels used by farmers to obtain agricultural information; examine their information seeking and information sharing behaviour; assess their planning, decision making and post marketing practices; and determine the relationship between communication behaviour and marketing behaviour, including factors that influence these behaviours. Insights from this study will help extension workers and policymakers tailor interventions that strengthen communication networks, enhance marketing skills, and ultimately boost tomato productivity and profitability in the region.

METHODOLOGY

The study was conducted in Gajapati and Rayagada districts of Odisha during the 2023–24 cropping season. These districts were purposively selected due to their prominence in tomato cultivation and their representative agro-ecological conditions. From each

district, three blocks with substantial tomato production were identified in consultation with local agricultural officers. Two villages were randomly selected from each block, resulting in a total of 12 villages. A list of tomato growers was obtained from village leaders, from which 10 respondents per village were randomly chosen. This multistage random sampling yielded a total sample size of 120 farmers, deemed sufficient for meaningful analysis.

Primary data were collected through personal interviews using a structured and pre-tested schedule. The communication behaviour of respondents was measured based on three key dimensions. The first dimension, mass media exposure, captured the frequency of using newspapers, farm magazines, radio, television, and mobile or internet platforms to access agricultural information. Respondents rated their frequency of use as “always,” “sometimes,” or “never.” The second dimension, information-seeking behaviour, assessed how often farmers consulted extension agents, block development officers, agricultural assistants, various media, and peer networks to obtain agricultural advice. The third dimension, information-sharing behaviour, examined the extent to which farmers shared agricultural knowledge and experiences with fellow farmers, relatives, neighbours, and members of farmer groups (Billah et al., 2024).

Marketing behaviour was evaluated across four dimensions. The planning component involved actions such as setting production goals, selecting tomato varieties, estimating input needs, and budgeting resources. The decision-making component included selecting appropriate sowing dates, cultivation practices, input combinations, marketing channels, and pricing strategies. Implementation behaviour focused on the actual execution of planned activities, including input procurement, crop management, harvesting, grading, packaging, and transportation. The post-marketing review dimension involved assessing marketing outcomes, calculating profit margins, obtaining feedback from buyers, and drawing lessons for future seasons (Rhamya, 2024). Each component was measured using a three-point response scale and scored accordingly. Composite indices were developed for both communication and marketing behaviours by summing relevant item scores and converting them into percentage values.

Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise communication and marketing behaviour levels among respondents. Pearson's correlation coefficients were computed to assess relationships between different communication behaviour components and marketing performance. Multiple regression analysis was employed to identify socio-economic variables that significantly influenced both communication and marketing behaviours. All data were analysed using SPSS version 23.0.

RESULTS

Mass media plays a vital role in transmitting agricultural information. Table 1 presents the distribution of respondents based on their use of different media. Approximately 81 per cent of farmers reported always using mobile phones/internet for agricultural information, and 72 per cent reported always watching television. These media were preferred for their accessibility, visual appeal and real-time updates. In contrast, only 31.7 per cent of

Table 1. Distribution of the respondents based on Mass Media Exposure

Mass Media	Extent of Use (%)		
	Always	Sometimes	Never
Newspaper	31.67	46.67	21.67
Farm magazines	0.00	30.83	69.17
Extension publication	0.00	24.17	75.83
Radio	0.00	30.00	70.00
Television	71.67	22.50	5.83
Internet / Mobile	80.83	14.17	5.00

respondents regularly read newspapers, and none reported always reading farm magazines or extension publications. Radio usage was negligible. The dominance of digital media reflects the rapid expansion of mobile networks and affordable smartphones in rural Odisha. The minimal use of extension publications indicates a gap in the dissemination of formal research outputs to farmers.

Farmers seek information from various sources depending on availability, accessibility and perceived usefulness. A notable pattern is the reliance on personal cosmopolite sources such as extension officers, block development officers and agricultural assistants. For instance, Table 2 shows that 50.8 per cent of farmers sometimes consulted agricultural extension officers, 42.5 per cent sometimes consulted block development officers, and 31.7 per cent sometimes sought advice from agricultural assistants. Very few farmers always consulted these officials (11.7%, 6.7%, and 11.7%, respectively), and a significant proportion never consulted them (37.5%, 50.8%, and 56.7%, respectively). These findings suggest that although extension personnel are recognised as credible sources, their interaction with farmers is sporadic. Reasons may include limited field staff, heavy workloads or farmers' perception that extension services focus more on crop production than marketing.

Mass media sources were also used for information seeking. About 19.2 per cent of farmers always consulted newspapers, 9.7

Table 2. Distribution of respondents based on information-seeking behaviour

Information Sources	Extent of Use (%)		
	Always	Sometimes	Never
<i>Personal cosmopolite</i>			
Agri. Ext. Officer	11.67	50.83	37.50
Block Dev. Officer	6.67	42.50	50.83
Agri. Assistant	11.67	31.67	56.67
<i>Mass Media</i>			
Newspaper	19.17	53.33	27.50
Radio	9.67	71.67	19.17
T.V.	74.17	22.50	3.33
Kisan Call Centre	4.17	66.67	29.17
Internet	35.00	45.00	20.00
<i>Participation in Extension Activities</i>			
Meetings	26.67	71.67	1.67
Demonstration	0.83	25.83	73.33
Field Visit	8.33	57.50	34.17
Farmers' Rally	0.00	9.17	90.83
Agri. Campaign	0.00	5.00	95.00
Workshops	0.00	3.33	96.67

per cent always listened to the radio, and 74.2 per cent always watched television programmes related to agriculture. Newspapers and radio were more commonly used sometimes or never, indicating that they serve as supplementary channels rather than primary sources. Digital media, particularly mobile-based applications and social media groups, were increasingly used to access weather forecasts, market prices, pest management tips and government schemes (Table 2).

Interpersonal communication, especially discussions with fellow farmers, input dealers and village leaders, remained an important channel. Focus group discussions revealed that farmers trusted information obtained from experienced peers and community elders. These interpersonal networks often shaped decisions about varieties to plant, input purchasing and market timing. Extension agencies can leverage these networks by training lead farmers as paraprofessionals to disseminate information.

Information sharing among farmers promotes collective learning and adoption of best practices. Table 3 presents the extent of sharing among respondents. Approximately 48 per cent of respondents reported always sharing information about cultivation techniques with neighbours and relatives, 36 per cent sometimes shared, and 16 per cent never shared. Sharing was more prevalent among farmers who were members of self-help groups or farmer-producer organisations (FPOs), suggesting that group membership fosters the exchange of knowledge. Farmers who attended training programmes were more likely to share information, perhaps because they valued the benefits of collective learning. Some respondents were reluctant to share information due to fear of competition or time constraints. Extension programmes should encourage participatory learning and create platforms where farmers regularly exchange experiences.

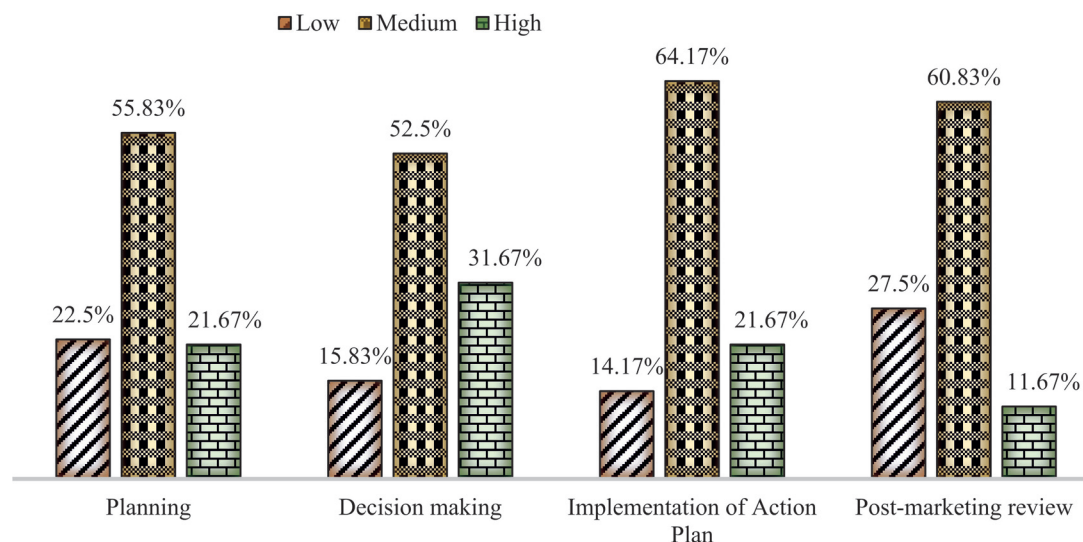
Table 3. Distribution of respondents based on information-sharing behaviour

Information Sources	Extent of Use (%)		
	Always	Sometimes	Never
Friends	35.00	49.17	15.83
Neighbours	14.17	45.83	40.00
Relatives	9.17	42.50	48.33
Progressive Farmers	22.50	48.33	29.17
Local Leaders	6.67	44.17	49.17

Planning involves setting objectives and allocating resources. Analysis of planning scores revealed that 55.8 per cent of farmers exhibited medium planning ability, 22.5 per cent had low planning and 21.7 per cent high planning (Figure 1). Medium planners generally prepared a planting schedule, identified suitable varieties and estimated input requirements, but did not prepare detailed budgets or risk mitigation plans. High planners performed comprehensive planning, including financial budgeting, yield estimation and risk management, whereas low planners made ad hoc decisions without systematic preparation.

Education level, farm size and training participation were positively associated with planning scores ($p < 0.05$). Farmers with secondary education or above and larger landholdings tended to plan better, possibly because they had more resources and knowledge. Participation in training programmes was also linked to higher

Figure 1. Distribution of the respondents based on stages of marketing behaviour



planning scores, suggesting that training equips farmers with planning skills. Regression analysis identified education ($\beta = 0.31$), farm size ($\beta = 0.24$) and extension contact ($\beta = 0.19$) as significant predictors of planning behaviour.

About 58 per cent of respondents belonged to the medium decision-making category, 24 per cent fell into the low category and 18 per cent into the high category (Figure 1). Medium decision makers considered several factors, such as soil fertility, availability of family labour, market price trends and input costs, but often lacked comprehensive information on improved practices. High decision makers sought multiple sources, compared information and consulted extension agents before deciding on variety selection, planting time, spacing, fertiliser doses and pest management. Low decision makers relied mainly on traditional practices and instinct.

Table 4 reveals that information seeking had a strong positive correlation with decision-making behaviour ($r = 0.62$, $p < 0.01$). Regression results showed that education ($\beta = 0.28$), extension contact ($\beta = 0.26$), training ($\beta = 0.23$) and farm size ($\beta = 0.21$) significantly influenced decision making (Table 5).

Implementation scores indicated that 60% of farmers were in the medium category, 23% in the low category and 17% in the high category (Figure 1). Medium performers carried out most of their planned operations but faced challenges in pest management, timely harvesting and quality grading due to labour shortages or resource constraints. Implementation behaviour was positively correlated with planning ($r = 0.55$) and decision making ($r = 0.59$) ($p < 0.01$). Regression analysis identified planning score ($\beta = 0.33$), decision score ($\beta = 0.29$), education ($\beta = 0.21$) and training ($\beta = 0.18$) as significant determinants of implementation (Tables 4 and 5).

Only 45 per cent of farmers always conducted a post marketing review, while 35 per cent did so sometimes and 20 per cent never. Regression analysis indicated that education ($\beta = 0.27$), extension contact ($\beta = 0.22$) and training ($\beta = 0.25$) significantly influenced post-marketing review behaviour. Determinants of marketing behaviour included communication behaviour, education, farm size and training. Regression analysis confirmed these relationships, aligning with Table 5. Table 4 shows significant positive relationships between each dimension of communication behaviour

Table 4. Pearson correlation coefficient analysis of the independent variable with the communication and marketing behaviour

Independent Variables	Communication behaviour (r)	Marketing behaviour (r)
Age	0.625**	0.241**
Education	0.423**	-0.181*
Family Size	0.030 ^{NS}	0.304**
Social Participation	0.631**	0.362**
Total Agricultural Land Holding	0.262**	0.146 ^{NS}
Area Under Tomato Cultivation	0.144 ^{NS}	0.338**
Secondary Occupation	0.233*	0.219*
Annual Income	0.377**	0.662**
Farming Experience	0.726**	0.758**
Training Exposure	0.701**	0.200*
Socio-Economic Status	0.263**	0.159 ^{NS}
Economic Motivation	0.460**	0.648**
Innovativeness	0.351**	0.363**
Risk Preference	0.059 ^{NS}	0.295**
Market Orientation	0.241**	0.756**

** Significant at 0.01 level, * Significant at 0.05 level, NS: Non-significant

and marketing behaviour. Multiple regression results confirmed that communication behaviour was a significant predictor of marketing behaviour, explaining 32 per cent of the variance. This underscores the critical role of communication channels in shaping marketing decisions.

DISCUSSION

The dominance of mobile phones and television in information access, as per the results of the study, highlights the growing importance of digital extension services in rural areas. Farmers use mobile-based platforms to access weather forecasts, pest advisories, market prices and government scheme updates. Smartphones enable farmers to join social media groups where they exchange experiences, ask questions and receive timely feedback from extension agents and agribusiness companies (Das et al., 2025). The high penetration of television and mobile phones suggests that extension agencies should produce more agriculture-related programmes and develop

Table 5. Linear multiple regression analysis of independent variables with the communication and marketing behaviour

Independent Variables	Coefficients of multiple regression			
	Communication behaviour		Marketing behaviour	
	'b' Values	't' Values	'b' Values	't' Values
Age	0.459	3.884	-0.017	-0.217
Education	0.200	4.271	-0.079	-1.893
Family Size	-0.084	-0.813	0.012	0.128
Social Participation	0.337	5.253	-0.029	-0.702
Total Agricultural Land Holding	0.111	0.864	-0.016	-0.165
Area Under Tomato Cultivation	-0.161	-1.316	0.176	1.900
Secondary Occupation	0.033	0.384	0.004	0.059
Annual Income	-0.093	-1.201	0.317	4.606
Farming Experience	0.621	4.589	0.305	2.564
Training Exposure	0.320	2.713	-0.004	-0.051
Socio-Economic Status	0.012	2.503	0.002	0.617
Economic Motivation	0.058	1.560	0.076	2.491
Innovativeness	0.172	2.644	0.126	2.505
Risk Preference	-0.031	-1.032	0.036	1.518
Market Orientation	0.031	0.763	0.119	3.359
R ² = 0.829		R ² = 0.783		
Adjusted R ² = 0.804		Adjusted R ² = 0.752		

mobile applications tailored to farmers' needs (Mapiye et al., 2023; Lahiri et al., 2024). These digital tools can complement traditional face-to-face extension, particularly in areas where extension staff are scarce.

The low use of newspapers, farm magazines and extension publications in the study area suggests that printed media are either inaccessible or perceived as less relevant. Farmers may find printed materials too technical or may lack literacy skills to interpret them. Ensuring that printed materials are written in local languages, use simple language and include visual aids could increase their utilisation (Lahiri & Mukhopadhyay, 2013; Singh et al., 2014). Alternatively, extension services can focus on audio visual media and participatory approaches where farmers learn by doing (Raina et al., 2011; Das et al., 2014; Kumari et al., 2024). The sporadic consultation of extension officers underscores the need to strengthen public extension systems. Inadequate staffing, insufficient mobility and competing responsibilities often limit extension officers' field visits (Saha et al., 2024). Improving the extension workforce, providing incentives for fieldwork and using ICT tools could enhance interaction (Nirmalkar et al., 2022). Encouraging private and community-based extension can also widen the outreach.

This study shows that farmers' medium level of planning behaviour suggests room for improvement. Many rely on experience rather than formal planning. To enhance planning, extension agencies should train farmers in basic business skills, such as budgeting, cost-benefit analysis and risk management. Farmer field schools and participatory rural appraisal techniques can help farmers plan collectively (Nolan et al., 2024). Financial institutions and government programmes offering credit and insurance can support farmers in planning for inputs and mitigating risks. Decision-making behaviour was influenced by education and information. Educated farmers with regular access to information were more confident and systematic in making production and marketing decisions (Raghavendra et al., 2023). Tailored training that integrates technical

knowledge with decision support tools can improve farmers' decision-making skills. Peer-to-peer learning and mentoring programmes may also enhance confidence (Shil et al., 2022).

The medium level of implementation and post-marketing review points to challenges in translating plans into action and evaluating outcomes (Vanacharla et al., 2024). Labour shortages during peak periods, limited access to quality inputs and a lack of storage and grading facilities hamper effective implementation. Strengthening supply chains for inputs, promoting mechanisation and establishing community storage and grading centres can help farmers implement their plans effectively (Sims & Kienzle, 2017). Market inaccessibility and lack of training among the top constraints and urges capacity building and better market access, aligning with your infrastructural remedies (Suman et al., 2025). Encouraging record keeping and developing simple tools for profit calculation and market analysis can improve post-marketing review behaviour.

The positive relationship between communication and marketing behaviour, as found in this study, implies that improving communication channels could enhance marketing outcomes. When farmers access diverse information sources and share experiences, they are more likely to adopt best practices, identify profitable markets and negotiate better prices. Extension services should therefore emphasise interactive communication methods, such as farmer discussion groups, on-farm demonstrations and learning videos, to facilitate knowledge exchange. Policy initiatives that invest in rural internet infrastructure, promote farmer organisations and integrate ICTs into extension programmes will enable farmers to make informed marketing decisions.

CONCLUSION

This study explored the communication and marketing behaviour of tomato growers in southern Odisha. Most farmers exhibited medium levels of planning and marketing, and digital media

were the primary sources of agricultural information. Low engagement with extension publications and sporadic contact with extension officers point to gaps in formal information dissemination. Education, farm size, training and extension contact significantly influenced both communication and marketing behaviours. The positive association between communication and marketing underscores the need for effective communication strategies to enhance marketing performance. Policymakers and extension agencies should focus on strengthening digital extension services, providing managerial and marketing training, promoting farmer organisations and improving market infrastructure. These measures will improve farmers' access to timely information, enable better planning and decision making and ultimately increase the productivity and profitability of tomato cultivation in Odisha.

DECLARATIONS

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

Conflict of interest: The author declares that there is no conflict of interest related to the publication of this article. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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.

Data Availability Statement: The data that support the findings of this study are available upon reasonable request.

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Modelling Livelihood Security of Tribal Farmers in South Odisha using Machine Learning

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HIGHLIGHTS

- Livelihood security declines with age, with a sharper drop among older farmers.
- Strong self-confidence markedly elevates livelihood security across farmer profiles.
- Better farm management practices boost security and cushion age-related disadvantages.
- Innovative tendency helps, but less than self-confidence and management.

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ABSTRACT

Tribal farming systems ensure livelihood security through complex socio-economic and behavioural interactions that defy simple linear models. The study analysed primary data collected through simple random sampling method from 180 households in Gajapati and Rayagada districts of Odisha during 2023-24 to analyse the Livelihood Security score using a Random Forest regression. Out-of-bag validation demonstrated model stability with an R^2 of approximately 0.865 using around 400 trees. The age was the most significant predictor, followed by self-confidence, with smaller contributions from management orientation and innovative proneness. One- and two-dimensional partial dependence outcomes highlighted non-linear age effects and interactions, indicating that increased confidence and enhanced management capacity improve predicted livelihood security across all age groups. These results suggest actionable strategies for agricultural extension: implementing confidence-building and management training tailored to life-stage constraints could yield substantial benefits. Limitations include the correlational nature of the data and the reliance on partial dependence.

INTRODUCTION

One of the key issues that tribal farming families face in the eastern hill and forest ecosystems of India is livelihood security. This challenge is exacerbated by factors such as rain-fed agriculture, fragmented and uneven land tenure, and limited access to markets. In South Odisha, the situation is further complicated by hilly terrain, inadequate irrigation facilities, high transaction costs for inputs and outputs, and commodity price volatility (Das et al., 2025). Households also encounter environmental threats like erratic

rainfall, dry spells, and degraded commons, which interact with social limitations such as lack of information, limited extension services, and insufficient credit (Kumari et al., 2024). Livelihood security is not determined by a single factor. Instead, it results from the combined arrangement of household resources, human capital, and behavioural-psychological motivations that influence the adoption of better practices and the ability to cope with shocks (Pal et al., 2017; Suman et al., 2025).

Traditional empirical methods have helped identify correlations between welfare and technology adoption in smallholder contexts.

These methods often assume linearity and additivity, which limits their ability to capture the threshold effects and interactions present in actual farming systems. The impact of an additional unit of land or income can vary significantly depending on a household's managerial capacity or confidence. The benefits of information from mass media can differ based on education levels or age-related preferences. These non-linearities and interactions are particularly significant in tribal areas, where livelihood strategies are diverse and context-dependent (Kerketa et al., 2025). There is a strong case for using analytical tools that can flexibly approximate complex response surfaces while remaining transparent enough to guide extension programming (Prusty et al., 2025). Most Odisha-focused livelihood security studies are macro/district-level and descriptive rather than household-level with predictor modelling (Pani & Mishra, 2022). While machine learning is widely used in agriculture, applications to household livelihood security and especially those using interpretable ML remain scarce (Ryo, 2022). Interpretable-ML works demonstrate context-dependent thresholds and interactions in rural systems, yet the studies are rarely leveraged to reveal capital access complementarities in tribal livelihood security (Rana et al., 2024).

This research employs a Random Forest (RF) modelling framework to investigate the factors that influence Livelihood Security scores among tribal farmers in South Odisha. RF is particularly suited for this analysis as it can handle mixed data types, model non-linear relationships and interaction effects without requiring predefined functional forms, and offers built-in validation and training-set evaluation (Breiman, 2001). To enhance the RF model beyond mere prediction and support decision-making, the integration of Permutation Feature Importance, Shapley Additive Explanations (SHAP), and Partial Dependence/Individual Conditional Expectation (ICE) plots, including two-dimensional surfaces, is used to visualise important interactions (Goldstein et al., 2015). This interpretability suite allows to elucidate not only which factors are significant but also how they influence livelihood security across the observed range (Lundberg & Lee, 2017).

The study enhances household-level analysis of livelihood security in the tribal context by modelling the livelihood security score using Random Forest regression evaluated on a held-out test set. It provides interpretable evidence on the relative influence, direction, & non-linear thresholds of capital, utilising SHAP & ICE.

METHODOLOGY

The study employed a correlational design to model the determinants of Livelihood Security among tribal farming families in South Odisha during 2023-24. Primary data were collected following simple random sampling through a structured interview schedule administered to 180 households of Gajapati and Rayagada districts of Odisha. The interview schedule assessed socio-demographic, resource, and psycho-behavioural variables commonly utilised in agricultural extension research, including age, education, family size, livestock possession, landholding, farming system practised, annual income, social participation, mass media utilisation, self-confidence, innovative proneness, economic motivation, scientific orientation, and management orientation. The dependent variable was the composite Livelihood Security.

Standard reproducible steps were followed in data preparation. Continuous variables were checked for outliers and converted into numeric categorical variables using one-hot encoding. Records lacking values in analysis fields were removed through listwise deletion, resulting in a stable modelling sample. The dataset was randomly split into a training set (80%) and a test set (20%) with a fixed seed to ensure replicability.

A Random Forest (RF) regressor was chosen as the primary predictive model due to its capability to capture non-linearities and higher-order interactions without stringent parametric assumptions. Hyperparameters were configured to a medium tree size (300-400) using out-of-bag (OOB) R^2 stabilisation, with bootstrap sampling enabled. The performance on the held-out test set was reported using R^2 and RMSE to estimate generalisation.

To numerically assess the relative importance of predictors, the Permutation Feature Importance was calculated using the test data. For local-to-global interpretability, SHAP was used to summarise the direction and magnitude of individual features' effects on households. To visualise marginal responses and potential interactions, Partial Dependence (PDP) plots and Individual Conditional Expectation (ICE) graphs were created for key predictors, as well as two-dimensional PDP surfaces for selected pairs. A one-way ANOVA, accompanied by Levene's test for homogeneity of variance, was utilised to examine categorical variables against Livelihood Security where appropriate (Levene, 1960). Analyses were conducted using Python, with scikit-learn for training RFs and calculating permutation importance; shap for generating SHAP visualisations; matplotlib for visualisation; and stats models/ scipy for inferential tests.

RESULTS

The Random Forest model effectively reproduces the observed Livelihood Security scores in the held-out training set (Figure 1). The data points were closely clustered around the 1:1 line throughout the observed range, indicating that the model was well-calibrated and not simply a tracking model. The gradient of the cloud of points relative to the 45-degree line suggests minimal systematic bias; households in both high and middle ranges were neither consistently over- nor under-predicted. A small number of points at the upper end did not deviate from the diagonal, indicating

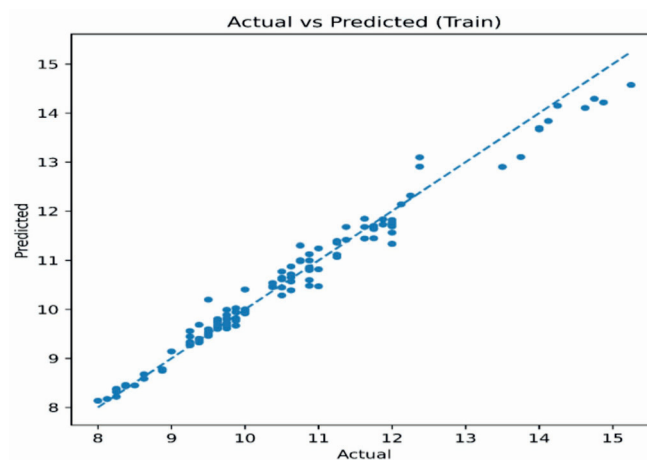


Figure 1. Training-set Actual vs Predicted for Livelihood Security

some shrinkage at the extremes. The spread of points did not significantly increase with higher scores, aligning with an approximation of homoscedastic errors in the training data. These findings demonstrated that the model provides precise and consistent forecasts of livelihood security for tribal agricultural families in South Odisha, characterised by a smaller error magnitude (RMSE) and mostly non-systematic errors.

The generalisation performance of the Random Forest improved with the size of the ensemble, eventually levelling off during out-of-bag (OOB) validation (Figure 2). The model's out-of-sample performance was tested, yielding an RMSE of 0.2264. The OOB R^2 exhibited a slight decrease from 0.8164 at 50 trees to 0.8159 at 100 trees, then recovered to 0.8171 at 150 trees and rose sharply to 0.8241 at 200 trees, then recovered to 0.8171 at 150 trees and rose sharply to 0.8241 at 200. Performance continued to improve, reaching 0.8263 at 300 trees, 0.8284 at 400 trees, and 0.8295 at 600 trees. The incremental gain beyond 300 trees was less than 0.0033, and beyond 400 trees was less than 0.0012, indicating a practical plateau around 300–400 trees. Therefore, $n_estimators = 400$ was adopted for subsequent analyses. Thus, the OOB curve indicated that ensemble sizes of approximately 300–400 trees were sufficient for optimal generalisation, and larger forests did not provide significant additional value for this dataset.

The permutation analysis of the training data ranked predictors based on the mean change in predictive score resulting from

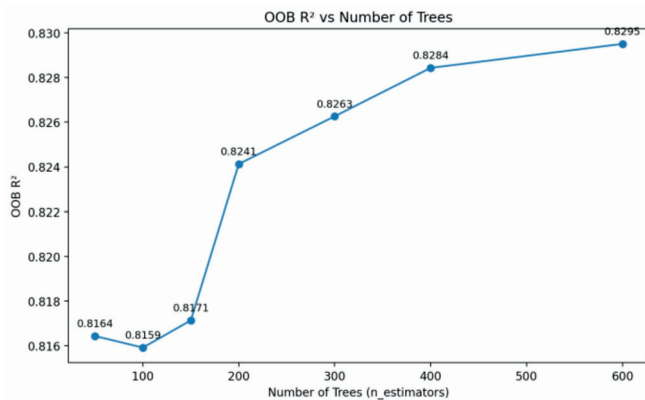
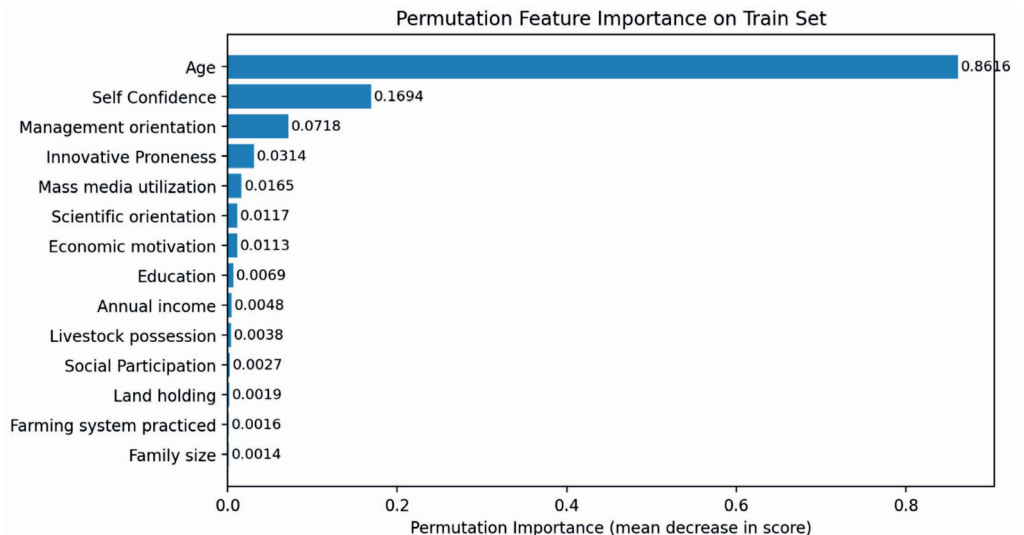


Figure 2. Out-of-bag (OOB) R^2 versus Number of Trees in the Random Forest

Figure 3. Permutation Feature Importance on the Training Set



permuting each variable, with the precise values displayed at the ends of the bars (Figure 3). The most significant predictor was age, with a value of 0.8616, followed by self-confidence at 0.1694. The second tier included management orientation (0.0718) and innovative proneness (0.0314). The next set of predictors showed relatively minor contributions: mass media utilisation (0.0165), scientific orientation (0.0117), economic motivation (0.0113), and education (0.0069). On the left side of the distribution, predictors with values below 0.005 included annual income (0.0048), livestock possession (0.0038), social participation (0.0027), land holding (0.0019), farming system practised (0.0016), and family size (0.0014). The bars illustrated a steep gradient, with age (0.8616) nearly five times more influential than self-confidence (0.1694) and over an order of magnitude greater than any other predictors below 0.07. This distribution featured a long tail of small values and no negative bars, as shown in the figure, with a strict descending order. These values represented the perturbation-based significance of each predictor in the training set, clearly visualised.

The SHAP beeswarm plot ranks features by their overall impact in descending order, as illustrated in Figure 4. Age ranked highest, followed by Self Confidence, Management Orientation, and Innovative Proneness, with the remaining predictors following in decreasing order. Age exhibited the widest spread of points on the horizontal axis, indicating the most extensive contribution range among all features. Self Confidence had the next widest spread, while the other features displayed narrower distributions. In terms of directionality, more Age values (red points) were located on the negative side of the SHAP axis (left of zero), whereas more Self Confidence values (red points) appeared on the positive side (right of zero). Management Orientation and Innovative Proneness had smaller clusters of points compared to the top features, but some noticeable positive shifts were observed at higher values. Features lower in the ranking showed narrow clusters around the zero value, which was expected for variables that contribute less compared to the top predictors. All observations in the figure were based on the held-out model, with colour encoding (blue = low, red = high) representing the value of each feature, and horizontal positioning reflecting the signed SHAP value (negative = decrease in predicted Livelihood Security; positive = increase), as visually represented.

Figure 4. SHAP Summary (Beeswarm) for the Random Forest Model



The marginal responses of the model were clearly defined and supported by data (represented by rugs on the x-axes) across the one-dimensional partial-dependence profiles with ICE overlays. In Figure 5a (Age), the average curve displayed a non-linear, stepped decline: it remained relatively flat until the late 30s/early 40s, then dropped sharply in the early to mid-40s, and decreased again around age 60, after which it stabilised at a lower level. The ICE lines clustered closely around the mean curve, indicating that this pattern was consistent across households. Figure 5b (Self Confidence) showed a monotonically increasing average partial dependence throughout the relevant range, with a noticeable uplift in the curve during the mid-teens. The ICE lines exhibited a parallel upward shift, suggesting consistent gains among respondents within the supported range. In Figure 5c (Management Orientation), the average curve was slightly elevated across the observed scores, with minor variations between ICE profiles. So the shift along the management orientation scale was positive but subtle.

Figure 6a (Age x Management Orientation) illustrates that the surface decreases with age across nearly all levels of management orientation. An increase in management orientation raises the surface for a given age. The highest labelled contours are observed at younger ages, with values ranging from 11.82 to 11.24 in the late 30s to early 40s, declining to 10.66 to 10.08 in the mid-40s to 50s, and further dropping to 9.50 by the late 60s to 70s. The iso-lines in this panel are nearly vertical, indicating that age primarily drives the gradient, while the management orientation elevates the overall level without altering the age trend. Figure 6b (Age x Self Confidence)

shows that higher self-confidence correlates with a higher surface at a given age, with younger ages yielding elevated projected values. The highest values are found in the upper-left quadrant (younger age, high confidence), with figures of 13.27, 12.50, and 11.74. These values decrease to a range of 10.98 to 10.21 in the early to mid-40s and approach 9.45 by age 60. The tilted contours reflect the additive contributions of both variables, showing the highest predictions in the high-self-confidence/low-age group and the lowest in the low-self-confidence/high-age group. In Figure 6c (Self Confidence x Management Orientation), the surface exhibits a higher magnitude on both axes, which are relatively low in the bottom-left corner. The magnitude of the predictions increases with either predictor. The middle range is concentrated between 10.45 and 11.01, while the upper right reaches 11.29. The iso-lines are approximately diagonal, indicating that changes in either self-confidence or management orientation lead to similar improvements. A combination of both factors results in the highest predicted scores within the observed ranges.

DISCUSSION

The Random Forest approach effectively described livelihood security among tribal farming households in South Odisha. The performance on the held-out training set was exceptionally high, confirming that the variation in the livelihood security score was accurately captured. The results align with the Sustainable Livelihoods Framework, where households combine human (education, self-confidence, management orientation), social (group

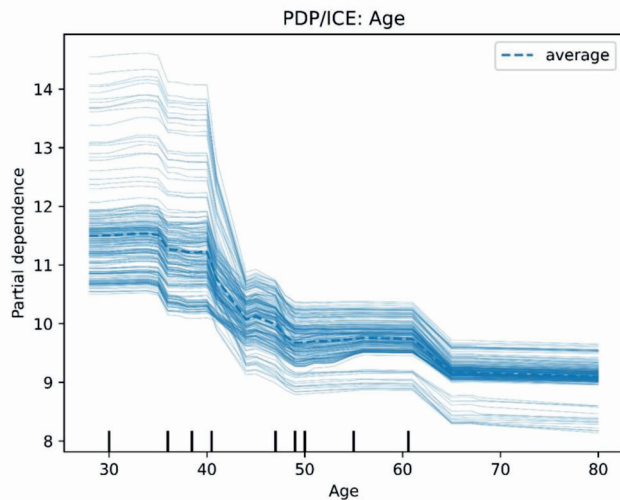


Figure 5a. Partial Dependence with Individual Conditional Expectation Plot for Age

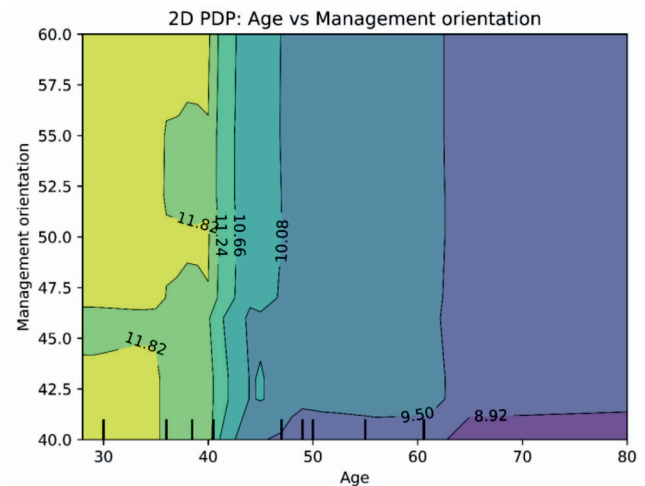


Figure 6a. Two-Dimensional Partial Dependence of Livelihood Security: Age × Management Orientation

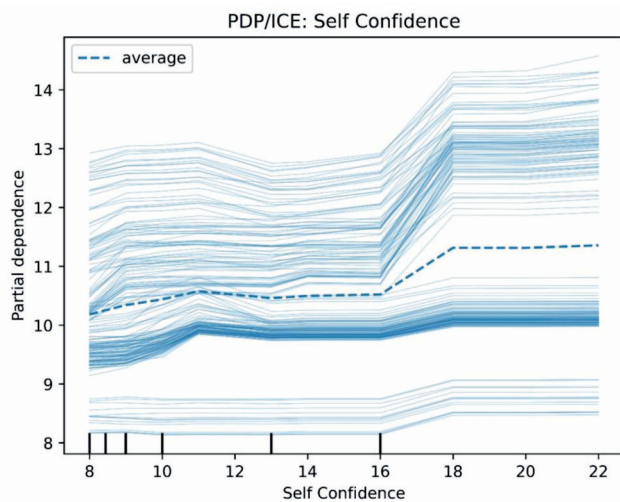


Figure 5b. Partial Dependence with Individual Conditional Expectation Plot for Self Confidence



Figure 6b. Two-Dimensional Partial Dependence of Livelihood Security: Age × Self Confidence

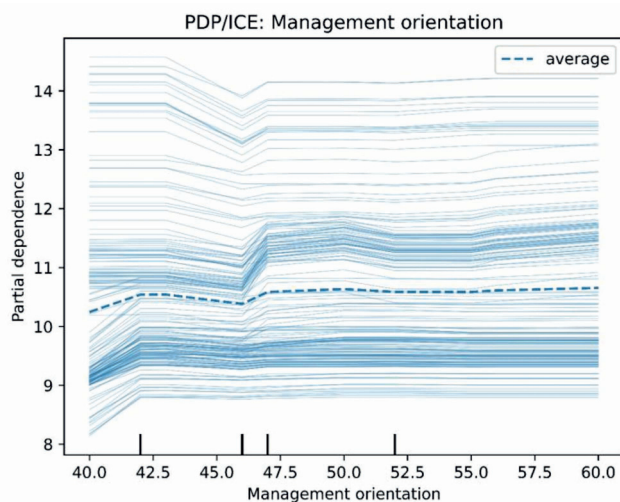


Figure 5c. Partial Dependence with Individual Conditional Expectation Plot for Management Orientation

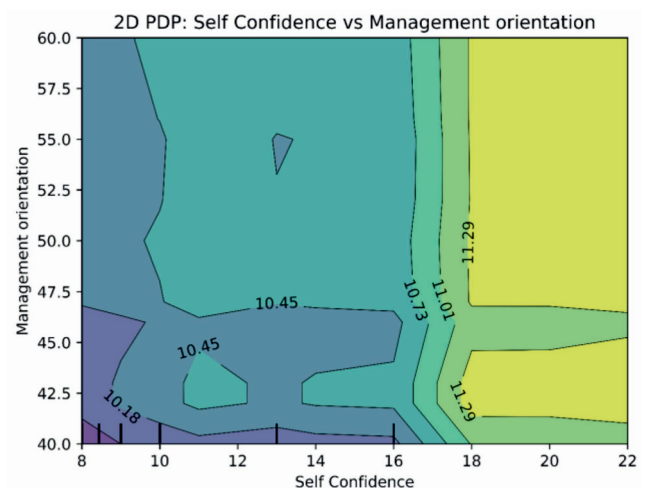


Figure 6c. Two-Dimensional Partial Dependence of Livelihood Security: Self Confidence × Management Orientation

participation), physical (irrigation, infrastructure), and financial capitals (asset/credit access) to pursue strategies that enhance livelihood security (Amghani et al., 2025). The model's non-linear response patterns suggest threshold effects followed by plateaus, consistent with capability perspectives in which small increments in key capitals move households past functional thresholds. These thresholds are plausible within the context of livelihoods, reflecting the combined effects of physical ability, caregiving demands, risk aversion, and varying access to opportunities and services throughout different life stages (Zhang et al., 2024). The uniformity of the ICE traces around the Age PDP suggested that this pattern was widespread among households, rather than limited to a small group.

Self Confidence was identified as the second significant factor, exhibiting a consistently positive relationship. The PDP/ICE profile for Self Confidence showed continuous increases, and the SHAP beeswarm indicated that higher self-confidence led to upward predictions in the sample. This aligns with field experiences in extension work: self-efficacy likely drives the adoption of recommended practices, readiness to engage in markets, and resilience in the face of climatic or price shocks (Mallick et al., 2025). There were also positive, albeit smaller, effects from management orientation and innovative inclination (Panigrahi et al., 2024). Although these factors contributed less than Age and Self Confidence, their directionality suggested that managerial skills and openness to new ideas remain valuable for enhancing livelihood security.

The interaction between age and self confidence indicated that the age-related decline in security could be partially offset by higher confidence levels. Similarly, the interaction between Age and Management Orientation suggested that greater management skills positively influenced security predictions at any age. The Self Confidence and Management Orientation interaction implied a complementary relationship, with households exhibiting both traits achieving the highest predicted scores. These interactions hold practical significance for program design: training investments can yield greater returns when confidence-building and managerial skill development are integrated and tailored to the life-stage challenges faced by older farmers (Lekang et al., 2016; Lekang et al., 2017; Saha et al., 2024).

Minor variables such as mass media use, economic motivation, and education received low permutation scores (Satapathy et al., 2024). This does not imply insignificance; rather, in the context where Age and psychosocial factors are considered, these variables contributed little incremental predictive value (Ruzzante et al., 2021). They may also have mediated their effects through the behavioural constructs already present in the model. Interpretation of these findings should be tempered by several limitations. While the sample size was adequate for exploring tree ensembles, it limited the investigation of rarer interactions and could inflate the variance in permutation estimates for low-signal features. Although PDPs are feature-independent, the ICE overlays and two-dimensional surfaces addressed some of these issues; Accumulated Local Effects (ALE) plots would serve as a valuable robustness check (Apley & Zhu, 2020). All measurements reflect observations at a specific time, and seasonal dynamics or policy shocks were not captured.

The most effective strategies may involve extension programs that combine confidence-building with management training while addressing the unique challenges faced by older farmers (Baul et al., 2024). Specific mentoring, peer-focused producer groups, and practical modules on planning, record-keeping, and market engagement could translate these relationships into tangible improvements in livelihood security (Magakwe et al., 2025).

CONCLUSION

This study's primary objective was to use random forest regression and interpretable machine learning approaches to estimate the factors that influence livelihood security among tribal farmers in South Odisha. This analysis revealed the livelihood security of tribal farming households and it was effectively modelled using a Random Forests approach, achieving a stable out-of-bag performance with an R^2 of 0.828 at around 400 trees. The age, self-confidence, and management orientation significantly shape livelihood security, with confidence-building and managerial capacity emerging as crucial levers to mitigate age-related declines. The livelihood security is not merely a function of resource endowment but is deeply influenced by psychosocial and behavioural factors. The findings suggest the adoption of targeted techniques such as experiential learning modules, role-play exercises for decision-making, farmer-to-farmer mentoring, and structured record-keeping workshops to build confidence and strengthen confidence building.

DECLARATIONS

Ethics approval and informed consent: The research was conducted in accordance with institutional guidelines and approved by all the authors. Ethical approval was obtained from all the participants, and informed consent was obtained from all participants before the study commenced.

Conflict of interest: The authors declare that there are no conflicts of interest in conducting this research study. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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.

Authors' Contribution: This work was carried out in collaboration between all the authors. Authors 1 and 2 collected the data, and Authors 3 and 4 performed the statistical analysis. The study was conceptualized, tabulated, interpreted, and the final draft of the manuscript was prepared by Authors 5, 6, and 7. All authors read and approved the final manuscript.

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

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Use of Generative AI by Small-scale Farmers in Nigeria: An Empirical Study

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HIGHLIGHTS

- Majority of the farmers demonstrated digital access
- More than half of the farmers had used generative AI, mostly for information access and basic research about their farm operations
- Educational attainment significantly enhances AI awareness

ARTICLE INFO

Keywords: Generative artificial intelligence, Small-scale farmers, Technology adoption, Digital divide, Nigeria.

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ABSTRACT

The study, conducted in 2025, investigated the digital readiness and use of generative artificial intelligence (AI) among small-scale farmers in Nigeria. A multi-stage sampling technique was used to select 120 small-scale farmers, and data were collected through interview schedules. The majority (62.5%) were small-scale farmers with over ten years of farming experience. Many of the small-scale farmers had digital access as a lot of them owned smart phones (64.2%) had internet connectivity (65%), and regularly used the internet (53.3%). Traditional media (Radio and TV) (63.3%) remained their primary source of agricultural information. Extension service access (4.2%) was notably low. Many small-scale farmers (64.2%) had used generative AI, mainly for accessing information (45%) and conducting basic research about their farm operations and general well-being (17.5%), and most indicated willingness to continue its use (89.2%). However, major barriers to the use of generative AI included limited awareness and lack of access to digital devices. AI awareness was generally low but positively associated with education. Although generative AI adoption is growing, significant challenges remain, underscoring the need for targeted generative AI training in agriculture as well as the design and implementation of more generative AI awareness program.

INTRODUCTION

Agriculture remains the backbone of rural economies in Africa, especially Nigeria where farming is a significant source of livelihood and food security. However, the productivity and sustainability of

farming are undermined by several challenges, including limited access to reliable agricultural information. The traditional extension system inability to deliver localized and adaptive agricultural information is a significant bottleneck in improving farming practices

and productivity in the developing economy. Therefore, rapid evolutions of artificial intelligence (AI) technologies, which have steered a wave of potential in different area of development, have also become a game changer in solving the limitation of Agricultural Extension for sustainable agriculture and rural development. Among these technologies, Generative Artificial Intelligence (Generative AI) stands out for its ability to create new, original content such as text, images, audio, and even video by learning from existing datasets (Bommasani et al., 2021).

Unlike traditional AI systems that rely on predefined rules and outputs, generative AI models, powered by architectures like Generative Adversarial Networks (GANs), transformers, and diffusion models are capable of generating novel and contextually relevant outputs, often mimicking human creativity (Goodfellow et al., 2014; Vaswani et al., 2017). Generative AI offers unprecedented potential to bridge the longstanding gaps in extension services, market intelligence, and farmer education. Nigeria faces a chronic shortage of agricultural extension agents, with the ratio of farmers to extension agents standing at approximately 1:10,000 in some regions (FMARD, 2023). This shortage limits farmers' access to timely, personalized information on crop management, pest control, weather forecasting, and market pricing. By leveraging generative AI tools such as ChatGPT and other language models, farmers can now obtain instant, tailored advice in multiple languages thereby facilitating a form of digital extension service (Sarfo et al., 2025). Moreover, generative AI supports low-literate or semi-literate farmers through the integration of voice-based assistants and localized language generation, enabling interaction in native tongues without requiring formal literacy (FAO, 2021). For example, applications such as Google's voice search and AI-enabled WhatsApp chatbots are increasingly being deployed in agricultural value chains to support farmer queries. Generative AI also enhances decision-making by analyzing patterns in historical farm data, weather trends, and pest outbreaks to generate early warnings and predictive insights (Shahriar, 2025). Despite these benefits, challenges such as digital illiteracy, unreliable internet connectivity, and limited access to AI-capable devices, and data privacy concerns continue to hinder widespread adoption, particularly among smallholder farmers (Ogwuegbu & Ajobiewe, 2025). This study, therefore, explores digital readiness, and awareness levels of farmers in Nigeria concerning generative AI. Understanding these factors is essential for scaling AI-enabled solutions in agriculture and ensuring that innovations like generative AI do not exacerbate existing inequalities but instead serve as catalysts for rural transformation and food security.

METHODOLOGY

The study adopted a quantitative survey design to assess the use of generative artificial intelligence (AI) as a source of agricultural information among farmers in Nigeria. Ekiti State was purposively selected due to its agricultural prominence and the increasing challenges associated with access to reliable, timely agricultural information. The population of the study comprised small-scale farmers across the 16 Local Government Areas (LGAs) of Ekiti State. A multistage procedure was employed to select the small-scale farmers. At the first stage, two LGAs, Irepodun/ Ifelodun and

Gbonyin were purposively selected based on Agricultural production relevance in Ekiti State. At the second stage, two communities were purposively selected from each LGA based on their unique farming and cropping system, such as Rice, Maize, Yam cropping system and Livestock farming. Based on this criterion, Igbemo Ekiti and Afao Ekiti from Irepodun/ Ifelodun LGA and Ijan Ekiti and Iluomoba Ekiti from Gbonyin LGA were selected. At the final stage, thirty (30) farmers were randomly selected from these four communities, yielding a total sample size of 120.

The Primary data were collected using an interview schedule. The questionnaire was developed and reviewed by the Software Engineers specialized in Generative AI as well as Agricultural Extension experts. The sections included are the socio-economic characteristics, awareness and use of generative AI, and its perceived impact on farming decisions. To accommodate varying literacy levels, questions were translated into Yoruba during interviews where needed. Descriptive statistics such as frequency, percentage, mean were used to summarize the socio-demographic data and levels of awareness and use of AI tools. Inferential statistics, particularly Chi Square test was used to understand the relationship between farmers' level of Education and AI awareness. SPSS was used to analyze the data. Hypotheses were tested at a 5% significance level ($p \leq 0.05$).

RESULTS

The results of demographics, Digital access and ICT usage of small-scale farmers in the study area were presented in Table 1. The socio-economic characteristics of respondents revealed a farming population dominated by middle-aged adults, with 68.4 per cent between 31 and 50 years, a period typically associated with high productivity and openness to innovation (FAO, 2020). Farming was overwhelmingly male-dominated (92.5%), reflecting structural gender imbalances in land access and decision-making (Doss, 2018). Educational attainment was relatively favorable as 79.1% had at least secondary education, a factor positively correlated with the adoption of improved technologies and management practices (World Bank, 2019). Farm structure reflected smallholder dominance, with 45.0% cultivating between one and five acres, consistent with regional patterns where smallholders provide over 80% of agricultural output yet face challenges in scaling (HLPE, 2013). Against this backdrop, digital readiness emerges as both promising and uneven. Smartphone ownership (64.2%) and internet access (65.0%) indicate considerable opportunity for digital agricultural transformation, aligning with evidence that mobile phones are the leading ICT tool in African farming systems (Aker & Mbiti, 2010). Comparable findings in rural India confirm this global trend (Anand et al., 2022). However, the 35.8% relying on basic phones and 34.2% without internet reflect a persistent digital divide. Traditional channels remain significant as 60.0% relied on radio for agricultural information compared to 4.2% for extension agents as presented in Table 2, underscoring that digital innovation must complement and not replace established communication modes (Omotayo, 2005; Lwoga, 2010). However, the growing role of the internet (16.7%) and social media (15.8%) indicates that digital channels are gaining ground, especially among tech-savvy farmers.

Table 1. Small-scale farmers' Demographics, Digital access and ICT usage

Characteristics	Items	Percentage
Farm Size	Small-scale dominance	1–5 acres: 45.0; 6–10 acres: 17.5; >10 acres: 10.0
Type of Device	Smartphone	64.2
	Basic Mobile Phone	35.8
Internet Access	Yes	65.0
	No	35.0
Internet Usage Hours	No Internet Access	34.2
	Less than 1 hour	10.0
	1–3 hours	18.3
	4–6 hours	16.7
	More than 6 hours	20.8
Internet Frequency of Use	No Internet Access	34.2
	Regularly	53.3
	Sometimes	12.5

Table 2. Small-scale farmers' Agricultural information sources

Information Source	Percentage
Extension Agents	4.2
Radio	60.0
TV	3.3
Internet including Generative AI	16.7
Social Media	15.8

The finding as presented in Table 3 was the moderately high usage of generative AI tools (64.2%) among the small-scale farmers. This is impressive considering that the adoption of emerging technologies in rural settings is often low due to infrastructural and educational constraints. The primary purposes of use information access (45.0%) and research (17.5%) underscore the value of generative AI as an advisory and knowledge tool, rather than for direct mechanization. This is consistent with Mittal and Mehar (2016), reported that ICT tools significantly improve access to

Table 3. Small-scale farmers' Generative AI usage and continuous willingness to use

Variable	Items	Percentage
Use of Generative AI	Yes	64.2
	No	35.8
Purpose of Use	For Information	45.0
	For basic Research about farm operations	17.5
	For Fertilizer Application	1.7
Reason for no usage	Not Aware of Generative AI	22.5
	Lack of Smartphone	13.3
Willingness to continue Use AI	Yes	89.2
	No	10.8
Motivation for continuous usage	Research	41.7
	Information Source	29.2
	Training	17.5
	Farming Methods	0.8
	Not Willing to Use	10.8

farm-related information, contributing to productivity enhancement. Das et al. (2024) also reported the same results in their study on ChatGPT as AI-enabled Assistant for Agriculture stakeholders in India. However, despite this high level of usage, 22.5% of non-users indicated lack of awareness as a barrier, followed by 13.3% who lacked smart phones. This shows that both informational and material access barriers continue to hinder the widespread adoption of AI technologies. As Adesina (2015) pointed out, access to devices and exposure to innovations are strong predictors of ICT tool adoption in agriculture. Encouragingly, the willingness to continue using generative AI was high (89.2%), suggesting strong future potential if barriers are addressed. Motivations for continued usage for basic research about their farm operations (41.7%), information (29.2%), and training (17.5%) indicate that farmers are seeking tools that can support evidence-based decision-making and learning. This corroborates Aker and Ksoll's (2012) assertion that digital tools empower farmers by providing timely and relevant information, thereby enhancing decision-making and resilience. The shifting trajectory of traditional Agricultural Extension to Digital Agricultural Extension system which was made possible through the advent of Mobile phone globally, has been a platform for adoption of Generative AI to thrive, especially in rural areas (Adenubi et al., 2021).

One of the most significant findings of this study was the strong positive correlation between educational level and awareness of artificial intelligence (Table 4). The Chi-Square test confirmed a statistically significant association ($\chi^2 = 45.965$, $p < 0.001$), with awareness increasing progressively with higher education (Table 5). Small-scale farmers with tertiary education demonstrated the highest awareness levels (48.4% high, 32.3% moderate), while those with no or only primary education had nearly 100% low awareness. This pattern highlights the role of education in shaping not only knowledge but also digital behavior. Educated farmers are more likely to explore and use AI-based tools because they can better comprehend technological features and evaluate their benefits. Kolapo and Didunyemi (2024) similarly found that educated farmers were more likely to adopt digital innovations and integrate them into their farming practices. The linear association value of 30.922 also suggests a strong positive trend: as education increases, so does awareness. This has significant implications for agricultural policy and training programs. To ensure inclusive adoption of digital agriculture, targeted interventions must focus on improving digital literacy among farmers with lower levels of formal education. This may include visual and audio-based training modules, community ICT centers, and peer-to-peer digital coaching programs.

Furthermore, the cross-tabulation (Table 4) showed that individuals with lower levels of education, particularly those with

Table 4. Cross-tabulation of Small-scale farmers' education level and awareness of Generative AI

Education Level	Low Awareness	Moderate Awareness	High Awareness	Total
No Formal Education	94.1	5.9	0	14.2
Primary Education	100	0	0	6.7
Secondary Education	71.9	20.3	7.8	53.3
Tertiary Education	19.4	32.3	48.4	25.8

Table 5. Chi-Square test results

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	45.965	6	.000
Likelihood Ratio	49.312	6	.000
Linear-by-Linear Association	30.922	1	.000
Number of Valid Cases	120		

no formal or only primary education, tended to exhibit very low levels of awareness about AI. For instance, 100% of those with only primary education and 94.1% of those with no formal education fell into the low awareness category. In contrast, a substantial portion of small-scale farmers with tertiary education demonstrated high awareness (48.4%) or at least moderate awareness (32.3%), indicating a strong association between higher educational attainment and increased AI awareness. This trend was further supported by the Chi-Square test in Table 5, where the Pearson Chi-Square value was 45.965 with a p-value of less than 0.001, confirming that the observed association is statistically significant and not due to chance. The Linear-by-Linear Association value of 30.922 ($p < 0.001$) also indicates a positive linear trend, meaning that awareness of AI increases steadily with higher levels of education. Although a small portion of the data (33.3%) included expected counts below 5, the minimum expected count remained above 1.0, suggesting the test remains robust. These findings suggest that education plays a critical role in shaping public understanding and awareness of AI. Therefore, efforts to increase AI awareness should prioritize educational outreach, especially to those with lower levels of formal schooling, to bridge the knowledge gap and promote inclusive technological literacy. This finding support Chaturvedi and Vatta (2025), who found that education can increase the awareness as well as the use of digital technology farming practices.

DISCUSSION

The unevenness in digital access, internet use, and AI awareness observed in this study reflects the broader digital divide in rural Nigeria. While some farmers are fully engaged with digital tools and AI platforms, others remain disconnected due to infrastructural, economic, or educational constraints. Bridging this divide will require concerted efforts from multiple stakeholders, government, private sector, NGOs, and academic institutions. Firstly, infrastructure such as reliable internet and electricity must be expanded to underserved areas. Secondly, affordable digital devices, particularly smart phones, should be made available through subsidized schemes or community ownership models. Thirdly, digital literacy initiatives tailored to the rural context are essential. These must be localized, accessible in native languages, and practical in their approach. Importantly, extension services must be re-imagined to incorporate digital tools like generative AI. Extension agents can act as digital intermediaries, demonstrating AI tools and assisting farmers in their usage. This integrated approach, combining human and digital channels, will ensure broader reach and deeper engagement.

CONCLUSION

The study highlights the critical socio-economic and digital factors influencing farmers' participation in agricultural innovation

and AI adoption. The findings revealed that majority of Small-scale farmers in the study area are digitally ready for the adoption of generative AI. However, limited internet access in the rural area, poor electricity to charge a Smartphone, gender disparity in on-farm activities, digital divide, low level of awareness of Generative AI, constitute a major barrier to the adoption of Generative AI by small-scale farmers in the rural areas. Notably, the high level of smart phone ownership and willingness to use generative AI tools indicates strong potential for digital transformation in agriculture. Furthermore, the significant relationship between education level and AI awareness underscores the importance of targeted educational interventions. To fully leverage technology for agricultural growth, policy efforts should prioritize digital literacy, infrastructure development, and inclusive access to extension services and AI-based tools.

DECLARATIONS

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

Conflict of interest: The author declares that there is no conflict of interest related to the publication of this article. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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.

Data Availability Statement: The data that support the findings of this study are available upon reasonable request.

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Economic Perspective of Trends and Determinants of Paddy Stubble Burning in North Western India

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HIGHLIGHTS

- The study focused on analyzing the spatio-temporal trends of paddy stubble burning events and area in North Western India.
- State-wise analysis figures out the districts that need attention to reduce the practice of burning.
- Panel regression provides an alternative way to curb this practice.

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Keywords: Paddy stubble burning, North Western India, Mann-Kendall test, Panel regression, Happy seeder.

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ABSTRACT

During the paddy harvesting season in North-Western India, a significant smog problem occurs due to the unhealthy practice of stubble burning, which also reduces soil fertility. The government has implemented various efforts to lessen its severity. By using tabular analysis of burning events, this study found that the number of such events decreased from 2016 to 2021 in North-Western India. The Mann-Kendall test indicated a negative trend in burning events for the three states of Punjab, Haryana, and WUP. In Punjab, about 49% of the paddy area is burned, with the growth rates of the burnt area and paddy area being nearly equal. Conversely, in Haryana, only 17% of the paddy area is burned, but its burnt area is growing at a faster rate than the paddy area itself. Districts like Firozpur, Faridkot, Patiala, and Sangrur in Punjab, along with Fatehabad, Kurukshetra, and Karnal in Haryana, require special attention due to their relatively high percentage of paddy area subjected to burning. Panel regression analysis suggests that cultivating potato and basmati rice can reduce the paddy area affected by burning.

INTRODUCTION

The burning of crop residue in open field has become a significant concern for climate change mitigation efforts worldwide (Raza et al., 2022). Although crop residue burning is a common practice in many Asian countries such as Brazil, Indonesia, Thailand, and China, this issue in India needs special attention (Kaushal & Prashar, 2021). India, being the second largest agro-based economy with year-round crop cultivation, generates a surplus crop residue of about 141 million tons a year, out of which 92 mt is subjected to burning. Haryana, Punjab are one of the most widely studied contributors of paddy residue burning (CRB) in

northern India. Uncontrolled CRB is a major source of air pollution that affects human health, global climate change, and atmospheric chemistry (both local and regional) (Hiloidhari et al., 2019; Mehmood et al., 2018). In Punjab about 95 per cent of the 22.9 metric tonnes of paddy straw is burnt on the field (Bimbraw, 2019). The episodic CRB in the States of Punjab, Haryana and Uttar Pradesh during post-monsoon has altered the air quality of Delhi and Kanpur for the worse (Nagar et al., 2019).

The WHO has set a standard for permissible levels of PM_{2.5} in the air is which is 5 µg/m³ whereas according to India's National Ambient Air Quality Standard (NAAQS) the permissible level for PM_{2.5} is 40 µg/m³ (Bhuvaneshwari et al., 2019). Study of Saxena et

al. (2021) has shown that in 2021, PM_{10} and $PM_{2.5}$ concentrations exceeded NAAQS limits by 2–3 times, while NO_2 and SO_2 stayed within the limits in post post-burning period in Delhi. They used MODIS fire observations to estimate CRB fire counts, and found that rabi fires in Haryana are ~3 times higher and more intense than in kharif. Furthermore, backward trajectories show air mass movement from Haryana, Punjab and Pakistan (Saxena et al., 2021). Between 2003 to 2019, agricultural residue burning caused 44,000–98,000 particulate matter exposure-related premature deaths annually, of which Punjab, Haryana, and Uttar Pradesh contribute 67–90 per cent. Due to a combination of relatively high downwind population density, agricultural output, and cultivation of residue-intensive crops, six districts in Punjab alone contribute to 40 per cent of India-wide annual air quality impacts from residue burning (Lan et al., 2022).

Having all these impacts, the study of burning scenarios of North Western India (NWI) becomes a matter of importance, which will serve to take curative measures to reduce this practice. So, this study makes a thorough analysis of burning events and burning area of paddy for each district of Punjab, Haryana and Western Uttar Pradesh (WUP), by applying various methodologies. It also assesses the factors influencing the practice of burning by the Panel regression technique.

METHODOLOGY

The secondary data used in the study includes the district-wise weekly number of paddy stubble burning events, for nine weeks (1st October to 31st November) that occurred in Punjab, Haryana and WUP for the past six years (2016 to 2021). Further, based on availability, we also used paddy stubble burnt area in only Punjab and Haryana states for four years (2018 to 2021). The secondary data for both analyses is collected from the CREAMS (The Consortium for Research on Agro Ecosystem Monitoring and Modeling from Space) website, handled by the Division of Agricultural Physics, ICAR-IARI. The CREAMS lab uses the thermal data to monitor in real-time, the active fire events for paddy and wheat in north India, and they have used a high spatial resolution multispectral image of pre and post-burning periods for mapping and estimating burnt area reliably (Sehgal et al., 2021; Jambagi et al., 2023). And the other related data, like area under paddy, wheat, potato, groundwater irrigated area, and cropping intensity, are taken from the Directorate of Economics and Statistics; the area under basmati paddy is taken from the “Basmati Crop Survey Report” of APEDA. Weekly data on the number of paddy stubble burning events that occurred in Punjab, Haryana, and WUP over the past six years were subjected to preliminary tabular

analysis to identify the spatial and temporal pattern of burning events in NWI.

The direction and magnitude of trends in burning incidents for each district in the aforementioned states were examined in this study using two non-parametric techniques: Mann-Kendall and Sen's slope estimator, as these techniques require that the data be independent regardless of distribution pattern (Athare et al., 2023).

Identifying stubble burning drivers is vital for communicating the effective policy. Data on the area subject to stubble burning from 2018 to 2021 was used to identify covariates influencing the proportion of area under paddy burning. The following model was used to estimate effect on paddy burnt area,

$$\text{Burnt area}_{i,t} = b_0 + b_1 X_{1,t} + b_2 X_{2,t} + \dots + X_n + e_{i,t}$$

Where, $X_1 - X_n$ = Area under potato, Area under basmati paddy, Area under paddy, Area under wheat, cropping intensity, rural male literacy, groundwater irrigated area. i, t = cross-sectional, time series component, e = error term

RESULTS

The spatio-temporal distribution of paddy straw burning events in NWI

The spatial distribution of paddy straw burning events in NWI for the period 2016 to 2021 is shown in Table 1, which reveals that the average number of events over the last six years is 87636.8 per year, among which 84 per cent of the events have occurred in Punjab, 11.6 per cent in Haryana and 4.2 per cent in Western UP. But, when we consider the area under paddy cultivation in the study region it was found that Punjab's contribution decreased to 71 per cent, whereas Haryana and Western UP's contribution increased to 22.6 and 6.6 per cent, respectively.

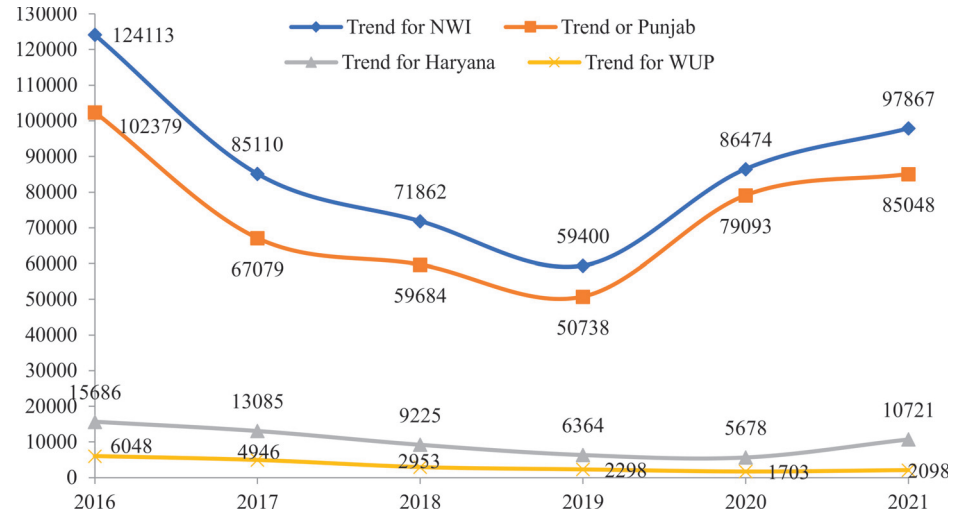
The trend of farm fire events in NWI for the period 2016 to 2021 is shown in Figure 1. Among the 5,24,826 number of farm fire events, a maximum of 23.6 per cent of the events have occurred in 2016 followed by a declining trend till 2019. The same has been reported on CREAMS portal, which stated that about 15 and 41 per cent reduction in number of burning events were observed in 2018, then that of 2017 and 2016 respectively. This decline can be attributed to the various efforts and measures taken by the government such as the ban on stubble burning implemented in 2015, the measure to give compensation of rupees 1500/acre for the farmers who has not burnt the paddy, and the scheme “Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi” implemented in 2018. However, again the number of events got raised in later years. This increase of fire events was

Table 1. The spatial distribution of paddy straw burning events in NWI

States	Average paddy area		Average burning events		Events/lakh ha of paddy area	
	Lakh ha	Share (%)	No./year	Share (%)	No.	Share (%)
Punjab	31.3	51.7	74003.5	84.4	2364	70.8
Haryana	13.4	22.1	10126.5	11.6	756	22.6
WUP	15.85	26.2	3506.8	4.2	221	6.6
Total	60.55	100.0	87636.8	100.0	3341	100.0

Source: Directorate of Economics and Statistics and <http://creams.iari.res.in>

Figure 1. The Temporal distribution of paddy straw burning events in NWI
Source: <http://creams.iari.res.in>



mainly contributed by the state Punjab in the year 2020 and Haryana in 2021. The reason for increase in the number of events from Punjab in 2020 can be partially attributed to the protest of farmers against new farm laws (Sharma, 2022) and the inaction of officials at the time.

A weekly analysis of the events has shown that around 70 per cent of the events occur in the fourth, fifth, and sixth weeks (22nd October to 11th November) of the study period (1st October to 30th November), which corresponds to the wheat sowing period. Among these, the sixth week, from 5th to 11th November, contributed 29 per cent, followed by the 5th and 4th weeks. Whereas, the initial weeks of October and the last weeks of November have a meager number of events.

District-wise trend and growth rate of burning events

As evident from Table 2, the negative sign of Kendall's tau statistics indicates that farm fire events have a decreasing trend in the state of Punjab in the study period, with an annual rate of decrement of 3466.20. And almost all the districts exhibited the negative trend except districts like Bathinda, Amritsar, Fazilka, Muktsar, and Kapurthala; however, most are non-significant.

The compound annual growth rate (CAGR) of area under paddy and area of paddy subjected to burning in the period 2018 to 2021, has been calculated for the state Punjab and given in the Table 5 and it has been found that burnt area has been grown at a rate of 1 % in the state, whereas the paddy area has been grown at

Table 2. Estimates of Mann-Kendall test, Sens slope and CAGR for Punjab

Districts	z value	Kendall's tau	Sens slope	p value	CAGR of paddy area (%)	CAGR of burnt area (%)	Share of burnt area in paddy area (%)
Amritsar	0.75	0.33	31.00	0.45	0.7	25	31.27
Barnala	0.00	-0.07	-151.00	0.01	0.5	4	54.73
Bathinda	0.00	0.07	535.00	0.09	2.6	-8	53.31
Faridkot	0.00	-0.07	-78.20	0.06	0.3	-9	67.02
Fatehgarh Sahib	-0.38	-0.20	-100.67	0.03	0.2	16	54.71
Fazilka	0.00	0.07	36.00	1.00	1.6	-5	47.75
Firozepur	0.00	0.07	-12.00	0.02	0.5	-9	66.59
Gurdaspur	-0.38	-0.20	-60.50	0.01	-0.1	8	34.26
Hoshiarpur	0.75	-0.33	-23.00	0.05	1.5	66	25.23
Jalandhar	0.00	-0.07	-79.33	0.07	0.6	-2	47.47
Kapurthala	0.00	0.07	11.00	0.08	-0.1	-11	49.42
Ludhiana	-0.38	-0.20	-680.60	0.01	0.1	6	47.23
Mansa	0.00	-0.07	-73.00	0.02	3.2	-6	51.32
Moga	0.00	-0.07	-56.00	0.03	0.3	6	54.75
Muktsar	0.00	0.07	19.00	0.09	1.7	-16	54.42
Pathankot	0.81	0.75	0.00	0.06	0.4	-5	21.08
Patiala	0.00	-0.07	-154.80	0.04	0.1	375	61.75
Rupnagar	0.00	-0.07	-42.67	0.02	0.3	-28	36.02
S.A.S Nagar	0.38	0.20	-365.00	0.01	-2.9	-39	41.64
Sangrur	-0.38	0.20	2.00	0.00	0.6	134	65.32
S.B.S Nagar	-1.50	-0.60	-184.00	0.13	0.7	99	25.05
Tarn Taran	0.00	0.07	4.00	1.00	0.5	-3	51.53
Total	0.00	-0.07	-3466.20	0.02	0.7	1	49.10

Source: <http://creams.iari.res.in>

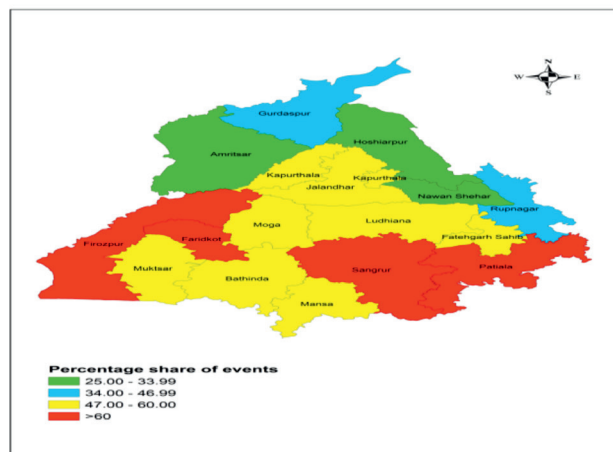
Table 3. Estimates of Mann-Kendall test, Sens slope and CAGR for Haryana

Districts	z value	Kendall's tau	Sens slope	p value	CAGR of paddy area (%)	CAGR of burnt area (%)	Share of burnt area in paddy area (%)
Ambala	-0.38	-0.20	-11.0	0.03	3.1	40	11.15
Bhiwani	-1.13	-0.47	-11.0	0.02	0.7	-49.6	5.82
Charkhidadri	1.62	0.73	1.0	0.01	-13.3	0	0.04
Faridabad	-1.88	-0.73	-71.3	0.06	5.4	-24	2.05
Fatehabad	-1.50	-0.60	-833.3	0.03	1.7	-2.7	43.07
Gurgaon	1.75	0.77	1.0	0.08	1	-15.16	6.02
Hisar	0.00	-0.07	-12.3	1.00	4.3	-20.5	10.64
Jhajjar	-0.75	-0.33	-4.4	0.45	1.2	-53.3	2.32
Jind	0.00	0.07	13.5	0.01	0.7	6	17.34
Kaithal	-1.50	-0.60	-163.3	0.13	1.4	9.1	20.99
Karnal	-1.13	-0.47	-138.0	0.26	0.5	28.3	24.07
Kurukshetra	-1.50	-0.60	-113.3	0.13	0	22.1	26.89
Mewat	0.45	0.26	0.0	0.65	-7.9	0	3.92
Palwal	1.41	0.60	29.0	0.02	2.1	-0.2	10.84
Panchkula	2.10	0.83	6.5	0.04	7.1	-19.48	0.80
Panipat	0.00	0.07	4.0	0.09	2.4	205.9	13.61
Rewari	0.45	0.26	0.0	0.65	-4.9	-67.39	7.52
Rohtak	0.00	-0.07	2.0	0.09	8.5	24.9	2.95
Sirsa	-1.50	-0.60	-626.0	0.00	1.2	-20.1	19.38
Sonipat	0.38	0.20	11.0	0.01	1.5	56.8	8.02
Yamunanagar	0.00	-0.07	1.3	1.00	3.9	36.9	10.00
Total	-1.50	-0.60	-2469.0	0.03	1.8	9.6	17.69

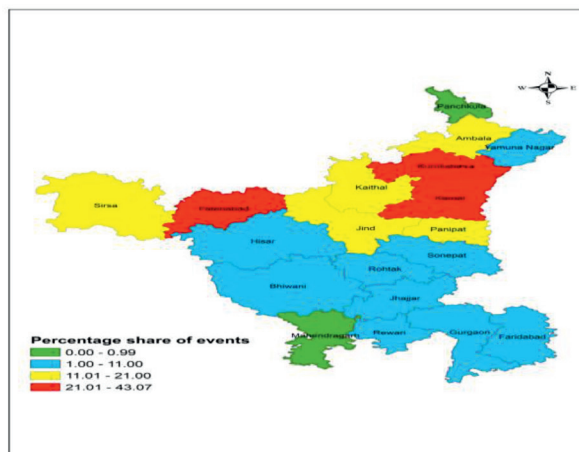
Source: <http://creams.iari.res.in>

rate of 0.7%. In some districts like Patiala, Sangrur, S.B.S Nagar, Hoshiarpur, and Amritsar, the growth rate of burnt area is comparatively higher than the growth rate of paddy area, which is a matter of serious concern. When the percentage of burnt paddy area in total paddy area is considered, the districts can be divided into four zones based on the mean (47) and standard deviation (13) values of percent burnt area. Accordingly, districts like Firozepur, Faridkot, Patiala, and Sangrur fall in the red region as the percentage of paddy area burnt in these districts is more than 60%. The districts like Barnala, Bathinda, Fatehgarh Sahib fall in yellow region (47 to 60%). Gurdaspur, Rupnagar, S.A.S Nagar in blue (34 to 47%) and districts like Amritsar, Hoshiarpur, and S.B.S Nagar (Nawan Shehar) fall in green region (< 34 %) (Figure 2).

As evident from Table 3, the negative sign of Kendall's tau statistics indicates that farm fire events have a decreasing trend in Haryana in a study period, with an annual rate of decrement of 2469. Districts like Fatehabad (-833.3) and Sirsa (-626) are exhibiting a significant annual rate of decrement. But some districts like Palwal, Jind, Panchkula, Sonipat, and Panipat need a special attention since they are exhibiting positive or increasing trend of burning events. The CAGR for the state of Haryana shows that the burnt area in the state has grown at a rate of 9.6%, which is higher than the paddy growth rate of 1.8%. And, also in districts like Panipat, Sonipat, Karnal, Kurukshetra, Kaithal, Jind, and Ambala, the growth rate of burnt area is comparatively higher than paddy growth rate, which calls for the need of special attention.



Punjab



Haryana

Figure 2. Classification of districts based on the percentage of paddy area burnt

Source: Author's calculation

The same analysis for Haryana, classifies the districts based on mean (11) and standard deviation (10). The districts like Fatehabad, Kurukshetra and Karnal falls in red region (>21%), Jind, Sirsa, Kaithal etc in yellow (11 to 21%), Hissar, Yamuna Nagar etc in blue region (1 to 11%) and Panchkula district falls in green region for having a less than one percent of burnt area in total paddy area (Figure 2).

Based on the availability of data, only trend analysis of burning events for WUP has been analyzed and is represented in Table 4, which reveals that there is a negative trend of fire events in the study period, with an annual decrement of about 7966. Almost all districts have a decreasing trend except districts like Amroha (5.50), Badaun (2.33) and Baghpat (6.25), which exhibited a significant increasing trend and call for a preventive measure.

Factors influencing the practice of burning

A fixed effects panel data regression model was employed to investigate the factors influencing the extent of stubble burning in the targeted region. Initially, both random effects and fixed effects models were applied. However, based on the Hausman test results ($\chi^2(7) = -533.07$, Probability < $\chi^2 = 0.00$), the fixed effects model was determined to be more appropriate for the analysis. To account for potential panel effects, a BP-LM test was conducted ($\chi^2(253) = 506.0$, Probability > $\chi^2 = 0.00$). The results of this test indicated the presence of significant panel-specific effects, which

further supported the choice of a panel data regression model over a pooled regression model. To address the issue of heteroscedasticity, as it can compromise the efficiency of ordinary least squares estimates and invalidate tests of statistical significance, the error terms of the panel data regression were subjected to a Wald test for group-wise heteroscedasticity ($\chi^2(36) = 4189.71$, Probability > $\chi^2 = 0.00$). In addition, an alternative approach was considered by utilizing the Generalized Least Squares (GLS) model to obtain efficient standard errors. Specifically, a two-way fixed effects model was employed, incorporating district dummies and time dummies. This approach allowed control for both time-invariant location-specific factors and time-varying factors that were uniform across different sections of the dataset. The analysis combined the data from both Punjab and Haryana, providing a comprehensive assessment of the factors contributing to stubble burning in this region.

The model's goodness of fit was assessed using R-squared (R^2) and the F-statistic, and the overall model was found to be suitable for interpreting the results. Based on the results presented in Table 5, it was observed that as the area under potato cultivation increased, there was a corresponding decrease in the area affected by stubble burning. This finding aligned with the null hypothesis, suggesting that an increase in the area under vegetable crops reduced burning. The production of basmati rice was also found to be inversely related to the area of burning. This relationship could be partially attributed to the market potential of basmati paddy straw, which is usually harvested manually. Conversely, a higher rural male literacy rate was associated with an increase in the area of burning. This indicated that awareness and adoption of improved agricultural practices were not effectively communicated in this context. 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. Furthermore, an

Table 4. Estimates of Mann-Kendall test and Sens slope for WUP

21	z value	tau	Sens slope	p value
Agra	1.81	0.75	1.75	0.07
Aligarh	0.38	0.20	-1.0	0.01
Amroha	2.21	0.89	5.50	0.03
Badaun	1.41	0.60	2.33	0.04
Baghpat	2.21	0.89	6.25	0.03
Bareilly	-2.63	-1.00	-45.50	0.01
Bijnor	0.00	-0.07	-8.00	1.00
Bulandsagar	0.75	0.33	1.40	0.45
Ethah	-0.75	-0.33	-3.00	0.05
Firozabad	-0.19	-1.38	-0.25	0.04
Gautambudhnagar	-0.75	-0.33	-4.00	0.04
Muzafarnagarshamli	-0.38	-0.20	-17.20	0.01
Ghaziabadhapur	-1.50	-0.60	-12.80	0.03
Hathras	0.00	0.12	0.00	0.00
Kannauj	-0.96	-0.41	-3.00	0.03
Kasganj	0.45	0.26	0.00	0.05
Mainpuri	-1.34	-0.55	-10.33	0.08
Mathura	-2.25	-0.87	-309.50	0.02
Meerut	-0.75	-0.33	-13.00	0.04
Moradabad	-0.75	-0.33	-4.67	0.03
Pilibhit	-2.25	-0.87	-200.50	0.02
Rampur	-1.50	-0.60	-107.00	0.01
Ambhal	0.90	0.43	0.00	0.03
Shahjahanpur	-1.50	-0.60	-172.00	0.01
Sharanpur	-0.38	-0.20	-12.75	0.07
Auraiya	-1.13	-0.47	-40.60	0.02
Etawah	-0.75	-0.33	-18.00	0.04
Farrukhabad	1.49	0.60	1.00	0.16
Total	-2.25	-0.87	-796.00	0.02

Source: <http://creams.iari.res.in>

Table 5. Two-Way Fixed Effect Panel Regression

Variables	Coefficient	Standard Error
Area under potato (ha)	-0.018***	0.006
Area under basmati (000 ha)	-1.785**	1.001
Area under paddy (000 ha)	0.356***	0.848
Area under wheat (000 ha)	0.006*	0.003
Cropping intensity (%)	0.169	0.206
Rural male literacy (%)	1.300***	0.385
Groundwater irrigated area (000 ha)	0.0148***	0.003
Constant	-2806.31	1785.8
Diagnostic Statistics	sigma_u	6494.2
	sigma_e	35.53
	rho	1.00 F (36, 89)
		Prob > F = 0.0000
R ² Within = 0.665	Sample size	133
R ² Between = 0.979	No. of groups	37
R ² Overall = 0.952		

Wald $\chi^2(36) = 4189.71$, (Probability > $\chi^2 = 0.00$), Hausman test $\chi^2(7) = -533.07$, (Probability < $\chi^2 = 0.00$), BP-LM test $\chi^2(253) = 506.00$, (Probability > $\chi^2 = 0.00$)

***Coefficient statistically significant at 1%, **Coefficient statistically significant at 5%, *Coefficient statistically significant at 10%

increase in the area under groundwater irrigation was associated with an increase in burning, thereby rejecting the null hypothesis (Jatav, 2024; Kumar et al., 2022). Field visits supported this finding, as access to groundwater irrigation enabled farmers to shorten the interval between paddy and wheat cultivation, which in turn led to a greater reliance on stubble burning.

DISCUSSION

Analysis of paddy stubble burning incidents across Punjab, Haryana, and Western Uttar Pradesh revealed a declining trend in North-Western India during 2016–2019, consistent with CREAMS data reporting 41% and 15% reductions in 2018 over 2016 and 2017, respectively. According to the Press Information Bureau (2019), in-situ burning decreased by 29.5%, 24.5%, and 11.0% in Haryana, Punjab, and UP, respectively, compared to 2017. However, a 45% surge in 2020, mainly in Punjab, coincided with farmer protests against new farm laws (DARE, 2022), indicating socio-political influences on burning practices. Still, the high percentages of paddy land subjected to burning in Punjab and the comparatively quicker expansion of burned land in Haryana highlight regional differences and are consistent with previous findings by Saxena et al. (2021) about state-specific difficulties with enforcement and farmer compliance. The findings from our regression analysis align with earlier research emphasizing the role of crop diversification in reducing environmental stress. As highlighted by Kumar et al. (2022), diversification into crops such as potatoes and basmati rice can mitigate the practice of residue burning our results support this evidence. At the same time, the strong positive relationship between groundwater irrigation and stubble burning points to the structural rigidity of the paddy–wheat system. This observation resonates with the concerns raised by Lan et al. (2022); Debangshi and Ghosh (2022) and Saha et al. (2022) regarding the interconnected pressures on water, air, and soil resources. Consistent with the findings of Huria et al. (2021), the results indicated that higher literacy levels were associated with an increase in stubble burning, a contrast to the common expectation that education would promote environmentally sustainable practices. Future research could contribute by adopting micro-level household surveys to better capture behavioral drivers, explore the economic feasibility of alternative crop choices, and assess the long-term adoption of residue management technologies such as the Happy Seeder under varying policy and market environments.

CONCLUSION

Trend statistics of the study have shown the decreasing trend of burning events for all three states from 2016 to 2021; however, when growth rates of paddy burnt area were compared vis-à-vis growth rate in area districts, viz., Haryana, like Palwal, Jind, Panchkula, Sonapat and Panipat and the districts of WUP like Amroha, Badaun and Baghpat, exhibited increasing trends. Panel regression highlights a positive effect of paddy cultivation, increased groundwater availability, and higher literacy rates on stubble burning. This underscores the need for targeted awareness and education programs directed toward literate populations. To address the challenges effectively, implementing stricter regulations on stubble burning, incentivizing farmers in high-frequency burning districts to transition

towards high-income vegetable crops (diversification) are evident. Furthermore, as per evidence supported by primary data of the current study and literature, the technological practices, viz., Happy Seeder, to be promoted through mass media channels during the paddy-wheat cultivation window period.

DECLARATIONS

Ethics approval and informed consent: Ethical approval was not required as the data was taken from published sources and public domain.

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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A Tool to Measure Livelihood Vulnerability of Climate-Sensitive Farming Communities

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HIGHLIGHTS

- A Livelihood Vulnerability Scale was developed based on the IPCC framework, covering exposure, sensitivity, and adaptive capacity.
- The Cronbach's alpha value was 0.90, indicating high internal consistency across all dimensions.
- The developed scale is a reliable tool for assessing climate-related livelihood vulnerability among farming communities.

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ABSTRACT

Climate change is one of the major concerns for rural livelihoods, particularly for families dependent on agriculture. Understanding livelihood vulnerability to climate change is essential for developing adaptive strategies. The present study, conducted in March 2025, aimed to develop a scale for livelihood vulnerability by incorporating three dimensions: exposure, sensitivity, and adaptive capacity. From an initial pool of 53 statements, 36 were finalized after expert validation and statistical screening. The Likert methodology was used to assess the statements. Content validity was established through expert review, and internal consistency of the scale was assessed by using Cronbach's alpha (0.90), indicating high reliability. The final scale offers a comprehensive, reliable tool for assessing livelihood vulnerability to climate change and can be used for research, policy formulation, and relevant interventions in climate-sensitive regions.

INTRODUCTION

Climate change is one of the most pressing global challenges, manifesting through shifting rainfall patterns, rising temperatures, increased frequency of natural disasters, and adverse effects on food systems and human health (Krishnan et al., 2020; Hussain & Hoque, 2022; Saxena et al., 2022; Vijayabhinandana et al., 2022). In India, with its diverse climatic conditions and heavy reliance on agriculture, the impact of climate change is particularly pronounced (Sonwani et al., 2021; Hussain et al., 2024). Studies have indicated a decline in monsoon rainfall and an increase in the intensity and frequency of extreme weather events such as floods, droughts, and cyclones (Kumar & Saxena, 2021; Kumar & Saxena, 2024).

According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures are projected to rise by 1.5°C, further

intensifying climate-related threats (Parmesan et al., 2022; WMO, 2022). The IPCC defines vulnerability as “the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change, including extreme events” (IPCC, 2007). This vulnerability is conceptualized across three dimensions: exposure, sensitivity, and adaptive capacity. India's position as the 7th most vulnerable country in the Global Climate Risk Index (Eckstein et al., 2021) highlights the urgency of assessing and addressing livelihood vulnerability at the grassroots level.

Agriculture, a key sector for rural livelihoods in India and particularly in states like Karnataka, is increasingly at risk. More than 50 per cent of the population depends on agriculture, and over 80 per cent of farms are rainfed (Reddy et al., 2023). The rising temperature and irregular monsoons are not only affecting crop

productivity and traditional agricultural practices but also increasing the prevalence of pests, diseases, and food insecurity (Ashoka et al., 2022). These changes pose serious challenges to the livelihood security of farming communities.

Despite numerous vulnerability studies, there remains a lack of standardized, reliable, and context-specific tools to assess livelihood vulnerability, especially tailored to climate-sensitive farming communities. Addressing this gap requires the development of a scientifically validated tool that incorporates multiple dimensions of vulnerability. Therefore, the present study was undertaken to develop and validate a Livelihood Vulnerability Scale based on the IPCC framework, aiming to provide policymakers, researchers, and practitioners with a reliable tool to assess and address the vulnerability of farmers to climate change.

METHODOLOGY

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as a function of three components: exposure, sensitivity, and adaptive capacity. The Livelihood Vulnerability Index is a widely accepted tool used to assess how susceptible a household or community is to various stressors such as climate change, natural disasters, and socio-economic shocks. In the present study, the Likert summated rating scale method (Likert, 1932) was adopted to develop a scale for measuring livelihood vulnerability. Based on a thorough review of literature and consultations with subject-matter experts, relevant indicators were identified and categorized under three key dimensions: exposure, sensitivity, and adaptive capacity.

The scale indicators were categorized as follows: exposure included climatic events such as floods, droughts, and cyclones experienced over recent years; sensitivity focused on aspects like water access, food security, and health conditions; and adaptive capacity was evaluated using indicators such as socio-demographic characteristics, livelihood strategies, social networks, access to services, use of technology, and natural resource availability. Initially, 70 statements were generated to represent these components. After careful editing and refinement, 53 statements were retained and subjected to expert judgment. These statements were shared with 110 experts, both electronically and in person, along with instructions to rate the relevance of each item on a five-point continuum ranging from “not relevant” (score 1) to “most relevant” (score 5).

To evaluate the relevance of each statement, the following statistical measures were applied, namely, Relevancy Weightage (RW), Relevancy Percentage (RP), Mean Relevancy Weightage (MRW), Scale Value (S), and Inter-Quartile Range (Q). Responses received from 50 experts were used for the final analysis. Statements were selected for inclusion if their median value exceeded the inter-quartile range, while those with lower relevance or greater variability were excluded. This process led to the selection of 36 statements across the three dimensions.

To ensure content validity, all statements were derived from literature and refined through expert feedback. Reliability of the scale was tested using Cronbach's alpha coefficient through SPSS software (Cronbach, 1951). A Cronbach's alpha value of more than 0.70 was considered acceptable. In this study, all three dimensions

showed very high reliability, with alpha values exceeding 0.90, confirming strong internal consistency of the scale.

RESULTS

The development of the Livelihood Vulnerability Scale involved a rigorous screening of 53 initial statements using expert judgment and statistical analysis to ensure relevance, clarity, and consistency. Fifty experts rated the items, and key parameters such as Scale Value (S), Inter-Quartile Range (Q), Relevancy Weightage (RW), Relevancy Percentage (RP), and Mean Relevancy Weightage (MRW) were calculated. Based on these metrics, 36 statements were finalized and grouped under three core dimensions: exposure, sensitivity, and adaptive capacity.

The exposure dimension comprised eight statements capturing the frequency and impact of climate-related events like floods, droughts, and variability in rainfall patterns. The sensitivity component included eleven statements addressing access to water, food security, and health services. The adaptive capacity dimension consisted of seventeen statements covering socio-demographic factors, livelihood diversification, access to technology, climate-related information, and institutional support systems. Each dimension demonstrated strong internal consistency, with Cronbach's alpha values of 0.985 for both exposure and sensitivity, and 0.991 for adaptive capacity, indicating excellent reliability.

Content validity was established through a comprehensive literature review and consultation with experts in climate change and rural development. This methodology aligns with standard scale development practices reported by Shitu et al., (2018); Chandra et al., (2024) & Arulmanikandan et al., (2025), who emphasized the role of expert validation in instrument construction. Cronbach's alpha, a widely accepted measure of internal consistency in extension research (Ray & Mondal, 2011; Arulmanikandan et al., 2025), was used to assess reliability. The consistently high alpha values across all dimensions confirm that the scale is both statistically robust and suitable for assessing livelihood vulnerability among climate-sensitive farming communities.

DISCUSSION

The final scale, comprising 36 carefully selected statements, demonstrated high internal consistency, as reflected by Cronbach's alpha values exceeding 0.90 for all three dimensions. The high reliability of the scale indicates that the items consistently measure the intended construct across different respondents. This is consistent with established practices in scale development within agricultural extension research, where Cronbach's alpha values above 0.70 are considered acceptable (Ray & Mondal, 2011). The results also align with the methodological standards demonstrated in previous studies such as Arulmanikandan et al., (2025), who developed a tool to assess farmers' training needs in drone-based technologies using expert validation, item selection criteria, and reliability analysis. Similar to their approach, our study applied inter-quartile range analysis and mean relevancy weightage to refine the statement pool, ensuring that only statistically significant and contextually relevant items were retained.

While the IPCC framework provides a robust theoretical foundation, the scale's practical strength lies in its ability to capture

Table 1. Item-wise Statistical Indicators for Final Selection of Statements in the Livelihood Vulnerability Scale

S.No.	Statement (S)	Scale value (S)	Inter- quartile range (Q)	RW	RP	MRS	Cronbach alpha (α)	
	I. Exposure							
	a. Climate shock							
1	Number of flood events occurred over the past three years	1.68	0.15	0.84	84.4	4.22	0.985	
2	Incident of floods during crop growth periods (Early / Mid/ Late)	2.42	1.24	0.86	86.4	4.32		
3	Flood has caused damage to my physical assets (farmland and buildings)	2.00	1.25	0.88	88.0	4.4		
4	Experienced the incidents of drought events over the past three years	2.75	0.81	0.83	83.2	4.16		
5	Droughts have occurred during crop growth periods (Early / Mid/ Late)	2.54	1.20	0.85	85.2	4.26		
	b. Climate variability							
6	Experienced the changes in the onset and withdrawal of rainfall	2.78	1.09	0.88	88.00	4.4	0.985	
7	Presence of high temperature and unusual dryness	2.54	1.13	0.85	84.80	4.24		
8	Observed the uneven distribution of rainfall during rainy season	1.88	0.59	0.86	85.60	4.28		
	II. Sensitivity							
	a. Water							
9	Usage of natural water source by you	2.50	1.09	0.88	88.00	4.16	0.985	
10	Access to consistent water supply	2.81	0.32	0.85	85.00	4.38		
11	Distance travelled by you to reach potable water source	2.63	0.61	0.86	85.60	3.96		
	b. Food							
12	Dependency on family farm for food	1.89	0.55	0.83	83.20	4.16		0.991
13	Struggle to find food (in months) by you	2.68	0.50	0.78	77.60	3.88		
14	Number of crops grown on your farm	2.94	0.40	0.85	85.20	4.26		
15	Saving crops for home consumption	2.25	2.49	0.89	89.20	4.46		
	c. Health							
16	Proximity to medical facility	2.04	1.73	0.87	87.2	4.36		
17	Members with a chronic illness	2.54	1.81	0.82	81.60	4.08		
18	Illness due to flooding	1.86	1.31	0.74	73.60	3.68		
19	Access or own a latrine on their premise	2.12	0.56	0.80	79.60	3.98		
	III. Adaptive capacity							
	a. Socio demographic profile							
20	Age of Household head	2.75	1.37	0.81	81.20	4.06	0.991	
21	Education of Household head	1.86	0.46	0.86	85.60	4.28		
22	Family Size	2.75	1.37	0.88	88.00	4.4		
23	Land holdings	1.86	0.46	0.90	90.40	4.52		
24	Out migration	1.69	0.70	0.84	84.40	4.22		
	b. Livelihood strategies							
25	Dependence on agriculture as their primary source of income	1.47	1.37	0.86	86.40	4.32	0.991	
26	Agriculture livelihood diversification	2.42	2.22	0.88	88.40	4.42		
27	Dependence on forest products as a source of supplemental income	3.16	2.69	0.87	86.80	4.34		
	c. Social network							
28	Membership in community-based or social organization	1.70	1.02	0.80	79.60	3.98	0.991	
29	Access to telecommunications services (telephone, mobile phone, and email)	2.50	1.06	0.87	87.20	4.36		
30	Climate change awareness	1.80	0.50	0.87	86.80	4.34		
31	Use of weather forecasting for farming decisions	2.42	1.29	0.86	86.00	4.28		
32	Trainings on climate change	1.94	0.60	0.89	89.20	4.46		
	d. Technology adoption and services							
33	Use of pesticides and fertilizers	2.42	1.24	0.84	84.0	4.2	0.991	
34	Use of climate-resilient varieties of seed	2.42	1.15	0.91	91.20	4.56		
35	Distance to market (km)	1.70	1.60	0.91	91.20	4.56		
36	Access to Climate information	1.76	0.30	0.88	88.40	4.42		

Note: RW = Relevancy Weightage, RP = Relevancy Percentage, MRW = Mean Relevancy Weightage.

localized aspects of vulnerability, such as climate variability, food insecurity, and access to services—factors particularly relevant for climate-sensitive farming communities. The scale incorporates diverse livelihood-related indicators, which makes it suitable for assessing vulnerabilities in various agro-ecological and socio-economic contexts. The inclusion of adaptive capacity indicators such as access to climate information, education, market linkage, and training further strengthens the scale, enabling a comprehensive understanding of the factors that support or hinder resilience. This approach is essential for designing context-specific interventions and policies. Furthermore, by aligning our scale development with recent tools developed by Chandra et al., (2024).

CONCLUSION

The scale was statistically reliable and valid for evaluating the livelihood vulnerability among the farmers for climate change. The final scale consists of 36 statements categorised under three main indicators i.e., exposure, sensitivity and adaptive capacity. Likert scale was used to validate each statement. Cronbach's alpha value was (> 0.90) across all the three indicators representing the internal consistency of the scale. This scale helps to guide the researchers, policymakers and development agencies in identifying vulnerable groups, prioritizing interventions and formulating strategies for climate resilience that are data-driven and contextually relevant.

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DECLARATIONS

Ethics approval and informed consent: The experts to judge the items were well informed regarding the purpose and only the responses of the judges who consented have been included for analysis purpose.

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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Development of a Scale to Assess Kerala Farmers' Attitude towards Digital Technologies in Agriculture

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HIGHLIGHTS

- A standardized 20-item attitude scale was developed to assess farmers' attitudes towards digital technologies in agriculture, resulting in a reliability coefficient of 0.91.
- The key elements of digital competency, comprising both positive and negative statements, were finalized by selecting items that had critical ratio t-values of at least 1.75.
- The developed attitude scale is appropriate for evaluating the attitude of farmers towards digital technologies and supporting digital agriculture efforts.

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ABSTRACT

The expanding role of digital technologies in agriculture highlights the importance of understanding farmers' attitudes toward their adoption, particularly in the context of Kerala's digital infrastructure and e-governance. The research, carried out in 2025, sought to create a standardized Likert attitude scale to evaluate the attitude of Kerala farmers on the employment of digital technologies in agriculture. A preliminary collection of 68 attitude statements was formed through literature research and expert input. These statements were assessed by 30 specialists in agricultural extension, and following their feedback, 56 items were chosen for further analysis. The chosen items were distributed to 60 farmers from non-sample regions-30 from Karuvatta Panchayat and 30 from Kayamkulam Municipality, situated in the Onattukara Sandy Plain agro-ecological unit. Participants rated the statements using a five-point Likert scale. Employing the t-test established by Edwards (1957, 1969), statements with strong discriminative ability were retained, resulting in a final scale of 20 items comprising 10 positive and 10 negative statements, achieving a Cronbach's Alpha of 0.91, which demonstrates excellent reliability and content validity confirmed through expert assessment.

INTRODUCTION

The integration of digital technologies has become an essential component of modern agricultural practices across the globe. Tools such as mobile apps, AI-based advisory systems, remote sensing, GPS-enabled devices, and digital platforms now enable farmers to access real-time information, improve the efficient use of resources, and expand their access to markets (Chander et al., 2022). In India,

the agricultural sector is slowly evolving into the digital era, aided by governmental initiatives such as Digital India, AgriStack, e-NAM, and Kisan Sarathi, which seek to digitize services and provide farmers with timely and localized advice (GoI, 2024).

India's digital landscape is rapidly expanding. According to the Internet and Mobile Association of India (IAMAI, 2023), by mid-2022, the country had over 759 million people actively using the internet, with nearly 400 million of these users residing in rural

areas. Remarkably, Kerala is one of the leading states in India, distinguishes itself with high digital literacy, almost universal mobile phone usage, and more than 70 per cent internet penetration in its rural regions (TRAI, 2023). The state has achieved significant advancements through the Kerala Fibre Optic Network (KFON) initiative, aiming to offer free internet access to 2 million households, thereby enhancing its digital foundation.

Despite these advancements, the uptake of digital technology in agriculture is still limited, especially among small and marginal farmers, who make up the majority in Kerala. These farmers often depend on traditional knowledge sources in agriculture, like Krishi Bhavans, fellow agriculturalists, and input suppliers, and are less inclined to engage with digital advisory services due to reasons such as a lack of trust, language issues, limited exposure, or the perceived complexity of digital solutions (Harilal & Eswaran, 2015). Research conducted by Jena et al., (2024) has shown that digital competence is essential in influencing the capacity of extension personnel and farmers to incorporate technology into their practices.

In agriculture, a farmer's attitude toward digital technologies significantly influences their willingness and ability to adopt and utilize such tools. Fishbein & Ajzen (1975) further assert that attitude plays a key role in shaping behavioural intention, which in turn drives actual behaviour. To address this shortcoming, the current study employs the Digital Competency Framework developed by Ferrari & Punie (2013), which identifies five key components of digital competence pertinent to farmers. The first component, information, refers to the capability to locate, evaluate, and utilize digital agricultural information; the second, communication, pertains to engaging with peers, experts, and markets through digital channels; the third, continuous learning, indicates the ability to adjust to emerging technologies and improve digital skills; the fourth, technology adoption, signifies the willingness to accept and incorporate innovative digital solutions into farming methods; and the fifth, problem solving, involves the proficient use of ICT tools to identify and tackle farming-related challenges. By incorporating these elements into the measurement tool, the study aims to create a thorough, context-specific, and standardized instrument for assessing farmers' attitude towards the utilization of digital technologies in agriculture.

METHODOLOGY

The goal of this study was to develop a standardized scale to evaluate the attitude of farmers in Kerala regarding the use of digital technologies in agriculture. The research utilized the well-established Likert summated rating method (Likert, 1932), which is appropriate for evaluating psychological constructs like attitude (Thurstone, 1946). The research was conducted in Karuvatta Panchayat and Kayamkulam Municipality within Agro Ecological Unit 3: Onattukara Sandy Plain of the Coastal Plain Zone, involving a sample of 60 farmers (30 from each location). Initially, 68 attitude statements were compiled based on existing literature and expert opinions, addressing five elements of the Digital Competency Framework-Information, Communication, Problem Solving, Continuous Learning, and Technology Adoption. The relevance of these statements was assessed by 30 judges in the field of agricultural extension, retaining those with a Relevancy Weight

(≥ 0.843), Relevancy Percentage ($\geq 84.29\%$), and Mean Relevancy Score (≥ 4.215). This evaluation led to the selection of 56 statements for further item analysis.

These 56 statements were presented to the 60 farmers using a five-point Likert scale. The respondents were classified according to their total scores, identifying the top 25% (high group) and bottom 25% (low group) for conducting a critical ratio (t-value) analysis following Edward's (1957) methodology. Only the statements with t-values ≥ 1.75 were included, which resulted in a final scale of 20 items. To evaluate the internal consistency of the scale, Cronbach's Alpha was computed and yielded a value of 0.91, indicating excellent reliability. The validity of the scale was established through expert evaluation and comprehensive coverage of the five dimensions of digital competency. Therefore, the scale produced through this meticulous approach is both reliable and valid for evaluating farmers' attitude towards the adoption of digital technologies in agriculture.

RESULTS

The development of an attitude scale aimed at assessing Kerala farmers' attitude regarding the use of digital technologies in agriculture adhered to established psychometric methods, which included relevancy testing, item analysis, reliability assessment, and verification of validity.

Relevancy test

An initial set of 68 attitude statements was rated for relevancy by 30 Agricultural Extension experts using a five-point scale, and the results were computed using the following equations;

$$\text{Relevancy Weightage (RW)} = \frac{[(\text{MOR} \times 5) + (\text{MR} \times 4) + (\text{R} \times 3) + (\text{LR} \times 2) + (\text{NR} \times 1)]}{\text{Maximum possible score}}$$

$$\text{Relevancy Percentage (RP)} = \frac{[(\text{MOR} \times 5) + (\text{MR} \times 4) + (\text{R} \times 3) + (\text{LR} \times 2) + (\text{NR} \times 1)]}{\text{Maximum possible score}} \times 100$$

$$\text{Mean Relevancy Score (MRS)} = \frac{[(\text{MOR} \times 5) + (\text{MR} \times 4) + (\text{R} \times 3) + (\text{LR} \times 2) + (\text{NR} \times 1)]}{\text{Number of judges responded}}$$

MOS = Most Relevant, MR = More Relevant, LR = Less Relevant, NR = Not Relevant

Maximum Possible Score = Total number of judges $\times$ Maximum score per item = $30 \times 5 = 150$, Number of judges responded = 30

Criteria with MRS ≥ 4.215 , RP $\geq 84.29\%$, and RW ≥ 0.843 were chosen for the subsequent phase, while items that were repetitive or overlapped were either rephrased or omitted as advised by experts.

Item analysis

To create a dependable and valid attitude scale, conducting an item analysis is an essential process, as explained in Likert's scaling method. This technique determines how effectively individual statements can distinguish between respondents with positive and negative attitudes. After completing the relevance assessment, 56 statements related to attitudes were preserved and presented to 60 farmers from non-sample regions in Karuvatta Panchayat and Kayamkulam Municipality, which are situated in Agro Ecological

Unit (AEU) 3: Onattukara Sandy Plain within the Coastal Plain Agro Ecological Zone (AEZ) of Kerala.

Using a five-point Likert scale, participants reported their degree of agreement. After computing the overall attitude score for each individual, farmers were ranked from highest to lowest. The top 25% (20 farmers) and bottom 25% (20 farmers) were retained as criterion groups for item analysis, while the middle 50% were excluded, consistent with Edwards' (1957) procedure. The critical ratio (t-value) for each statement was then calculated using the Edwards (1969) method to determine discriminative effectiveness:

$$t = (X_H - X_L) / \sqrt{S_H^2/n_H + S_L^2/n_L}$$

Where, X_H = Mean score of the item for the high group

X_L = Mean score of the item for the low group

S_H = Variance of the high group for the item

S_L = Variance of the low group for the item

n_H & n_L = Number of respondents in high and low groups, respectively (in this case, 20 each)

Following the criteria established by Bird (1940), statements yielding a t-value below 1.75 were removed due to inadequate discriminatory power. Ultimately, items that achieved t-values ≥ 1.75

were chosen for inclusion in the final attitude scale. These items displayed a strong ability to differentiate between favourable and unfavourable respondents and were, therefore, deemed valid for evaluating farmers' attitudes towards digital technologies in agriculture. Consequently, the final standardized attitude scale consisted of 20 highly discriminating items with 10 positive and 10 negative statements, which together capture the varied views of Kerala farmers on the use of digital technology in agriculture.

Reliability of the scale

To ensure the robustness of the final attitude scale measuring farmers' attitudes toward the use of digital technologies in agriculture, its reliability was tested using Cronbach's Alpha. The resulting value of about 0.91 signifies excellent internal consistency, demonstrating that the items work cohesively to reflect the targeted construct.

Validity of the scale

Content validity was ensured through detailed expert judgment. A group of thirty experts assessed and rated the clarity and relevance of each item. Changes were implemented in response

Table 1. Final statements to assess farmers' attitude towards digital technologies in agriculture along with "t" values

Statements	Relevancy Percentage	Mean Relevancy Score	t-value
Information			
Identifying crop-specific pest and disease management practices is easier with ICTs	0.873	4.37	3.07
I believe farmers can efficiently access agricultural data through digital platforms despite language barriers, technical jargon, and complex interfaces (-)	0.867	4.33	2.19
Retrieval of multimedia information, like videos, benefits farmers more than text-based content	0.867	4.33	3.36
I believe digital platforms are necessary for the future growth of agriculture	0.906	4.53	2.04
Communication			
ICTs help farmers communicate with experts in real-time	0.853	4.27	3.65
ICT-based platforms promote transparent communication with stakeholders	0.886	4.43	1.78
Only resourceful farmers can fully benefit from the advantages of digital platforms (-)	0.853	4.27	2.43
Sharing successful farming practices on social media can create unrealistic expectations, pressuring farmers to adopt practices that may not suit (-)	0.86	4.3	2.78
Social media platforms are useful tools for farmers to share experiences and learn from others	0.853	4.27	1.95
I believe technology-driven agriculture benefits those with digital skills, putting traditional farmers at a disadvantage (-)	0.866	4.33	3.65
Technology Adoption			
ICTs facilitate easy access to agricultural credit and crop insurance	0.866	4.33	2.88
Farmers avoid mobile banking due to security fears, mistrust, and lack of awareness	0.88	4.4	3.96
Agricultural portals overwhelm farmers with excessive information, making decision-making difficult (-)	0.846	4.23	1.78
Continuous Learning			
I believe farmers can effectively apply online knowledge from ICTs even without hands-on, localized training (-)	0.866	4.33	2.19
Training on ICT tools increases farmers' confidence in their usage	0.853	4.27	2.44
I believe online communities and groups are well-moderated and provide accurate information, maintaining farmers' trust and supporting their decision-making (-)	0.846	4.23	2.20
Problem Solving			
ICT platforms identify the best practices tailored to local requirements	0.873	4.36	3.36
ICT based tools are best suited to value added services such as railway tickets, e-governance rather than providing agricultural information (-)	0.86	4.3	2.57
Digital platforms fail to bridge the gap, leaving remote farmers disconnected from the agricultural mainstream (-)	0.846	4.23	3.42
The transition to ICT-based extension services may exclude farmers who rely on face-to-face interactions, widening the knowledge gap for those unfamiliar with technology (-)	0.88	4.4	3.07

to their feedback. Given that the scale covers various facets of digital competency in agriculture and has been reviewed by experts, it is viewed as having robust content validity. The scale effectively measures what it purports to measure—the attitude of Kerala farmers towards digital technologies in agriculture.

DISCUSSION

In this research, we aimed to create and validate a standardized tool for measuring farmers' attitude regarding the adoption of digital technologies in agriculture. The study adopted a structured process of item generation, expert validation, and statistical analysis, consistent with methods used by Shitu et al., (2018); Chandra et al., (2024) & Vavilala et al., (2024). Iterative refinement, as emphasized by Gupta et al., (2023) & Kour et al., (2025), further ensured the scale's validity and contextual relevance. The developed scale demonstrated excellent internal consistency, with Cronbach's alpha at 0.91, confirming that the items measured the same underlying construct, similar to the robustness established by Sandeep et al., (2023) in digital agricultural services. Its validity, ensured through content validation and expert refinement, reflects the methodological rigor seen in Reddy et al., (2023) on climate-resilient dairy farming, thereby strengthening confidence in the tool's reliability and relevance.

The present scale also adds new value to the existing body of ICT-related attitude measures in agriculture. Earlier instruments focused on farmers' general attitude towards ICT use (Samatha et al., 2012), ICT-based extension services (Kumar & Ratnakar, 2011), or the perceptions of agricultural scientists (Pal et al., 2023). However, none effectively captured the multi-dimensional construct of digital competency. The current scale addresses this gap by integrating key dimensions such as information use, communication, technology adoption, continuous learning, and problem-solving. By doing so, it moves beyond binary measurement of positive or negative perceptions to assess the breadth of attitude and skill necessary for effective digital engagement in agriculture. Consequently, it serves as a practical tool for academic research, extension evaluations, and policy planning, particularly in benchmarking farmers' readiness for digital agriculture in Kerala. Despite its strengths, the scale is not without limitations. The reliance on content validity alone, while ensuring expert consensus, may restrict the generalizability of the results beyond the study region. Moreover, validation was conducted only within selected regions of Kerala, which may not reflect the diversity of India's farming contexts. The rapid and dynamic evolution of digital technologies also means that the items included in the scale may require periodic revision to remain relevant. Furthermore, prior standardization concerns caution against applying the tool directly outside India without additional testing. Nonetheless, these limitations provide opportunities for future research. Cross-regional testing, longitudinal studies, and the incorporation of qualitative insights could significantly enhance the robustness and applicability of the scale across diverse contexts. Overall, the final instrument offers a statistically sound and contextually appropriate means to evaluate farmers' attitudes towards digital technologies in agriculture, ensuring both academic utility and practical application in extension systems.

CONCLUSION

With the growing emphasis on digital transformation in agriculture, understanding farmers' attitudes towards digital technologies is essential for successful implementation and policy planning. The standardized attitude scale created in this study is specifically aimed at farmers in Kerala and provides a scientifically validated instrument for evaluating their attitude and willingness to adopt digital tools in agriculture. Developed through careful and systematic procedures that included expert validation, item analysis, and reliability testing, this scale achieved a high Cronbach's Alpha of approximately 0.91, signifying excellent internal consistency. Researchers, policymakers, and extension professionals can utilize this tool to carry out baseline surveys and make well-informed choices that promote the adoption of digital technologies in agricultural practices. Due to its strength and relevance in the context of agricultural digitalisation, this scale promises broader use in similar agro-ecological environments.

DECLARATIONS

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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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Psychometric Development of a Knowledge Test on Tick Infestation in Small Ruminants

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HIGHLIGHTS

- 30 out of 48 knowledge items met the selection criteria and were retained.
- Items with difficulty index (P) between 0.30–0.70 and discrimination index (D) above 0.30 were selected.
- Test items showed acceptable validity with point-biserial correlation values > 0.30.
- Test showed high reliability with a KR-20 coefficient of 0.9162.

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ABSTRACT

A test was developed to assess farmers' knowledge on tick infestation in small ruminants. Following the literature review, experts' input, and pilot findings, a list of 48 items was identified and screened for relevancy by experts, resulting in 36 items retained for item analysis. These items were pretested during 2024-25 on 60 purposively selected farmers from non-sampling areas using a direct interview method with dichotomous scoring of '1' for correct and '0' for incorrect response. Based on item difficulty and discrimination indices, 30 items were finalized. Validity of the instrument was established using point-biserial correlation, with all items exhibiting acceptable correlation values of more than 0.30. Reliability of the tool was measured by the Kuder-Richardson Formula 20 and was found to be excellent with the value of 0.9162. Finally, the test consisted of 30 well-structured items organized under six thematic dimensions of tick infestation. The developed test offers a valuable means to assess farmers' knowledge, serving as a foundation for developing targeted awareness and capacity-building interventions.

INTRODUCTION

India holds the distinction of having the largest goat population and the second-largest sheep population in the world (FAO, 2019). As per the 20th Livestock Census, the country is home to approximately 223.2 million small ruminants, including 148.9 million goats and 74.3 million sheep, reflecting a growth of 10.13 per cent and 14.13 per cent, respectively, since 2012 (DAHD, 2019). These animals are primarily reared for milk, meat and fibre, with India

producing 7.81 million tons of goat milk, 1.59 million tons of chevon, 1.14 million tons of mutton and 33.69 million kg of wool in 2023-24 (DAHD, 2024). Small ruminants are especially important for the livelihoods of resource-poor and marginalized rural households, serving not only as sources of food and income but also as liquid assets that can be converted into cash during times of financial need (Birthal & Taneja, 2012). Moreover, India stands as the largest exporter of chevon and mutton (Bhateshwar et al., 2022), having exported 11,027 metric tons valued at Rs. 646.66

crores in 2023–24 (APEDA, 2025). Despite their economic and social importance, small ruminant production in India faces several challenges, including poor social acceptance, lack of defined breeding policies, degradation of grazing lands, and inadequate veterinary and health management services (NAAS, 2021). Among the most critical issues are health-related constraints, particularly the prevalence of diseases and ectoparasites such as ticks, which significantly reduce productivity and profitability, especially among smallholder farmers (Makwarela et al., 2025). Ticks are blood-feeding ectoparasites that inflict direct damage through bites, blood loss, skin lesions, and reduced livestock performance in terms of growth and milk yield (Rajput et al., 2006). Additionally, tick infestations lead to hypersensitivity, anaemia, immunosuppression and secondary infections (Ghosh et al., 2007), along with a 20–30 per cent decline in the market value of damaged skins (Rashid et al., 2018).

Ticks and tick-borne diseases impose a significant global economic burden, contributing to estimated annual losses ranging from USD 22 to 30 billion through their detrimental effects on livestock health, productivity, fertility, and survival (Singh et al., 2022; Shahzad et al., 2025). In India alone, ticks and associated diseases represent a major economic burden to India's livestock sector, particularly in the dairy sector, estimated at approximately \$787.63 million USD annually (Singh et al., 2022). With nearly 80% of the global livestock population vulnerable to tick infestations, the issue represents a major constraint to livestock-dependent livelihoods worldwide (Wall & Shearer, 2001).

Currently, there is no standardized instrument available to assess farmers' knowledge regarding tick infestation in small ruminants. While previous studies have developed knowledge assessment tools for dairy animals (Kumari et al., 2023), the literature reveals a clear gap in measuring small ruminant farmers' understanding of tick infestation. To address this gap, the present study aimed to develop a valid and reliable test instrument capable of systematically evaluating farmers' knowledge on tick infestation in small ruminants.

METHODOLOGY

The knowledge test on tick infestation in small ruminants was developed using a standard procedure outlined in the ICAR Handbook of Agricultural Extension (Padaria et al., 2020). A total of 48 items related to tick infestation were initially compiled from scientific literature, expert consultations in veterinary sciences, personal experience, and findings from a pilot study. These items were subsequently revised and refined using standard guidelines proposed by Edwards (1969), ensuring each item was clear, relevant, and easy to understand.

Following initial screening, an expert panel comprising 30 subject matter specialists evaluated each item using a structured relevancy rating scale, in line with the methodology utilized by Vijayan et al., (2022). Each expert rated the items on a 5-point relevancy scale and from these ratings, relevancy measures (relevancy percentage, weighted relevancy scores and mean relevancy scores) were calculated for each item. The resulting selected items, structured as multiple-choice and yes/no questions, underwent a pilot test among 60 small ruminant farmers from non-sample areas in the Chhattisgarh Plain agro-climatic zone during 2024–25.

Participants responded to each item, and scores were assigned based on their correctness viz., for correct answers a score of '1' and for incorrect '0'. The sum of the scores from all participants for each item provided the basis for subsequent psychometric evaluation namely, difficulty index (P) and discrimination index (D) using established formulas.

$$P_i = \frac{k_i}{K_i}$$

Where, P_i = item difficulty index of the i^{th} item, k_i = total number of participants who responded correctly to i^{th} item, K_i = total number of participants

$$D = \frac{a_1 H - a_2 L}{a}$$

Where, D = item discrimination index, $a_1 H$ is the number of correct responses from the top 27 per cent of farmers (high scorers), $a_2 L$ is the number of correct responses from the bottom 27 per cent of farmers (low scorers) and a is the total number of farmers in these two groups.

Items with a moderate difficulty index (between 0.30 and 0.70) were preferred for inclusion, whereas items outside this range (too difficult, less than 0.30, or too easy, more than 0.70) were removed to maintain the effectiveness of the assessment. Similarly, items with a discrimination index above 0.30 were retained due to their effectiveness in distinguishing farmers' knowledge levels. Items below this threshold were considered insufficiently discriminating and therefore eliminated (Hopkins, 1998; Kline, 2000).

To further establish validity, point-biserial correlations ($r_p b$) were computed to evaluate the internal consistency of the test items. Mathematically, point-biserial correlation aligns with Pearson product-moment correlation and is used to measure the relationship between a dichotomously scored item and the total test score, thereby indicating internal validity (Khandelwal & Dangi, 2013).

$$r_p b = \frac{\mu_1 - \mu_0}{s} \sqrt{\frac{pq}{N}}$$

Where μ_1 = mean score of the group answered correctly, μ_0 = mean score of the group answered incorrectly, s = standard deviation of the total scores, p and q refer to the proportions of the sample in groups 1 and 0, respectively, and N = total number of observations

Since the response format was dichotomous, the internal consistency of the knowledge test was evaluated using the Kuder-Richardson Formula 20 (KR-20).

$$KR - 20 = \frac{t}{(t - 1)} \left[1 - \frac{\sum d_i q_i}{\sigma^2} \right]$$

Where, t = total number of test items, d_i = proportion of farmers that answered i^{th} item correctly, q_i = proportion of farmers that answered i^{th} item incorrectly, σ^2 = variance of the total scores.

RESULTS

Farmers' knowledge regarding tick infestation in small ruminants served as the foundational construct of the present study. To ensure comprehensive coverage, 48 items were compiled and organized across key thematic dimensions, including 'tick

biology and identification', 'tick ecology and transmission routes', 'clinical signs and symptoms in small ruminants', 'tick-borne diseases in small ruminants', 'zoonotic potential of ticks' and 'control and prevention'.

Expert-based relevancy evaluation

An expert panel assessed these items for relevance, appropriateness, and representativeness. Items were quantitatively evaluated based on relevancy percentage, weighted relevancy, and mean relevancy scores derived from their ratings. Items satisfying

predefined criteria (relevancy percentage >70%, relevancy weightage >0.70, and mean relevancy score >3.0) were retained. Accordingly, a total of 36 items qualified for the subsequent psychometric analysis.

Psychometric analysis of items

The selected items were subjected to psychometric evaluation based on the difficulty (P) and discrimination indices (D) calculated from respondents' data. Table 1 reflects 30 items selected as appropriate and relevant for the knowledge assessment tool after

Table 1. Psychometric properties of knowledge items on tick infestation in small ruminants

Items	P	D	$r_p b$	KR-20
Tick biology and identification				
What type of parasite is a tick?	0.32	0.75	0.58	0.9162
Other than ticks, what are the other external parasites that can infest small ruminants?	0.65	0.63	0.53	
Do ticks infest animal species other than small ruminants?	0.48	0.50	0.50	
In which developmental stage does a tick not require attachment to a host?	0.15*	—	—	
What do ticks feed on when they are attached to animals?	0.33	0.75	0.61	
Do ticks prefer soft or hidden areas on an animal's body for feeding?	0.42	0.56	0.44	
Tick ecology and transmission routes				
Can ticks survive in cracks and crevices of animal sheds?	0.35	0.56	0.43	
Are grazing areas, animal sheds and contact with infested animals are potential sources of tick infestation in small ruminants?	0.48	0.63	0.51	
During which season does the tick population generally increase?	0.65	0.81	0.64	
Does tick infestation vary between male and female animals?	0.63	0.69	0.59	
Are older animals more likely to have tick infestations than younger ones?	0.62	0.56	0.56	
Which of the following is the most likely way ticks attach to animals?	0.17*	—	—	
Clinical signs and symptoms in small ruminants				
What is a common early sign of tick infestation in small ruminants?	0.45	0.50	0.42	
Can untreated tick infestations lead to weight loss in animals?	0.53	0.75	0.60	
Can ticks cause anemia in heavily infested animals?	0.67	0.38	0.36	
Does tick infestation improve the productivity of small ruminants?	0.67	0.44	0.39	
Do some animals develop fever due to tick-borne infections?	0.73†	—	—	
In severe cases, can tick infestation lead to the death of the animal?	0.67	0.63	0.47	
Do ticks remain permanently on an animal's body unless removed or killed?	0.27*	—	—	
Tick-Borne Diseases in small ruminants				
Which type of pathogens can ticks transmit to animals?	0.58	0.50	0.49	
Do tick-borne diseases such as Babesiosis, Anaplasmosis, and Theileriosis affect small ruminants?	0.57	0.69	0.54	
What can happen if tick-borne diseases in small ruminants are left untreated?	0.62	0.56	0.46	
Can ticks spread diseases from one animal to another?	0.40	0.69	0.55	
What is a common consequence of tick-borne diseases in small ruminants?	0.55	0.75	0.64	
Zoonotic potential of ticks				
Can ticks bite both animals and humans?	0.48	0.81	0.66	
Which method helps to reduce the risk of tick bites in humans?	0.52	0.63	0.57	
How do humans typically contact tick-borne diseases?	0.52	0.69	0.56	
What are possible symptoms of tick bites in humans?	0.63	0.69	0.56	
Should a doctor be consulted after a tick bite?	0.65	0.75	0.61	
Can tick bites transmit diseases to humans?	0.43	0.25‡	—	
Control and prevention				
Can tick infestation in animals be identified by examining their body parts?	0.33	0.50	0.48	
Which method is commonly used to kill ticks on animals?	0.33	0.81	0.66	
Does regular use of acaricides help in preventing tick infestation?	0.67	0.19‡	—	
Should acaricides be used as per a veterinarian's advice?	0.32	0.63	0.49	
Can improper use of acaricides lead to resistance in ticks?	0.53	0.69	0.48	
Should new animals be quarantined before being introduced into the flock?	0.63	0.81	0.60	

Note: *items with P values <0.30; †items with P values >0.70; ‡items with D values <0.30

systematically removing items that failed to fulfill the established selection standards. Items 4, 12 and 19 were excluded due to their high difficulty levels ($P < 0.30$), while item number 17 was removed for being excessively easy ($P > 0.70$). Additionally, items 30 and 33 were discarded due to low discrimination indices ($D < 0.30$), indicating poor ability to differentiate between well-informed and less-informed respondents. Consequently, psychometric analysis resulted in the selection of 30 items, which were subsequently subjected to validity and reliability assessment for inclusion in the final knowledge assessment instrument.

Assessment of validity and reliability

The consistency of the final 30-item knowledge test was confirmed by establishing content validity through expert evaluations and construct validity using the point-biserial correlation coefficient (r_{pb}). All items demonstrated r_{pb} values greater than 0.30 (Table 1), indicating acceptable internal consistency and construct validity. Furthermore, the reliability of the test was assessed using the Kuder-Richardson Formula 20 (KR-20), which yielded a coefficient of 0.9162, well above the acceptable threshold of 0.70 and thus confirmed the high reliability of the instrument (Table 1).

Assessment of knowledge level

In total, the final test consisted of 30 carefully selected items organized under six thematic areas associated with tick infestation. This assessment aimed at determining the knowledge level among small ruminant farmers outside the primary sampling frame. Each respondent's knowledge score could vary from a minimum of 0 to a maximum of 30 score. The respondents' knowledge was classified into three distinct categories viz., high, moderate and low, based on equal score intervals (Table 2). Among the non-sample respondents, 36.67 per cent exhibited moderate knowledge, followed by 33.33 per cent with high and 30.00 per cent with low knowledge on tick infestation in small ruminants.

Table 2. Classification of farmers based on knowledge score

Knowledge category	Score range	Per cent (%)
High	21-30	33.33
Moderate	11-20	36.67
Low	0-10	30.00

DISCUSSION

The present study focused on the development and validation of a standardized instrument for assessing farmers' knowledge regarding tick infestation in small ruminants. The meticulous process began with an exhaustive identification of potential items across six comprehensive thematic dimensions. Including a wide range of relevant themes follows recommended test development practices and helps improve both the content coverage and accuracy of what the test measures (Boateng et al., 2018). Expert relevancy analysis resulted in a refined set of 36 items, indicating strong consensus among subject matter specialists about their appropriateness, clarity and representativeness. Similar methodological approach was employed by Kumar et al., (2016);

Kumari et al., (2023); Shruti et al., (2022); Vijayan et al., (2022) & Vijayan et al., (2023) in their study. Subsequent item analysis further strengthened the test's psychometric robustness by evaluating each item's difficulty and discrimination indices. Items that were either excessively difficult ($P < 0.30$) or overly easy ($P > 0.70$) were systematically excluded to maintain optimal test balance and effectiveness. Additionally, items exhibiting poor discrimination ($D < 0.30$) were discarded to ensure the test's capacity to distinguish effectively between respondents with varying levels of knowledge. Similar item analysis methodology was adopted by Kumari et al., (2023) & Roy et al., (2025). The finalized test comprised 30 items that demonstrated strong internal consistency and construct validity, confirmed through point-biserial correlation coefficients (r_{pb}) greater than 0.30 for all retained items. The high KR-20 reliability coefficient (0.9162), substantially exceeding the standard acceptance threshold (0.70), indicates excellent internal reliability of the developed test, thus making it a dependable measure for evaluating farmers' knowledge. The provisional findings suggested that a considerable proportion of small ruminant farmers in the non-sampled area had moderate knowledge about tick infestation. Probable factors contributing to this include limited formal education, absence of targeted training programs and low awareness of the zoonotic potential of ectoparasites and their capacity to transmit diseases to humans. The observed results align with earlier research that highlighted comparable deficiencies in knowledge among small ruminant farmers in relation to the management of parasitic infestations (Insyari'ati et al., 2024; Ullah et al., 2024; Ramzan et al., 2018; Sertse & Wossene, 2007). Similarly, Jadav (2021) observed that the majority of dairy farmers in Gujarat possessed only a medium level of knowledge concerning bovine ectoparasites. Overall, the developed knowledge test provides a reliable and valid tool for both diagnostic assessment and educational interventions. It can effectively identify knowledge deficiencies, thereby guiding targeted training programs and extension activities aimed at improving farmers' capacity to manage tick infestations sustainably. However, regional variability and socio-cultural factors influencing knowledge toward tick management should be considered when applying this instrument in broader contexts or diverse geographical settings.

CONCLUSION

Tick infestation remains a critical constraint to optimal productivity in small ruminant farming, primarily due to insufficient farmer awareness and knowledge. Addressing this knowledge gap, a context-specific test was developed to reliably assess farmers' understanding of tick infestation management. This instrument not only evaluates current knowledge levels but also informs targeted policies, training programs and extension interventions tailored specifically to farmers' needs. By identifying precise knowledge gaps, the test supports evidence-based decision-making aimed at improving tick management practices. Ultimately, enhanced farmer knowledge can lead to improved animal health, reduced tick burden and increased productivity and profitability. Thus, the developed knowledge test represents a valuable tool for future research, capacity-building and extension strategies in small ruminant health management.

DECLARATIONS

Ethics approval and informed consent: The experts to judge the items were well informed regarding the purpose and only the responses of the judges who consented have been included for analysis purpose.

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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A Scale to Measure Farmers' Perception of Capacity Needs under NICRA

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HIGHLIGHTS

- A standardized scale with 31 statements was constructed to measure farmers' perceptions of capacity needs under NICRA.
- The reliability coefficient of the scale was 0.955.
- The scale helps assess farmers' needs, aiding policymakers in designing effective climate-resilient training programs.

ARTICLE INFO

Keywords: Climate resilience, Capacity building, Perception scale, Extension services, Farmer training, NICRA initiatives, Adaptive strategies.

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ABSTRACT

A study conducted in 2024 developed and standardized a summated-rating scale to measure farmers' perceptions of capacity needs under the National Innovations in Climate Resilient Agriculture (NICRA) program. An initial pool of 155 statements was generated from literature and expert consultation, then screened by 100 judges (41 responses) and reduced to 80 items using a relevancy index threshold of ≥ 80 . The 80 items were pilot-tested with 32 farmers in a non-sampled area; item analysis followed Edwards' top/bottom 25 per cent t-test procedure, and 31 items with $t > 2.145$ were retained. The final instrument's reliability was assessed using the split-half method with 40 respondents (odd-even split), yielding a coefficient of 0.955. Criterion validity was examined by correlating perception scores with operational landholding; the correlation was moderate ($r = 0.531$), supporting the scale's validity. The resulting scale provides a consistent and interpretable measure of farmers' capacity-need perceptions under NICRA and can inform targeting of training, advisory, and monitoring interventions. The tool is adaptable to other locations and projects with minor contextual changes.

INTRODUCTION

Climate change causes major challenges to agriculture, particularly in regions dependent on consistent weather patterns (Ashoka et al., 2022; Kotir, 2011; Khan et al., 2025). In India the National Initiative on Climate Resilient Agriculture (NICRA) plays a good role in helping farmers adapt to climate variability by fostering practices that improve their resilience (Prasad et al., 2014; Hayat et al., 2025). NICRA, launched in 2011 by the Indian Council of Agricultural Research (ICAR), aims to make Indian agriculture more resilient to climate variability (Gupta, 2021). It promotes climate-resilient technologies in crops, livestock, fisheries, and natural resource management through activities such as technology

demonstrations, capacity building, custom hiring of machinery, weather-based advisories, and contingency planning. Implemented via KVKs, ICAR institutes, and State Agricultural Universities, NICRA covers four modules - Natural Resource Management, Crop Production, Livestock and Fisheries, and Institutional Interventions and provides a national platform for research, demonstration, and policy support. NICRA provides training, demonstrations, and on-farm trials that link research with real-world applications, thus considerably enhancing sustainable agricultural development and farmers' livelihoods (Prem et al., 2024). To make sure that the program successfully satisfies these requirements, it is crucial to comprehend how farmers view their needs for capacity building under NICRA (Nguyen et al., 2016). This involves assessing the

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extent to which NICRA's initiatives, such as information exchanges, trainings, and adaptive trials, assist farmers in implementing climate-resilient farming methods (Saini et al., 2020).

In the study, perception was defined as the meaningful recognition of the gap between the current availability and the required level of knowledge, skills, resources, and institutional support needed by farmers to effectively adapt to and mitigate the effects of climate change on agriculture. This recognition reflects the comprehension of what is necessary to achieve resilience and sustainability in agricultural practices amid changing climate conditions.

This research seeks to answer the question: "How can a reliable and valid scale be developed to measure farmers' perceptions of their capacity needs under NICRA?" The specific objective is to develop and standardize a perception scale that captures farmers' beliefs, feelings, and tendencies towards NICRA services. The tool, though not a needs assessment itself, is intended for future use in assessing such needs and generating data that can guide policymakers and practitioners in designing targeted and effective capacity-building programs. By providing a valid and reliable measure, the scale can support improvements in NICRA's effectiveness, ultimately strengthening farmers' resilience to climate change and promoting growth in the farming sector.

METHODOLOGY

The approach of summated rating was adopted for constructing the scale. A summated rating scale is a set of statements, each carrying distinct scores based on the degree of agreement or disagreement from subjects (Jaisridhar et al., 2013). This method was adopted for the present study because it avoids using a single statement to represent a concept (Harpe, 2015). Instead, multiple statements are used as indicators, each representing different facets of the concept, providing a more well-rounded perspective (Thakur et al., 2017).

A set of items and statements that elicit the perception of farmers' capacity needs under NICRA was compiled in consultation with experts in Agricultural Extension Education and officials of KVK. A preliminary list of 155 statements, consisting of 85 positive and 70 negative statements, was drafted, ensuring their relevance to the study area. These items were then meticulously revised according to the criteria proposed by Likert, and Edwards (1957), leading to the elimination of 21 statements. The remaining 134 statements were included for judges rating.

The relevancy of the items was determined by distributing the statements to 100 judges along with clear instructions. These judges were experts from agricultural universities and KVKs. They were asked to rate the relevance of each item in assessing farmers' perceptions of capacity needs under NICRA on a five-point scale: Most Relevant (MR), Relevant (R), Somewhat Relevant (SWR), Less Relevant (LR), and Not Relevant (NR), with corresponding scores of 5, 4, 3, 2, and 1, respectively and reverse scoring for negative statements. Of the 100 judges, 41 responded within two months. The scores for each item were aggregated across all respondents, and a relevancy index was calculated using the following formula:

$$\text{Relevancy index} = \frac{\text{Total score obtained on each item}}{\text{Maximum possible score}} \times 100$$

Items that achieved a relevancy index of 80 or above were selected, resulting in the retention of 80 items. Item analysis was then conducted on the selected statements, with the scale standardized by testing its reliability and validity. Item analysis is a set of procedures applied to determine the indices for truthfulness (or validity) of the items within a scale (Rezigalla, 2022). The t-test, as suggested by Edwards (1957) was used for item selection. This method was employed to evaluate the ability of each item to discriminate between high and low effectiveness groups of respondents.

The 80 items, based on the relevancy ratings provided by the judges, were administered to 32 farmer respondents in a non-sampled area, with responses collected using a five-point scale: 'Strongly Agree,' 'Agree,' 'Somewhat Agree,' 'Disagree,' and 'Strongly Disagree.' For the item analysis, two types of scores were utilized: the item score, referring to an individual's score on a specific item, and the total score, which is the sum of an individual's scores across all items. These scores were used to calculate the t-test.

The t-test reflects an item's ability to distinguish between respondents in the high-effectiveness and low-effectiveness categories. As suggested by Edwards (1957), the top 25 per cent of respondents with the highest total scores and the bottom 25 per cent with the lowest total scores were selected for analysis. The critical ratio (t-value) for each item was then calculated using the following formula:

$$t = \frac{\bar{X}_H - \bar{X}_L}{\sqrt{\frac{\sum(x_H - \bar{X}_H)^2 + \sum(x_L - \bar{X}_L)^2}{n(n-1)}}$$

Where, $\bar{X}_H$ = Mean of the score of an item for the high group, $\bar{X}_L$ = Mean of the score of an item for the low group, N = Number of subjects in a group

The developed scale was standardized by assessing its reliability and validity. In this study, the split-half method was utilized to test reliability. The scale was split into two halves based on the odd and even-numbered statements and administered to 40 respondents. The two sets of scores were then obtained, and Karl Pearson's product-moment correlation coefficient was calculated between them to determine the reliability of the scale. In this investigation, criterion validity was evaluated using the operational landholding of the farmers as the criterion.

RESULTS

The t-values for the 80 items were analysed to determine the most relevant statements for the final scale. As shown in Table 1, 31 items had t-values above 2.145 and were selected for inclusion in the final scale. To ensure the scale accurately measures the intended construct and maintains consistency in measurements, it was standardized by evaluating its reliability and validity. The reliability coefficient of the test was 0.955, indicating a high level of reliability. This suggests that the scale provides consistent results and is suitable for assessing farmers' perceptions of capacity needs under NICRA.

The scale was developed through a systematic examination of its content to ensure it represented a comprehensive sample of the

Table 1. Final Items included in the perception scale

S.No.	Items	t value
1.	Familiarity with integrated crop management approaches through training is highly advantageous for me.	2.16
2.	Training on pest and disease management methods is highly beneficial for me.	2.72
3.	Familiarity with human nutrition and childcare practices through training is not beneficial for me. (-)	5.49
4.	Training on climate change did not enable me to actively engage in NICRA project tasks. (-)	2.81
5.	Less emphasis should be placed on the horticultural sector. (-)	2.55
6.	Training on fodder and feed management practices is not beneficial for me. (-)	2.17
7.	Learning about natural resource conservation methods through training is not advantageous for me. (-)	2.30
8.	Learning livestock and fishery management techniques through training is not beneficial for me. (-)	2.41
9.	Understanding drudgery reduction methods for women in agriculture through training is not beneficial for me. (-)	3.05
10.	Proficiency in nursery raising practices through training is not beneficial for me. (-)	3.99
11.	Training on crop diversification strategies is highly beneficial for me.	2.35
12.	The training themes don't correspond well with my farming activities. (-)	6.14
13.	I believe using field days for showing technology related to climate change adaptation is necessary for effective climate change adaptation in the village.	2.64
14.	I think dissemination through electronic media is occasional.	2.30
15.	I support group discussions are the highly effective training method.	5.96
16.	I think fields of successful farmers are not suitable venues for effective training. (-)	2.25
17.	I believe using farmer field school extension approaches for developing farmers' problem-solving skills is necessary for effective climate change adaptation in the village.	4.12
18.	I feel scientists are not effective trainers. (-)	4.68
19.	I think video lessons are the highly effective training method.	2.25
20.	I feel training for more number of days at a stretch are not much effective.	2.91
21.	I believe agro-advisory services are helping less number of farmers. (-)	2.57
22.	I believe that in-person monitoring really helps the project.	2.35
23.	In my view, monitoring and evaluation play a crucial role.	3.47
24.	I perceive that the primary function of the monitoring committee is to evaluate and offer recommendations.	4.91
25.	I believe that additional training would enhance my understanding of the complexities of adaptation interventions.	2.39
26.	I think there ought to be a designated budget allocated specifically for exposure visits.	2.57
27.	I feel that capacity building should be organized in a more systematic manner.	4.53
28.	ICT plays a vital role in effectively reaching out to people.	4.85
29.	I feel that greater attention should be given to capacity building for farm women.	2.30
30.	There is a necessity to shift away from conventional methods of project activities.	2.29
31.	I find the distribution of soil health cards to be greatly beneficial.	2.43

(-) Negative statements

domain being measured. Essential items reflecting farmers' capacity needs were included, confirming content validity. The perception scores were compared with the operational landholding of 40 non-sampled respondents. Pearson's product-moment correlation coefficient ($r = 0.531$) confirmed the validity of the scale.

The final scale consisted of 31 statements arranged in random order. Respondents indicate their responses using a five-point Likert scale: Strongly Agree (5), Agree (4), Somewhat Agree (3), Disagree (2), and Strongly Disagree (1) for positive statements, with reverse scoring for negative statements. The total score for each respondent is computed and classified into high, medium, or low perception levels based on predefined score ranges.

DISCUSSION

The selection of 31 statements based on t-values above 2.145 ensures that the final scale retains only the most significant items, improving its precision in assessing farmers' perceptions. The high reliability score (0.955) indicates strong internal consistency, suggesting that the scale will yield stable results across different applications. The reliability of the present scale is higher than that reported by Salam et al., (2025) in their scale for assessing farmers'

attitude towards indigenous cattle conservation and Kour et al., (2025) in their attitude towards the maize and wheat crops. The reported values were also less in case of Shitu et al., (2018) & Gupta et al., (2022). The content validity of the scale was established by carefully selecting statements that comprehensively represent farmers' capacity needs under NICRA. The criterion validity, supported by a moderate correlation ($r = 0.531$) with operational landholding, further confirms that the scale effectively captures the intended perception construct.

The administration procedure ensures a structured and quantifiable assessment of perceptions. The five-point Likert scale allows for nuanced responses, while the categorization into high, medium, and low perception levels enhances interpretability. This standardized approach ensures that the scale can be effectively used in future research and policy assessments related to capacity-building interventions under NICRA.

CONCLUSION

A scale was developed and standardized to measure farmers' perceptions of their capacity needs under NICRA. The scale was identified to be both reliable and valid. This tool will quantify

farmers' perceptions regarding their capacity needs, and the data obtained can be replicated in similar projects with minimal modifications. Ultimately, this will aid in formulating strategies to effectively mitigate the consequences of climate change on agriculture and support farmers.

DECLARATIONS

Ethics approval and informed consent: The experts to judge the items were well informed regarding the purpose and only the responses of the judges who consented have been included for analysis purposes.

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 a Knowledge Test on Scientific Walnut Cultivation

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HIGHLIGHTS

- The developed knowledge test provides valuable insights in making logical decisions towards any psychological objects, as it will act as a diagnostic tool to ascertain the knowledge gaps.
- Reliability coefficient through the split-half method yielded the highly reliable value of 0.90, whereas the reliability coefficient using Cronbach's alpha (0.83) was within the good range of internal consistency.
- The value of Scale- content validity index (S-CVI) was 0.89, which falls near the excellent range.

ARTICLE INFO

Keywords: Knowledge, Difficulty index, Discrimination index, Reliability, Validity, Internal consistency.

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ABSTRACT

Knowledge is the foundation for shaping attitudes, encouraging adoption of innovations, and guiding logical decision-making. Since knowledge forms the first step in the innovation-diffusion process, followed by persuasion and attitude change. In 2024, a study was carried out in the Pulwama district of the Kashmir region of J&K UT to design a knowledge test for systematic walnut growers with the aim to assess their understanding of various production recommendations. The test was developed using standard psychometric methods to ensure accuracy and reliability. Initially, 32 knowledge-based statements were framed with the help of subject experts. Each statement was analyzed using the difficulty index and discrimination index, which helped identify the most suitable for effectively measuring farmers' knowledge. Based on this analysis, 14 statements were retained for the final test. To check reliability, the split-half method was applied, yielding a high reliability coefficient of 0.90, using the Spearman-Brown prophecy formula. Furthermore, internal consistency was assured using Cronbach's alpha, which gave a coefficient of 0.83. It confirmed that the knowledge test was both reliable and valid, making it a strong tool for evaluating the knowledge of walnut growers.

INTRODUCTION

The economy of Jammu and Kashmir is strongly supported by horticulture, which contributes between Rs. 5,000 and Rs. 7,000 crores annually to the region's GDP (Bhat et al., 2019). This sector plays a vital role in enhancing the livelihoods of small and marginal farmers, serving as one of the major sources of income in the region. Among the various horticultural crops, walnuts occupy a prominent position. The walnut (*Juglans regia* L.), belonging to the family

Juglandaceae, is one of the most important tree nuts in global trade. While the English walnut (*J. regia*) traces its origin to Persia (present-day Iran), the black walnut (*J. nigra*) is native to Eastern - North America.

Globally, China is the leading producer of walnuts, contributing about 1.1 million metric tons in 2021–22, followed by the United States with 657.71 thousand metric tons. India ranked seventh with a production of about 36 thousand metric tons (Shahbandeh, 2022). In India, Jammu and Kashmir dominates walnut cultivation,

accounting for nearly 98 per cent of the country's total output, with smaller contributions from Himachal Pradesh, Uttarakhand, and Arunachal Pradesh. Despite holding this near-monopoly in India, the walnut industry in Jammu and Kashmir has witnessed a decline in both production and exports. For instance, walnut exports fell from 3,292 MT in 2015–16 (valued at Rs. 117.92 crores) to just 1,504.87 MT in 2018–19, fetching only Rs. 55.02 crores (DOS, 2020–21) which may be due to the non-adoption of scientific walnut cultivation practices. Lack of scientific knowledge regarding different cultivation practices may be one of the main reasons leading to its decline in its production and export. Thus, the devised knowledge test will act as a benchmark for assessing the knowledge gaps in production, protection and post-harvest practices of walnut. Furthermore, walnuts represent a crucial cash crop for the people of Jammu and Kashmir and significantly influence their economic well-being. Therefore, addressing these knowledge gaps is essential. So, in this direction an attempt was made to formulate the knowledge test for assessing the same and will help in guiding future interventions to enhance walnut production and improve the economic resilience of growers in the region.

METHODOLOGY

In the current study, “farmers’ knowledge” refers to the degree of understanding that a particular farmer has on the various methods used in walnut farming. Once knowledge is gained, it causes a person's thought process to alter, which in turn causes a change in attitude and aids the farmer in making logical decisions and adopting any agricultural intervention. It has been evaluated based on how well the farmer answered the knowledge test statements, and for that purpose research tool was formulated. According to Roy & Mondal (1999), a test consists of a series of questions with proper answers for each like those who answered correctly were given 1, and those who did not answer the item correctly were given 0. The knowledge test formulation includes processes like item collection, item analysis, which includes the difficulty index and the discrimination index. For calculating the reliability of the research tool, the Split-half method and Cronbach's Alpha were also calculated. After which, the final statements that fall within the range were retained. For validity, 40 items were sent to a panel of 25 judges, experts in the field of extension education with a request to critically scrutinize and evaluate each item for its relevancy, out of which 10 experts responded who had critically scrutinized and evaluated the knowledge tool. The judges were requested to give their response on 4-point continuum viz, 1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = highly relevant). The relevance score of each item was calculated by using Lynn's scale, in which the item content validity index (I-CVI) and scale content validity index (S-CVI) were calculated. After calculating the item content validity index (I-CVI) and scale content validity index (S-CVI), only 14 statements were valid.

Firstly, 32 knowledge statements were developed after thorough consultations with relevant literature. The selection of items was based on their representativeness, simplicity, and apparent absence of ambiguity. Domain specialists were consulted throughout the framing knowledge test statements. The purpose of knowledge test statements is to distinguish between well-

informed respondents and those who are not; they were designed to encourage critical thinking rather than memorization. Based on the two mentioned criteria above, a total of 32 knowledge test statements were first made to elicit the response from non-sampled respondents. Every item that was gathered to create the knowledge test was in the right combination and appropriate mix.

Two types of information are often obtained from a test's item analysis: item discrimination and item difficulty. While the item difficulty index shows how challenging a particular item is, the discrimination index shows how much an item separates respondents with good knowledge from those with low knowledge. The knowledge test was administered on walnut growers of non-sampled area. The knowledge score of each walnut grower was obtained by counting the correct answers provided by a particular farmer. Every respondent who answered the correct answer was given a score of 1 and 0 otherwise (Kour et al., 2022). The possible scores ranged from 0 to 32. Afterwards, the total scores of all the respondents were arranged in descending order and six groups were formed, each having six respondents. The corresponding names of these groups were G1, G2, G3, G4, G5, and G6. The middle two groups, G3 and G4, were eliminated for item analysis. Four extreme groups with high and low scores were considered, after calculating item difficulty and discrimination.

The difficulty index for a knowledge test statement was the percentage of respondents who correctly answered that specific question. This was determined using the formula as given below:

$$P_i = \frac{N_i}{N_i} \times 100$$

Where P_i = Difficulty index in percentage of i^{th} item, n_i = Number of walnut growers gave correct answer

N_i = Total no. of walnut growers to whom i^{th} item is administered.

The difficulty index of all the knowledge test statements included for item analysis was calculated.

For calculation of discrimination index, the formula used by Verma et al., (2018); Rani et al., (2020) as given below:

$$E^{1/3} = \frac{(S_1 + S_2) - (S_5 + S_6)}{N/3}$$

Where, $E^{1/3}$ is the discrimination index, S_1, S_2, S_5 and S_6 indicated the frequencies of correct answers given for the respective G_1, G_2, G_5 and G_6 groups of respondents respectively for an item in the test.

N = Total number of respondents to whom the item was applied.

When a respondent answered an item correctly, it was assumed as that item was less difficult than his ability to cope with it (Coombs, 1950). For the knowledge test, items with discrimination index 0.20 to 0.80 and difficulty index ranging from 20 to 80 per cent were retained. Thus, 14 items were retained for the assessment of knowledge based on discriminating index and difficulty index. However, keeping in mind the importance of other knowledge test statements in the research pursuit 14 out of 18 valid statements, whose CVI also falls within the valid range were retained as per the recommendations of domain experts and the advisory committee members. Therefore, the final knowledge test comprised of 28 statements.

The test's content validity was judged. According to Kerlinger (2004), content validity refers to the representativeness and sampling adequacy of a measuring instrument's content, substance, and themes. The test's content validity was determined to be satisfactory because it was based on numerous literatures and submitted to varying expert opinions. The content validity index CVI is calculated by using Lynn Method (1986), based on 4-point relevance scale i.e., 1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = highly relevant). In this method, firstly the item content validity index (I-CVI) and scale content validity index (S-CVI) was calculated by using the formula given below:

$$\text{Item-Content Validity Index I-CVI} = \frac{\text{Number of experts rating 3 or 4}}{\text{Total number of experts}}$$

Valid items are those with I-CVI ≥ 0.78 (Lynn's rule of thumb for adequate content validity when panels are ~6+ experts)

$$\text{Scale - level Content Validity Index (S-CVI)} = \frac{\sum \text{I-CVI}}{\text{Total items}}$$

According to Lynn (1986), S-CVI ≥ 0.80 = Acceptable, S-CVI ≥ 0.90 = Excellent

According to Kerlinger (2004) reliability refers to the consistency and stability of a measurement or research instrument over time. It indicates the degree to which an instrument yields the same results under consistent conditions. Reliability refers to a measuring instrument's accuracy or precision. According to Guilford (1954), a test is considered trustworthy when it regularly produces the same results when applied to the same sample. For the present study, reliability was determined by applying split-half method and Cronbach's alpha method.

Split-half method

In this method, the test was divided into two equal halves. One half contains odd numbered items and other half contains even numbered items. Then Pearson correlation formula given below was put forth to calculate the half test reliability.

Pearson's Correlation (without mean method):

$$r = \frac{\{N \sum XY - (\sum X)(\sum Y)\}}{\sqrt{\{(N \sum X^2 - (\sum X)^2)(N \sum Y^2 - (\sum Y)^2)\}}}$$

Where, N = number of respondents

$\sum XY$ = sum of cross-products of paired scores

$\sum X, \sum Y$ = sums of scores on each half

$\sum X^2, \sum Y^2$ = sums of squared scores

The value of correlation coefficient (r) was 0.824 which indicates the reliability of half-length test. After which Spearman Brown prophecy was used to calculate the reliability of full-length test which yielded the value of 0.90 by using the formula given below. The value of reliability $r_{xx} = 0.90$ which indicates that the test is highly reliable. Typically, 0.70 or above is considered acceptable in social sciences (Nunnally & Bernstein, 1994).

$$r_{xx} = \frac{2 \times r_{hh}}{1 + r_{hh}}$$

Where, r_{xx} = reliability of the full-length test

$r_{1/2}$ = correlation between two half score

Another method which was used to calculate the internal consistency of the test items were Cronbach's alpha. Cronbach's alpha (α), introduced by Lee J. Cronbach (1951), is a measure of internal consistency reliability of a test or scale. It assesses how closely related a set of items are as a group, indicating the degree to which items measure the same underlying construct. A higher alpha value suggests greater reliability. Interpretation guidelines given by Lee J. Cronbach:

$\alpha \geq 0.90 \rightarrow$ Excellent

$\alpha \geq 0.80 \rightarrow$ Good

$\alpha \geq 0.70 \rightarrow$ Acceptable

$\alpha \geq 0.60 \rightarrow$ Questionable

$\alpha \geq 0.50 \rightarrow$ Poor

$\alpha < 0.50 \rightarrow$ Unacceptable

Then Cronbach's alpha was calculated by using the formula given below:

$$\alpha = \frac{k}{k-1} \times \left(1 - \frac{\sum \sigma^2 y_i}{\sigma^2 x}\right)$$

α = Cronbach's alpha,

k = Number of items (questions) in the test

$\sigma^2_{j^2}$ = Variance of the scores for the j^{th} item

$\sigma^2_{T^2}$ = Variance of the total test scores (sum of all items)

Σ = Sum over all items

RESULTS

The Content Validity Index (CVI) was calculated for each item and for the overall scale using Lynn's (1986) method. The I-CVI values for each of the 40 items, as formulated through the expert panel, are presented below in Table 1. The Scale-CVI (S-CVI) computed across all 40 test items was 0.84, indicating acceptable content validity. When only the 32 items that met the minimum acceptable I-CVI threshold were considered, the Scale-CVI increased to 0.89, demonstrating stronger overall content validity for the refined set of items. For the knowledge test, items with a discrimination index of 0.20 to 0.80 and a difficulty index ranging from 20 per cent to 80 per cent were selected. Thus, 14 items were selected for the final knowledge test as shown in Table 2. Furthermore, the reliability of the knowledge test was calculated using the split-half method, in which the Spearman-Brown prophecy formula was applied (Kerlinger, 1973). The full test reliability yielded a value of 0.90, which indicates that the test was highly reliable. Cronbach's alpha was also put forth to determine the test's internal consistency, which was found to be 0.83, which falls within a good range of internal consistency, indicating that the test was reliable (Nunnally & Bernstein, 1994). However, keeping in mind the importance of other knowledge test statements in the research pursuit, 14 out of 18 valid statements, whose CVI also falls within the valid range were retained as per the recommendations of domain experts and the advisory committee members. Therefore, the final knowledge test consisted of 28 statements.

Table 1. Item-level content validity index

Item no.	I-CVI	Item No.	I-CVI	Item No.	I-CVI	Item No.	I-CVI
1	0.50	11	1.00	21	1.00	31	0.90
2	1.00	12	1.00	22	0.90	32	0.90
3	1.00	13	0.90	23	0.90	33	0.80
4	0.60	14	0.90	24	0.60	34	0.80
5	1.00	15	0.80	25	0.80	35	0.80
6	1.00	16	0.90	26	0.80	36	0.80
7	0.70	17	0.80	27	0.90	37	0.80
8	0.70	18	0.60	28	0.90	38	0.80
9	0.70	19	0.80	29	0.90	39	0.90
10	0.70	20	0.80	30	0.90	40	0.60

Table 2: A test to gauge the knowledge of walnut growers towards walnut cultivation

S.No	Statements	Difficulty Index (P_i)	Discrimination Index ($E^{1/3}$)
1.	What should be the ideal dimensions of a pit for a walnut tree	63.66	0.59
2.	Which of the following planting systems are used	72.22	0.67
3.	Which of the following planting system is used for walnuts in undulating areas	58.33	0.25
4.	In which month FYM should be applied to the walnut trees	61.11	0.64
5.	How much urea is required for your walnut trees	30.55	0.50
6.	How much MOP is required for your walnut trees	22.22	0.24
7.	What is the best time to apply the first half dose of urea	50.00	0.66
8.	What is the training system of walnut	66.66	0.75
9.	Name any insect that occurs in walnut	66.66	0.75
10.	What is the management strategy for that insect pest damage	69.44	0.50
11.	Name any disease that occurs in walnut	36.11	0.66
12.	What is the management strategy for that disease	41.66	0.58
13.	Name the chemical that should be used as pre-harvest treatment of walnut	38.88	0.42
14.	What are the methods of dehulling walnut	69.44	0.57

DISCUSSION

Knowledge test statements were formulated with input from domain experts after analyzing item difficulty and discrimination indices. Content validity was established by identifying key subject matter areas through an extensive review of relevant literature and consultations with subject matter experts to find the relevancy of the items by calculating item content validity index (I-CVI), scale content validity index (S-CVI) following the methodological framework outlined by Lynn (1986); Polit & Beck (2006) & Polit et al. (2007); Velamuri et al., (2024). To ensure the reliability of the instrument, both the split-half method and Cronbach's alpha were employed, confirming a high level of internal consistency following the methodological frameworks outlined by Roy et al., (2025); Vijayan et al., (2022); Vijayan et al., (2023); Anshida et al., (2022); Ghouse et al., (2022) & Kumar et al., (2016) & Chandhana et al., (2022). The finalized knowledge test includes a comprehensive set of well-structured and validated statements that reflect the critical domains of walnut cultivation including varietal selection, orchard management, pest and disease control and post-harvest practices. This test instrument is both valid and reliable for assessing the knowledge level of walnut growers. It also serves as a practical diagnostic tool for identifying specific knowledge gaps, thereby informing the design of targeted capacity-building and extension programs. For example, if a large proportion of growers answer orchard management questions correctly but struggle with post-harvest practices, the test clearly diagnoses a knowledge gap in post-harvest handling.

CONCLUSION

It is a matter of concern that there is drop in demand of walnut due to the lack of quality and uniformity in the size of walnut kernel which also hampers the export industry. The knowledge test developed is of immense utility in extracting information about the major concerning areas that needs to be addressed so that walnut industry may not dip further. The knowledge test so developed will act as a benchmark in assessing the knowledge gaps of walnut growers regarding different production, protection and post-harvest practices. Moreover, this devised knowledge test will help the field extension functionaries of straight-lined departments and other concerned stakeholders to formulate the need-based training programmes for the farmers to mitigate the knowledge gaps in walnut production technologies.

DECLARATIONS

Ethics approval and informed consent: The experts to judge the items were well informed regarding the purpose and only the responses of the judges who consented have been included for analysis purposes.

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 Standardization of a Scale to Measure Vegetable Growers' Attitude towards Safety Measures in Pesticide Application

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HIGHLIGHTS

- The attitude scale with 52 items was created with 0.82 reliability coefficient value.
- Selection and transportation, storage, precautions during preparation and application, precautions after application, disposal of containers, environmental protection, health and safety, record keeping and monitoring, pesticide regulations, education and training, and first aid and emergency response were included as major dimensions.
- The items were selected on the basis of relevancy percentage, relevancy weightage and mean relevancy score (MRS) for all statements.

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ABSTRACT

The study aimed to develop a scale for assessing the attitude of vegetable growers towards safety measures in pesticide application was conducted during 2024. A total of 110 statements were initially framed under eleven dimensions: Selection and Transportation, Storage, Precautions during Preparation and Application, Precautions after Application, Disposal of Containers, Environmental Protection, Health and Safety, Record Keeping and Monitoring, Pesticide Regulations, Education and Training, and First Aid and Emergency Response. These were evaluated by 60 judges, based on their judgment and subsequent item analysis, 52 statements were retained after calculating the t-values. The scale was constructed using the Likert methodology, yielding an overall mean relevancy score of 2.50. A pilot test was conducted with 60 vegetable growers from a non-sampled area, setting the cut off value for item selection at equal or more than 1.75 t-value. Reliability was assessed using the split-half method, which yielded a coefficient value of 0.82. This result was further verified using the Spearman-Brown formula, producing a value of 0.89, thereby confirming the reliability of the scale. In addition, the Cronbach's alpha value of 0.86 indicated a high level of internal consistency in the developed scale.

INTRODUCTION

Pesticides played a vital role in enhancing crop yields and ensuring food security in India (Arora, 2018; Kumar et al., 2025). In vegetable cultivation, insect pests and diseases remain serious challenges, accounting for 10–30 percent yield losses (Roy et al., 2017). To manage these problems, most Vegetable growers

rely heavily on chemical pesticides, making vegetable farming one of the most pesticide-intensive agricultural activities due to the high susceptibility of vegetables to pests and diseases (Meenakshi & Saini, 2022). However, the gap between recommended scientific practices and actual pesticide use by Vegetable growers is considerable. Indiscriminate and unsafe pesticide practices pose serious risks to human health,

environmental sustainability, and agricultural ecosystems (Mishra et al., 2021; Pathak et al., 2022). Research consistently highlights that while Vegetable growers recognize the necessity of pesticides, their compliance with safety measures—such as the use of personal protective equipment (PPE), safe storage, proper disposal of containers, and adherence to label instructions—remains unsatisfactory (Hossain et al., 2024). Even trace levels of pesticide residues in vegetables may cause long-term health risks to consumers (Gupta et al., 2008; Gupta et al., 2010). Several studies in India have documented this paradox: although Vegetable growers are aware of pesticide hazards, they continue unsafe practices. For instance, in Haryana, more than 77 per cent of vegetable growers acknowledged the harmful effects of pesticides, yet most were unable to interpret toxicity color codes or follow label instructions, which led to frequent cases of acute poisoning (Meenakshi & Saini, 2022). These findings highlight the urgent need for interventions that address not only Vegetable growers knowledge but also their attitudes toward safe pesticide use. Integrated Pest Management (IPM) has emerged as a sustainable alternative to excessive reliance on chemical pesticides. Promoted through national programs, Krishi Vigyan Kendras (KVKs), and state extension agencies, IPM emphasizes biological control, cultural practices, and judicious pesticide application (Meenakshi & Saini, 2022). However, successful adoption of IPM depends largely on Vegetable growers positive attitudes toward safety and sustainability. Studies indicate that while awareness of IPM is gradually improving, adoption remains limited due to entrenched attitudes that favour chemical pesticide use (Gupta et al., 2020). Therefore, a systematic measurement of Vegetable growers attitudes toward pesticide safety—including IPM practices—is crucial for designing targeted interventions. Although several Knowledge, Attitude, and Practice (KAP) studies have explored pesticide use among Indian Vegetable growers, there is still a paucity of standardized instruments to specifically assess vegetable growers attitudes toward safety measures. A rigorously developed and validated attitude scale can fill this gap by capturing multidimensional aspects of pesticide safety, including handling, storage, application, post-application precautions, container disposal, health and environmental protection, and adherence to regulatory norms. Recognizing this need, the present study seeks to develop and standardize an attitude scale to evaluate vegetable growers attitudes toward safety measures in pesticide application.

METHODOLOGY

The developed scale systematically incorporated all dimensions of pesticide safety measures, including Selection and Transportation, Storage, Precautions during Preparation and Application, Precautions after Application, Disposal of Containers, Environmental Protection, Health and Safety, Record Keeping and Monitoring, Pesticide Regulations, Education and Training, and First Aid and Emergency Response. The standardized attitude scale was constructed using the Likert method of summated ratings (Likert, 1932) with a five-point psychological continuum to measure the attitude of vegetable

growers towards the safe use of pesticides. A pool of 110 statements was generated from diverse sources such as literature, interactions with scientists, extension professionals, NGO personnel, government officials, Vegetable growers, teachers, senior citizens, and other stakeholders. These items were screened following the 14 informal criteria for attitude statement construction proposed by Likert (1932) and Edwards (1957), resulting in 52 items relevant to the study. The selected statements were arranged in a five-point continuum and compiled into a questionnaire. For expert evaluation, the questionnaire was distributed to 90 professionals, of whom 60 with specialized expertise in extension education responded. Their feedback was used to finalize the tool for the pilot study. Data were collected through interviews with 60 vegetable growers, and t-values were calculated. Items with a t-value ≥ 1.75 , as suggested by Edwards (1957), were retained for the final scale. For relevancy testing, statements were rated on a five-point continuum ranging from “Most Relevant” (5) to “Not Relevant” (1). The mean relevancy score was computed, and statements with an average score of ≥ 2.50 were retained. Item analysis was carried out following Edwards’ (1957) procedure using the critical ratio (t-test) method to determine the discriminating power of each item. Respondents were divided into high and low groups (top and bottom 25%), and statements with a t-value ≥ 1.75 (Bird, 1940) were selected.

A systematically developed scale was finalized with the support of 60 experts in extension education, who reviewed the revised statements and provided their judgment for selecting the most appropriate items. Ultimately, 52 statements under 11 dimensions were retained to assess the attitude of vegetable growers towards the safe use of pesticides. The Cronbach’s alpha coefficient was calculated. The scale was then administered to 60 vegetable growers from non-sampled areas. Reliability was further tested through the split-half method, where the items were divided into two sets based on odd and even numbers, and the reliability coefficient was computed using the prescribed formula.

RESULTS

Table 1 presents the t-value estimation of the selected items, which include statements reflecting the attitude of vegetable growers towards safety measures in pesticide application. To standardize the scale, both reliability and validity were assessed using established techniques, including the split-half method (Spearman-Brown coefficient), Pearson’s correlation coefficient, and Cronbach’s alpha. Expert judgment was also used to ensure content validity.

Validity and reliability analysis

Reliability testing, the split-half method was employed following the approach of (Shitu et al., 2018; Shelar et al., 2022; Sushree et al., 2024 & Vavilala et al., 2024). The statements were divided into two groups based on odd and even numbered items and administered to 60 respondents. The scores of the two sets were correlated using Pearson’s product moment correlation, which yielded a value of 0.82. This was further verified through the Spearman-Brown formula, resulting in a reliability coefficient

Table 1. Selected Statements and t values

Item statements	t-value
<i>Selection and Transportation of pesticides</i>	
Before selection of any pesticides, the causal organism(s) / pest(s) (insects/ diseases/ nematodes) has properly been identified.	3.82
For the same I consult agricultural officer of our area.	
After identification, I purchase recommended pesticides of its recommended formulations against the said pest.	2.44
I always purchase the required amount of pesticides required for the current cropping season.	3.23
I agree that pesticide shop owners often suggest two or more pesticides for managing any particular pest when seek for management of any pest.	3.43
Proper care has been taken while carrying pesticides. All containers/ packets are tightly closed.	3.52
<i>Storage of pesticides</i>	
I always store the pesticides in their original containers and keep their label intact and legible.	1.80
I never store the pesticides where food, feed, seed, water and medicines can become contaminated or living room or in kitchen.	2.96
I store the pesticides in dry, well- ventilated place which is away from sun light.	3.51
I store the pesticides in separate storage room or cabinets/ cupboards under locked condition so that they are away from reach of children, mentally retarded people, pets etc.	2.79
Before entering the pesticide store room, I open its doors & windows and wait for at least 30 minutes to enter.	1.94
<i>Precautions during preparation & application</i>	
I read carefully the directions given on the labels of package of pesticide containers.	2.66
I apply the doses of pesticides recommended by the Agriculture Officers/University/KVK/CIBRC/Input dealers	2.46
I believe that wearing protective clothing is essential for Vegetable growers health during pesticide application to shield the body from pesticide exposure.	3.34
Wearing full pants, full sleeve shirts, masks, plain goggles etc. are also an effective safety measure to protect skin and body parts from pesticide contact.	3.12
I feel safer when I use a cloth or gamcha to cover my face while spraying pesticides than uncovered / without this.	2.87
Before spraying of any pesticides, all the mature fruits and harvestable products are plucked from the plants.	2.68
I take due care while opening the pesticide containers to avoid splashing of the liquid or puffing up the powder.	2.85
I believe that through mixing of pesticide with water is crucial for the effectiveness of pesticides.	3.67
For mixing of pesticides, separate containers like drums or buckets etc. are used which are further not used for any other purpose. A long-handled rod or even wooden stick are used for stirring.	3.08
I follow the recommended dilution ratio while use pesticides.	3.16
Always spray pesticide in the direction of flow of wind. Never spray against the winds.	3.21
I never smoke or eat or drink during application of pesticides. If very essential, then thoroughly wash the hands and other body parts with soaps before to do so.	3.10
I prefer to spray pesticides during early morning or during afternoon hours only.	3.62
<i>Precaution after application</i>	
I neither leave excess pesticides in the equipment nor pour in irrigation channel or water bodies. I prefer to spray excess pesticides on border or barren land, if needed.	3.87
After spraying, the sprayer was thoroughly washed & rinsed thrice with plenty of water. Decontaminate properly the drums, buckets, long rod, measuring cylinders etc. with soap solution and water repeatedly at least thrice.	4.14
I take proper bath with soap & plenty of water. I wash all the protective clothing with soap water thoroughly & sundry properly.	3.77
I follow proper waiting period of the pesticides. Do not harvest immediately.	3.26
<i>Disposal of empty containers</i>	
I never use empty pesticide containers for any purposes.	2.89
I believe that proper disposal of pesticide waste is important to prevent chemical pollution.	2.79
I do not throw empty pesticide containers in to ponds, water channels, dustbins, crop field or any other places.	3.11
I always crush empty pesticide containers and cut the empty bags to prevent their reuse.	4.05
To decontaminate the empty pesticide containers before burying the minthe waste land, firstly drain out the excess fluid from the containers by keeping them in an inverted position in that area for few minutes, then rinse the container with water 3-4 times & drain out in the similar way.	3.62
The decontaminated empty pesticide containers or bags buried in waste or unused land at about 0.5 to 1 meter depth.	3.96
<i>Environmental Protection</i>	
Integrated pest management (IPM) is a better approach for reducing chemical pesticide use in the field.	3.67
I prefer using environmental friendly alternatives (biological/ cultural/ mechanical/ botanical pesticides etc.) to chemical pesticides whenever possible.	3.41
<i>Health and Safety</i>	
I believe that pesticide exposure poses health risks.	3.77
I believe that pesticide exposure can have long-term effects on health of the applicator.	2.72

Table 1 contd..

Item statements	t-value
It is important to ensure that family member & other persons to stay away from the fields during pesticide application.	3.56
I seek medical attention immediately whenever feel pesticide poisoning symptoms.	3.82
<i>Record Keeping and Monitoring</i>	
I believe that maintaining accurate records can help in reducing unnecessary pesticide use.	2.66
I believe that record keeping helps me to evaluate the cost-effectiveness of the pesticides.	2.87
I document any adverse effects or unusual symptoms in the crop after pesticide use.	3.26
<i>Pesticide Regulations</i>	
I believe that use of banned or restricted or non-label claim pesticides should strictly be avoided.	3.64
I believe that compliance with safety regulations can reduce health risks.	3.68
I think provision of penalty/punishment should be there in case of improper use of pesticides and do not follow the proper waiting period.	2.96
<i>Education and Training</i>	
I believe that attending training on pesticide use is very crucial for my safety.	2.79
I would like attend workshops related to safe application of pesticides.	2.92
Educating Vegetable growers on different pests and their IPM practices can help to reduce pesticide use.	2.36
I believe that proper training on handling of pesticides can minimize ill-effects of pesticides.	3.25
<i>First Aid and Emergency Response</i>	
It is important to value and prioritize first aid training as an essential component of pesticide safety education.	3.05
It is important to educate Vegetable growers family members about what to do in case of pesticide poisoning.	2.64
I recognize nearby health centres/ hospitals are crucial for ensuring timely care during pesticide poisoning.	2.89

of 0.89. In addition, the Cronbach's alpha value, was found to be 0.86, indicating high internal consistency of the instrument.

The validity of a scale reflects its ability to accurately measure the intended construct. Specifically, content validity evaluates whether the items adequately represent the domain of interest (Kumar et al., 2015; Gupta et al., 2022). In this study, content validity was established by reviewing relevant literature and incorporating expert opinions from the field of extension, ensuring that the selected statements were both representative and appropriate.

DISCUSSION

Several studies have examined vegetable growers' attitudes toward pesticide use; however, limited attention has been given to their safety measures while handling pesticides. Addressing this gap, the present research aimed to develop and standardize an attitude scale to measure vegetable growers' perceptions regarding the safe use of pesticides. Initially, 110 statements were collected through a review of scientific literature and consultation with experts. These were screened using the 14-point criteria proposed by Edwards (1957), resulting in the retention of 61 statements. In the relevancy test, 61 statements with an overall mean relevancy score of 2.50 were selected and subsequently subjected to item analysis in a non-sampled area. Item analysis, a crucial step in scale development, helps identify statements based on their ability to differentiate respondents. Data were collected from 60 individuals using a five-point continuum. Scores were arranged in ascending order, and following Edwards (1957), the top 25% (15 respondents) and bottom 25% (15 respondents) were used to calculate the t-value. Based on this, 52 statements with a t-value ≥ 1.75 (Bird, 1940) were retained. Reliability and validity tests were then conducted to

standardize the scale. Reliability was established using Pearson's correlation coefficient (0.82), further verified by the Spearman-Brown formula (0.89), confirming strong reliability. Additionally, the Cronbach's alpha value of 0.86 indicated a high level of internal consistency (Cronbach, 1951). For validity, content validity was employed to ensure that the items adequately represented the construct. Statements were carefully selected from scientific sources, and expert opinions were sought to refine their relevance. Thus, the scale was successfully developed, standardized, validated, and that can guide future evaluations and strengthen efforts toward improving pesticide safety practices among vegetable growers.

CONCLUSION

The developed attitude scale serves as a valuable tool for assessing vegetable growers' attitudes toward the safe use of pesticides. The scale demonstrated strong reliability, as indicated by the reliability coefficients, and its content validity was ensured through expert judgments and a thorough review of scientific literature during the statement selection process. By fulfilling the essential criteria of reliability and validity, the scale can be regarded as a standardized instrument. It holds significant potential for use by researchers and policymakers, as well as by various stakeholders as an effective intervention tool. Overall, this scale provides an efficient means to evaluate vegetable growers' attitudes toward pesticide safety practices.

DECLARATIONS

Ethics approval and informed consent: The experts to judge the items were well informed regarding the purpose and only the responses of the judges who consented have been included for analysis purposes.

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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Determinants of ARYA Adoption for Livelihood Security in Nalgonda district of Telangana

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HIGHLIGHTS

- Integrated Farming System had the highest adoption under Attracting and Retaining Youth in Agriculture (ARYA), enhancing income and sustainability.
- Attitude and knowledge were the strongest predictors of adoption.
- Education, income, landholding, and extension contact influenced adoption significantly.

ARTICLE INFO

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ABSTRACT

The study was conducted during 2023-25 to identify the determinants influencing the adoption of the ARYA programme in Nalgonda district. Employing a multistage random sampling technique, data were collected from 160 rural youth across four agriculturally prominent blocks using structured interview. The analysis revealed that the integrated farming system emerged as the most widely adopted component of the ARYA programme, followed by animal husbandry and horticultural activities. 70.63 per cent of respondents exhibited medium adoption levels, indicating partial engagement with programme components. Correlation analysis identified attitude ($r = 0.753^{**}$) and knowledge ($r = 0.738^{**}$) as the most significant predictors of adoption, while education, landholding, annual income, and extension contact also showed strong positive associations. The study highlighted critical gaps in the adoption of marketing and post-harvest practices, suggesting the need for strengthening forward linkages, value addition infrastructure, and market accessibility. The findings emphasised the importance of targeted awareness campaigns, skill enhancement initiatives, and institutional support to promote entrepreneurship among rural youth. Strengthening extension services and refining programme implementation strategies can enhance adoption levels, ensuring livelihood security and sustainable development in rural communities.

INTRODUCTION

Agriculture remains the cornerstone of India's rural economy, engaging approximately 58 per cent of the population in agricultural and allied sectors (GoI, 2023). Despite its socio-economic significance, the sector contributes only 17–18 per cent to the national Gross Domestic Product (GDP), highlighting inherent structural inefficiencies and a growing need for targeted reforms

(Chand et al., 2020). Major challenges, including small and fragmented landholdings, degraded soil health, fluctuating productivity, erratic weather patterns, and low adoption of scientific technologies, continue to limit the sector's potential. Globally, the challenge of attracting youth to agriculture is not confined to India alone. Countries in Sub-Saharan Africa, Southeast Asia, and Latin America are facing similar youth disengagement due to poor profitability, lack of innovation, and weak infrastructure

(Simbanegavi, 2019). These shared experiences underscore the urgent need for globally inspired yet locally adopted policies like ARYA to make agriculture appealing again. Furthermore, rural-to-urban migration, driven by diminishing returns in farming, has led to depopulated villages and underutilized farmlands. Initiatives like ARYA offer opportunities to reverse this trend by promoting agro-enterprise development and community-based employment options.

The Government of India has implemented several interventions to rejuvenate rural agriculture and engage key demographic groups. Among these, the ARYA programme, initiated by the Indian Council of Agricultural Research (ICAR) in collaboration with Krishi Vigyan Kendras (KVKs), represents a significant step toward youth-centric agricultural development. ARYA aims to promote agricultural entrepreneurship among rural youth by encouraging them to adopt viable, sustainable, and locally relevant agri-based enterprises. The programme's broader objectives include reducing rural-to-urban migration, increasing income generation at the village level, and fostering innovation in farming practices (ICAR, 2021).

ARYA promotes a variety of entrepreneurial modules such as Integrated Farming Systems (IFS), poultry farming, beekeeping, mushroom cultivation, vermicomposting, fruit and vegetable nurseries, and value-added agri-processing. This comprehensive approach allows youth to diversify their sources of income, manage resources more efficiently, and access sustainable livelihood opportunities (Murthy et al., 2019). Empirical studies have reported positive outcomes associated with ARYA implementation, including improved awareness, increased income, enhanced skills, and greater adoption of improved agricultural technologies (Sayana et al., 2022; Sahoo et al., 2023). However, the success of such programmes is heavily influenced by a range of socio-economic and psychological factors. Research indicates that variables such as education, landholding size, household income, institutional exposure, knowledge level, and personal attitudes significantly determine the likelihood of adoption of agricultural innovations (Afros et al., 2021; Kobba et al., 2021; Gowda et al., 2023; Sai et al., 2024). Youth with higher levels of education and greater exposure to extension services are more likely to recognize the utility of such programmes and adopt them effectively. The Nalgonda district of Telangana serves as a pertinent location for assessing the effectiveness of the ARYA initiative. Characterized by small and marginal landholdings, diverse cropping systems, and moderate levels of infrastructure development, Nalgonda reflects both the opportunities and constraints present in rural agricultural landscapes. Preliminary field insights indicate variable adoption rates of ARYA components across villages, potentially influenced by gaps in awareness, institutional support, and access to necessary resources.

METHODOLOGY

The present study was conducted during the period 2023-2025 in four purposively selected blocks of Nalgonda district of Telangana, namely Miryalaguda, Vemulapalli, Damaracherla, and Tripuraram. These blocks were chosen due to their significant involvement in agricultural activities and the implementation of the ARYA programme aimed at enhancing livelihood security among

farming communities. The study focused on understanding the determinants influencing the adoption of the ARYA programme for livelihood security. A multistage sampling technique was adopted to select the respondents for the study. Initially, the four blocks were purposively selected, followed by random selection of four villages within each block. Subsequently, a total of 160 farmers were selected randomly from these villages to represent diverse socio-economic backgrounds and varying degrees of programme adoption. The sample size ensured adequate representation for meaningful statistical analysis. Primary data were collected through structured interviews using a pre-tested interview schedule designed to capture information on socio-economic characteristics, knowledge, attitude and adoption status related to the ARYA programme. Variables such as family type, education level, size of landholding, annual income, extension contact, innovativeness, and social participation were included based on their relevance in adoption studies. The key dependent variable was the adoption status of the ARYA programme, categorised as fully adopted (2), partially adopted (1) and non-adopters (0). The independent variables included socio-economic and institutional factors hypothesised to influence adoption behaviour. To determine the association between these categorical variables and the adoption status, the Chi-square test was used to assess association between socio-economic characteristics and adoption levels, appropriate for categorical data. Cramér's V was further employed to assess the strength of association, which allowed a deeper understanding of variable influence beyond significance alone (Duke et al., 2020).

Data analysis was performed using IBM SPSS V.26 Statistics software. Before the Chi-square test, data were coded and validated for consistency. The level of significance was fixed at 5% ($p < 0.05$). Variables showing significant association with adoption were identified as key determinants influencing farmers' participation in the ARYA programme. The findings aimed to provide empirical evidence to support targeted extension interventions for enhancing programme adoption and livelihood security in the region.

RESULTS

The analysis of different enterprise components under the ARYA programme is presented in Table 1. Under horticulture aspects, the highest adoption was recorded for vegetable nursery units, with 33.75 per cent of respondents having fully adopted the practice, and 43.12 per cent partially adopting. This component achieved a weighted mean score of 36.79, indicating moderate-to-high engagement. Conversely, mushroom production witnessed only 6.25 per cent full adoption and a significant 58.12 per cent non-adoption. Similarly, commercial floriculture and protected cultivation had modest adoption rates, with non-adoption levels at 43.75 per cent and 50.63 per cent, respectively. In the post-harvest domain, the bakery unit activity showed the highest level of partial adoption (53.12%), while full adoption remained low at 12.50 per cent. The value-added food ventures and training to manage post-harvest losses also demonstrated limited full adoption (12.50% and 9.38%, respectively), with over 47 per cent and 56 per cent of respondents reporting no adoption. The weighted mean for this category stood at 30.54, suggesting that post-harvest interventions under ARYA had relatively weak penetration among the beneficiaries. The

Integrated Farming System (IFS) category displayed the highest overall adoption intensity, with a weighted mean of 46.45. In particular, the vermicompost unit had a full adoption rate of 39.37 per cent and only 18.75 per cent non-adoption. However, entrepreneurship training through IFS showed limited full adoption (5.00%) despite having a relatively high partial adoption rate (52.50%), indicating interest among farmers, but potential gaps in accessibility or implementation. For marketing aspects, adoption remained low. Marketing strategies introduced under the ARYA programme had only 11.25 per cent full adoption, while 48.13 per cent of respondents reported no adoption. Similarly, use of social media for rural enterprises saw 9.37 per cent full adoption and a majority of 51.83 per cent non-adoption. The weighted mean score for marketing was calculated at 32.81, highlighting the need for greater focus on market linkage and digital extension strategies. Within animal husbandry aspects, the most adopted practice was poultry farming, with 24.37 per cent full and 38.75 per cent partial adoption. Goat and sheep rearing, aquaculture, and dairy farming also showed moderate adoption patterns. Among these, dairy farming had a relatively higher partial adoption rate (45.63%), whereas aquaculture and fish rearing had the highest non-adoption rate (50.00%) within the category. The weighted mean for animal husbandry stood at 38.20, suggesting a comparatively better adoption profile than post-harvest and marketing interventions.

The overall adoption level of the ARYA programme. A majority of the respondents (70.63%) fell into the medium adoption category. This indicated that most beneficiaries had implemented several components of the programme, but had not yet fully adopted its entire range of interventions. A smaller segment, 16.87 per cent followed by 12.50 per cent, belonged to the high adoption

category, suggesting that only a limited number of respondents had extensively integrated ARYA-promoted practices, such as integrated farming, value addition, and enterprise diversification into their livelihood activities.

The correlation analysis presented in Table 2 revealed that several socio-psychological and economic variables exhibited statistically significant and positive relationships with the level of adoption of the ARYA (Attracting and Retaining Youth in Agriculture) programme components. Among all variables studied, attitude towards the programme recorded the strongest positive correlation with adoption ($r = 0.753$, $p < 0.01$), followed closely by knowledge level ($r = 0.738$, $p < 0.01$). The robustness of these findings is further confirmed by substantial Chi-square values ($\chi^2 = 1416.486$ for attitude and $\chi^2 = 512.461$ for knowledge) and high Cramer's V coefficients (0.683 and 0.540, respectively), denoting a strong degree of association. Extension contacts ($r = 0.533$, $p < 0.01$) and education level ($r = 0.528$, $p < 0.01$) were also significantly and positively correlated with adoption, underscoring the role of regular interaction with extension personnel and higher educational attainment in enhancing receptiveness to new agricultural practices. These relationships were further supported by significant Chi-square values ($\chi^2 = 1223.348$ for extension contacts and $\chi^2 = 1184.726$ for education level) and strong Cramer's V coefficients (0.646 and 0.608, respectively).

Similarly, annual income ($r = 0.458$, $p < 0.01$) and landholding size ($r = 0.233$, $p < 0.05$) demonstrated significant positive correlations with adoption. This suggests that farmers with stronger economic resources and larger land availability tend to have higher adoption rates. The statistical significance of these relationships was reinforced by high Chi-square values ($\chi^2 = 1528.733$ for income

Table 1. Different adoption aspects of ARYA Programme for livelihood security

Category	Adoption Level			Weightage mean
	Fully Adopted (%)	Partially Adoption (%)	No Adoption (%)	
1. Horticulture aspects				
Vegetable Nursery Units	33.75	43.12	23.13	36.79
Mushroom production	06.25	35.63	58.12	
Commercial floriculture	15.63	40.62	43.75	
Protected cultivation	10.00	39.37	50.63	
2. Post-harvest aspects				
Bakery Unit activities	12.50	53.12	34.38	30.54
Value-added food ventures	12.50	40.00	47.50	
Training provided by the ARYA Programme to manage post-harvest losses	09.38	34.37	56.25	
3. Integrated farming system (IFS)				
Vermicompost unit along with farming	39.37	41.88	18.75	46.45
Entrepreneurship training through IFS initiatives	05.00	52.50	42.50	
4. Marketing aspects				
Marketing strategies provided by the ARYA Programme	11.25	40.62	48.13	32.81
Social media for rural entrepreneurial activities	09.37	38.80	51.83	
5. Animal Husbandry aspects				
Poultry farming activities	24.37	38.75	36.88	38.20
Goat and sheep rearing activities	19.38	41.87	38.75	
Aquaculture and fish rearing	13.75	36.25	50.00	
Dairy farming	20.00	45.63	34.37	

Table 2. Relationship between demographic variables and adoption of ARYA for livelihood security

Independent Variables	Correlation Coefficient “r”	Pearson’s Value Chi-square (χ^2)	Cramer’s V-value	P- value
Age	-0.056 NS	215.332	0.335	p > 0.05
Gender	0.028 NS	18.506	0.340	p > 0.05
Family Type	-0.148 NS	33.080	0.322	p > 0.05
Education	0.528**	114.377**	0.423	p < 0.01
Occupation	0.112 NS	90.267	0.376	p > 0.05
Land Holding	0.233*	1289.550*	0.651	p < 0.05
Annual Income	0.458**	1528.733**	0.709	p < 0.01
Mass media exposure	0.152 NS	283.619	0.356	p > 0.05
Extension Contact	0.533**	457.522**	0.388	p < 0.01
Innovativeness	0.329**	162.709	0.357	p < 0.01
Social Participation	0.104 NS	183.879	0.357	p > 0.05
Knowledge	0.738**	512.461**	0.540	p < 0.01
Attitude	0.753**	1416.486**	0.683	p < 0.01

p < 0.01 = Highly significant (1% level of significance), p < 0.05 = Significant (5% level of significance), p > 0.05 = Not significant

and $\chi^2 = 1289.550$ for landholding size) and robust Cramer’s V scores (0.709 and 0.651, respectively), highlighting the socio-economic advantage in accessing and implementing ARYA interventions. Innovativeness, although moderately correlated with adoption ($r = 0.329$, $p < 0.01$), still exhibited a statistically significant relationship. In contrast, several demographic variables—including age ($r = -0.056$, $p > 0.05$), gender ($r = 0.028$, $p > 0.05$), family type ($r = -0.148$, $p > 0.05$), primary occupation ($r = 0.112$, $p > 0.05$), mass media exposure ($r = 0.152$, $p > 0.05$), and social participation ($r = 0.104$, $p > 0.05$)—did not show statistically significant correlations with adoption. These non-significant results indicate that such demographic characteristics were not decisive factors in influencing an individual’s likelihood of adopting ARYA programme components in the study area.

DISCUSSION

The study identified the Integrated Farming System (IFS) as the most widely adopted component under the ARYA (Attracting and Retaining Youth in Agriculture) programme, reflecting its perceived importance in promoting income diversification and enhancing livelihood resilience among rural youth. The widespread adoption of IFS highlights the practicality of integrating crop production with livestock and allied enterprises, thereby providing a more stable source of income amid uncertainties in resources and markets (Chaudhary et al., 2019; Murthy et al., 2019). Animal husbandry emerged as the second most adopted enterprise. Its popularity can be attributed to its compatibility with small landholdings, relatively low initial investment requirements, and the potential for generating regular income through the sale of milk, eggs, meat, and other livestock products (Sharma, 2021). The enterprise also offers opportunities for women and family members to participate in management, thus increasing household-level engagement in agricultural activities. However, adoption levels were noticeably lower in the areas of marketing and post-harvest management. These constraints hinder the scalability and profitability of agricultural enterprises despite production gains. The results align with Pasula & Sreedaya (2022), who emphasized that strengthening post-production support systems—such as storage

facilities, processing units, branding initiatives, and market linkages—is essential for maximizing income from agricultural ventures.

The analysis also revealed that a majority of respondents demonstrated medium-level adoption of ARYA programme components, indicating partial engagement rather than full-scale integration into their livelihood systems. Similar observations were made by Saleh et al. (2012), who noted that adoption disparities often stem from variations in contextual and perceptual factors. Their work further emphasises that youth who are better informed and supported are more likely to participate in productive agricultural ventures. In this regard, incorporating youth-centric curricula into vocational training and leveraging social media as a dynamic educational platform could significantly improve adoption rates by increasing both knowledge and motivation.

The statistical analysis underscored that attitude and knowledge were the most significant predictors of adoption, as evidenced by strong correlation coefficients. These findings reaffirm the importance of designing targeted awareness campaigns, experiential learning opportunities, and skill-oriented training modules to facilitate positive behavioural change (Sai et al., 2024; Gowda et al., 2023). This reinforces the argument that capacity building, improved economic standing, and consistent institutional engagement play pivotal roles in enhancing the effectiveness of the ARYA programme (Singh, 2023). In contrast, certain demographic characteristics such as age, gender, and social participation did not show any statistically significant influence on adoption. This suggests that individual personal attributes are less decisive compared to enabling conditions, access to resources, and institutional support mechanisms.

CONCLUSION

The ARYA programme had a moderate adoption rate among farmers in Nalgonda district, with most respondents falling under the medium adoption category. Among various components, the Integrated Farming System emerged as the most adopted, indicating its practical viability and integration into local livelihoods. Statistical analysis revealed that adoption was significantly influenced by variables such as attitude, knowledge, education, income,

landholding, and extension contact. The findings emphasised the importance of improving awareness, building positive perceptions, and strengthening institutional support mechanisms to enhance the effectiveness and reach of the ARYA programme. Targeted interventions are required, which include developing mobile-based learning modules, strengthening access to financial services, offering input subsidies for youth-led agri-enterprises, and introducing gender-sensitive training modules. Policy emphasis should also be placed on forming youth cooperatives and establishing forward linkages with processing industries. Strengthening institutional collaboration between ICAR, KVKs, and NGOs can facilitate more localised and inclusive implementation models.

DECLARATIONS

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

Conflict of interest: The authors 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 they have thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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Constraints in the Adoption of Stress Tolerant Rice Varieties (STRVs) in Odisha

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HIGHLIGHTS

- Low literacy, social inequality, and risk aversion hinder technology transfer.
- High input costs, labor expenses, and loan difficulties restrict adoption.
- Negligence, seed shortages, and inadequate training programs remain major constraints.

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ABSTRACT

The study investigated barriers to the adoption of stress-tolerant rice varieties (STRVs) among farmers in Odisha during 2024-2025. Data from 240 randomly selected farmers, collected via an ex-post facto design and analysed using Henry Garrett's ranking technique. The analysis revealed key constraints across social, economic, managerial, technological, and organisational dimensions. Major barriers identified were low literacy, social marginalization, risk aversion, high input costs, limited financial literacy, weak post-adoption evaluation, insufficient STRV knowledge, inadequate demonstration trials, and poorly designed training programs. The results highlight the complex interplay of these obstacles and emphasise the need for comprehensive interventions—such as targeted literacy and capacity-building initiatives, improved financial support, adaptive extension services, and participatory demonstrations, all tailored to meet the needs of marginalized farmers to enhance STRV adoption in the countryside.

INTRODUCTION

Agriculture remains vital to Odisha's economy, employing 49 per cent of the workforce and supporting over 60 per cent of its population. Despite a declining Gross State Democratic Product (GSDP) share, it remains key for rural employment and food security. Among the different sectors, the crop sector still enjoys the dominance of over 61 per cent of contribution towards agricultural Gross State Value Added (GSVA). With foodgrain production of 143 lakh MT, Odisha ranks fifth among all states in rice production, accounting for eight percent share in the nation's total production and is cultivated in 45 per cent of Gross Cropped Area (Odisha Economic Survey 2024-25, 2025). With agriculture

being the cornerstone for the livelihood of countryside and shaping state's economy, rice reigns as the primary player in crop cultivation and production in the state (Murali Krishna et al., 2025). But in contemporary times of changing climate under the aegis of global warming, this also affects the surrounding environment of paddy fields, which has have significant impact on their potential yield. Paddy during the reproductive stage i.e., flowering and grain filling stage, is the most vulnerable phase to stresses due to heat, drought, cold, saline or alkali or even in combinations of these, which are more than their individual effects as well as at low levels (Sinha et al., 2023). So, stress-tolerant varieties prominently come into the picture of managerial strategies of stresses that the crop has to face (Dar et al., 2021).

Stress-tolerant rice varieties are crucial for farmers in Odisha, India, where droughts and floods significantly impact rice production. Studies show that farmers in both drought-prone and flood-prone regions value stress-tolerant cultivars and are willing to pay a premium for these traits (Arora et al., 2019). Field experiments demonstrate the superior performance of drought-tolerant varieties like Swarna Shreya compared to local checks in various districts of Odisha. Swarna Shreya consistently outperforms other varieties in terms of yield, economic returns, and agronomic characteristics (Mohanta et al., 2024; Mangaraj et al., 2021). For instance, in Bolangir district, Swarna Shreya showed a 13-15 per cent increase in yield compared to the farmers' practice variety (Mohanta et al., 2024). Similarly, in Ganjam district, Swarna Shreya recorded significantly higher grain yield, straw yield, and economic returns compared to farmers' practice (Mangaraj et al., 2021). These findings highlight the importance of adopting stress-tolerant rice varieties to enhance productivity and farmers' income in Odisha's rainfed ecosystems.

Adopting stress-tolerant rice varieties is vital for climate resilience, yet uptake remains limited due to awareness gaps, seed access, and market concerns (Vergara et al., 2023; Khanam, 2023). Extension efforts, peer learning, and public-private collaboration are key to improving adoption in vulnerable regions (Dar et al., 2020). In this regard, an investigative attempt to analyze the constraints affecting the technology transfer of STRVs in Odisha.

METHODOLOGY

The investigation was conducted in the two districts of Odisha: Puri and Kalahandi as these are prone to cyclones (Bahinipati, 2014) and the drought (Swain et al., 2024), respectively. A multistage random sampling strategy was employed, starting with the random selection of two blocks from each district. Four villages were randomly chosen from each block, resulting in eight villages overall. The study's participants were farmers engaged in paddy cultivation for a minimum of three years, ensuring that respondents had sufficient experience and thus were selected purposively. Each village contributed 30 farmers, leading to a total sample of 240 farmers. To validate the main questionnaire, a pre-test was conducted with 10 per cent of the sample size, prior to the principal data collection. Although the questionnaire was first written in English, it was clearly communicated to respondents in Odia, their local language, to promote understanding and accuracy. The insights gained from pretesting guided the revision and refinement of the final interview schedule. Data were collected using face-to-face interviews in the respondents' homes, fostering genuine and open responses (Jayasingh & Mishra, 2024). This process was conducted between September 2024 and May 2025, following an ex-post facto design. There are number of methods were there at disposal for dealing with constraint analysis but Henry Garrett's ranking technique was executed to assess the challenges faced by farmers in adopting STRVs.

RESULTS

A broad array of factors was found to be restricting the adoption of stress-tolerant rice varieties by farmers. For better understanding, these factors were placed into separate categories and elaborated in the following sub-sections.

Social constraints

The information depicted in Table 1 speaks about the seriousness of the issues that were proving to be roadblocks for technology adoption of rice cultivars which were of stress tolerant in nature. The issue 'Low literacy levels hindering comprehension' was the most serious one with maximum mean scores of 67.52 followed by 'Social inequality and marginalization of resource poor' (59.34) and 'Risk aversion due to fear of crop failure' (54.12) as the next two prominent issues. Likewise, other issues comprised from 'Strict adherence to conventional norms' to 'Dependency on local leaders resisting to change' have been put-together in the list with their respective ranks as given to them on the basis of seriousness seen by the farmers. These findings do draw analogy to that of Muthukumar et al., (2020) & Usha et al., (2021).

Economic constraints

This section speaks about the issues towards technology adoption of stress tolerant rice varieties which are of economic in its nature as depicted in Table 1. The issue 'Higher capital outlay for farming inputs' with the mean score of Garrett value '64.33' was found to be highest, followed by 'Increased labour costs during transplanting and harvesting' (57.87) and 'Lack of comprehensibility towards loan approval' (55.56) as second and third ranked issues. The next in line were from 'Higher rate of interests on loans' to 'Lack of crop insurance coverage for risk mitigation' as ranked on the basis of perception of seriousness of respondents. These results showcase similarities to those studies conducted by Gireesh et al., (2019); Usha et al., (2021); Sabu & Roy (2024).

Managerial constraints

The information depicted in the Table 1 below the section of economic constraints expresses the issues related to managerial aspects as faced by the respondents. The top-most ranked troubles as rated by the respondents found to be 'Negligence to post-adoption evaluation and feedback system' with mean score value of 77.81 followed by 'Weak linkage with input suppliers and market intermediaries' and 'Gaps in channels to extension agents and researchers' with the corresponding mean score values of 73.22 and 69.33. Likewise, other constraints have been ranked accordingly as per the seriousness perception by farmers.

Technological constraints

Under this section where it speaks about the technological related barriers that proved to be roadblocks for adoption of STRVs for farmers, the first, second and third ranked constraints were found to be 'Limited availability of region specific STRV seeds', 'Insufficient demonstration trials in stress-prone areas' and 'Lack of tools for monitoring and evaluation' with the corresponding mean scores of 74.78, 70.57 and 64.71 respectively. Likewise, from 'Poor integration of STRVs into local cropping systems' to 'Inappropriate system of monitoring and evaluation' have been listed with their corresponding rankings based on seriousness to be dealt with according to the farmers. The findings were quite similar to that of Sangeetha et al., (2018) & Kumar et al., (2023).

Table 1. Constraint as opined for transfer of STRVs

S. No.	Statements	Mean	Rank
Social constraints			
1.	Low literacy levels hindering comprehension	67.52	I
2.	Dependency on local leaders resisting to change	36.33	VII
3.	Risk aversion due to fear of crop failure	54.12	III
4.	Strict adherence to conventional norms	47.54	IV
5.	Peer pressure and fear of criticism	42.17	V
6.	Social inequality & marginalization of resource poor	59.34	II
7.	Restricted networks to their closely knitted groups	39.33	VI
Economic constraints			
1.	Higher capital outlay for farming inputs	64.33	I
2.	Limited access to proper marketing channels	46.35	V
3.	Limited access to institutional credit	38.88	VI
4.	Lack of comprehensibility towards loan approval	55.56	III
5.	Lack of crop insurance coverage for risk mitigation	34.33	VII
6.	Higher rate of interests on loans	49.11	IV
7.	Increased labour costs during transplanting and harvesting	57.87	II
Managerial constraints			
1.	Absence of record keeping to keep track on activities	58.33	IV
2.	Lack of decision-support tools to assess and act	37.59	VI
3.	Weak linkage with input suppliers and market intermediaries	73.22	II
4.	Proactive approach to climatic issues instead of reactive one	46.44	V
5.	Negligence to post-adoption evaluation and feedback system	77.81	I
6.	Inadequate integration of STRVs into broader enterprises	29.79	VII
7.	Gaps in channels to extension agents and researchers	69.33	III
Technological constraints			
1.	Absence of digital platforms for advisory and trouble-shooting	44.31	VI
2.	Availability of sub-standard quality of farming inputs	37.84	VII
3.	Limited availability of region specific STRV seeds	64.71	III
4.	Insufficient demonstration trials in stress-prone areas	70.57	II
5.	Lack of technical knowledge of STRVs	74.78	I
6.	Limited access to climate resilient agronomic practices	50.27	V
7.	Poor integration of STRVs into local cropping systems	56.75	IV
Organizational constraints			
1.	Training locations far-away from the villages	54.49	IV
2.	Less number of exposure visits	67.71	II
3.	Training timings unsuitable for most of the farmers	61.38	III
4.	Training programmes were less practical oriented	47.23	V
5.	Lack of season long training programs	76.73	I
6.	Fragmented linkage in inter-organizational relations	33.89	VII
7.	Lack of field day visits	41.22	VI

Organizational constraints

As depicted in table, the primary issue was found to be the first ranked 'Lack of season long training programs' (76.73) followed by second and third with 'Less number of exposure visits' and 'Training timings unsuitable for most of the farmers' with their respective mean Garrett scores of 67.71 and 61.38 respectively. The other issues from 'Training locations far-away from the villages' to 'Training timings unsuitable for most of the farmers' were accordingly ranked down based on the mean Garrett scores. The findings were similar to that of Das et al., (2014); Hareesh (2017) & Usha et al., (2021).

DISCUSSION

Under social constraints, at first was the low literacy which impairs farmers' ability to interpret agronomic instructions, evaluate varietal benefits, and engage with extension materials, thereby limiting their capacity to adopt STRVs and thus reducing productivity gains. Dar et al., (2021) & Mehar et al., (2022) have also concluded on the same lines of the context that educational disadvantage of farming communities keeps them deprived of any sort of technological innovation. Social inequality and marginalization of resource-poor farmers restrict access to extension services, quality inputs, and credit facilities, thereby impeding the adoption of STRVs and reinforcing vulnerability in stress-prone regions. Dar et al., (2020) had showcased how marginalized farm sections face pronounced barriers to accessing from the likes of agri-extension services, seeds and other resources. Risk aversion driven by fear of crop failure discourages farmers from adopting unfamiliar STRVs, stifles experimentation, delays trials, and reduces feedback, ultimately hindering technology transfer, institutional learning, and wider regional adoption. According to Akter et al., (2025), it has been observed that in most of the cases, risk managing farmers tends to better adoption of STRVs since uncertainties in the yield production can compel them towards reduced adoption.

In the banner of economical constraints for adoption of STRVs, higher capital requirement for inputs such as irrigation systems, fertilizers, and machinery, limits the resource-poor farmers' ability to adopt STRVs, despite their low-risk benefits. Raghu et al., (2025) revealed that smallholder farmers face economic challenges adopting STRVs due to limited finances, which hinder technology adoption and widen productivity gaps in vulnerable regions. Rising labour costs during transplanting and harvesting increase production expenses, discourage adoption of new rice varieties, and strain smallholder budgets. This reduces experimentation, delays uptake, and hampers the effective technology transfer as affirmed by Das et al., (2025). Owing to their low levels of educational background, limited understanding of loan approval processes deters farmers from accessing financial support for adopting STRVs. This restricts input purchase, delays experimentation, and ultimately hampers widespread technology transfer and adoption. Patil & Veetil (2024) had pointed out in their study about the issues of higher transplanting and harvesting costs deterred variety adoption, strain budgets, and reduce experimentation accompanied with limited financial literacy which has hindered the access to credit, stalling input use and technology transfer.

The constraints under managerial section has been discussed further in the incoming passage. Neglecting post-adoption evaluation hinders learning from farmers' experiences, obscures performance data, and blocks iterative improvements. It weakens trust, disconnects researchers from field realities, and impairs future outreach which leads to stalling technology transfer and compromising long-term success of STRV adoption. This same nature of obstruction to technology adoption due to lethargy towards evaluation in post-adoption phase has been reported by Vaiknoras & Larochele (2025) in their research ventures conducted in Nepal. Poor linkage with suppliers and intermediaries limits farmers' access to seeds, fertilizers, and buyers which in turn hinders adoption of STRVs. It disrupts support networks, impairs coordination, and stifles market flow, leads to weakening overall effectiveness of technology adoption initiatives. The disruption of input accessibility and market coordination due to incapacitation of supplier-intermediary connective bonds which leads to limitation of scalability of STRV technologies has also been reported in studies conducted by Mehar et al., (2022) in eastern India comprised of eastern Uttar Pradesh, Bihar, Odisha and West Bengal. Limited connectivity with extension agents and researchers weakens advisory support, delays information flow, restricts farmer training, and reduces feedback loops—hindering the effective dissemination and adoption of STRV technologies. In analogy to this, Ojo et al., (2024) inferred that feebleness in the bond between extension agents and researchers lags the advisory system, limits training and eventually deprives of technological transportation of STRVs as observed in the farmers of north-Central Nigeria.

Under the technological viewpoint, lack of technical knowledge of STRVs limits farmers' ability to apply recommended practices, assess performance, and manage inputs effectively. This reduces confidence, leads to poor outcomes, and ultimately hinders technology adoption. Vaiknoras & Larochele (2025) reiterated on the emphasis laid on the know-how on the STRVs along with the awareness regarding newer cultivars of STRV types and older available ones by the farmers. Insufficient demonstration trials in stress-prone areas erode farmer confidence, obscure real-world performance, and limit practical learning. Without visible proof of effectiveness under local conditions, adoption stalls, reducing stakeholder buy-in, delaying feedback, and hindering the technology transfer of STRVs. The importance of demonstration trials have been laid by Dar et al., (2021) in their study which advocates that head-to-head trials in farmers' fields with the support of KVKs and NGOs, has enhanced the altitudinal boost needed for adoption of STRVs in Eastern India's undeserved region. Insufficient monitoring and evaluation tools hinder performance tracking, feedback collection, and impact assessment (Saha et al., 2024). This limits refinement, discourages evidence-based scale-up, and ultimately impedes effective technology transfer of STRVs to farmers. Yamano et al., (2018) also laid emphasis on the continuous monitoring and evaluation on the farming operations of Sahbhagi Dhan in the farmer's field.

Without season-long training, farmers lack critical knowledge on stress tolerance traits, agronomic practices, and optimal timing for implementation. This knowledge gap leads to misapplication, reduced confidence, and poor adoption of STRVs, weakening the

effectiveness of technology transfer. Prasad Babu et al., (2021) in their study also reaffirmed the importance of season long training programme on the knowledge level of personnel targeted in the training programme. Fewer exposure visits limit farmers' first-hand experience with STRVs, reducing trust, practical understanding, and peer influence, which were the crucial factors of adoption and thereby undermining technology transfer effectiveness. The studies conducted by Vergara et al., (2023) also supports the pre-eminence of the exposure visit for the effective transfer of STRV technology. Unsuitable training timings often overlapping with peak farming activities, restrict farmers' participation and attention, resulting in poor knowledge absorption and delayed adoption of STRVs. The issue of timing mismatches in technology transfer is critical as effective contact between farmers and extension workers is essential as concluded by Dibba et al., (2019).

CONCLUSION

The study underscores the multifaceted constraints that hinder the transfer and adoption of stress-tolerant rice varieties among resource-poor farmers in vulnerable regions. Social barriers such as low literacy and marginalisation limit engagement with extension services and technological innovations. Economically, high input costs, rising labour expenses, and limited financial literacy prevent farmers from investing in STRVs. Managerial challenges, particularly weak post-adoption evaluation and inadequate supply-advisory linkages, further impede technology diffusion. Technologically, inadequate knowledge, insufficient demonstration trials, and limited monitoring reduce confidence and practical learning. Organizational limitations, including mismatched training schedules, minimal exposure visits, and a lack of season-long capacity-building, further restrict adoption. The interconnected constraints stall institutional learning and reduce farmers' ability to adopt climate-resilient practices requires integrated, context-specific strategies are needed, such as enhancing literacy, expanding financial access, strengthening extension networks, and tailoring participatory learning models to improve the uptake of STRVs and fortify agricultural resilience across stress-prone landscapes.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the farmer respondents of 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 author declares that they have thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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Perceived Constraints among Dairy Farmers in Eastern India Using Logistic Regression

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HIGHLIGHTS

- The logistic regression model was well-fit, explaining about 32.6 percent of variance in constraints faced.
- Targeted policy interventions like insurance reforms & extension outreach, are needed to promote inclusive dairy sector growth.
- Rural transformation and inclusive development can enhance income security, productivity, and livelihood resilience.

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ABSTRACT

The dairy sector plays a crucial role in sustaining rural livelihoods, especially among the small and marginal farmers, by providing food security, nutrition, and a regular source of income. However, these farmers often face a variety of structural and operational constraints that hinder their growth and economic development. This study investigated the key perceived constraints experienced by selected 270 Marginal-Small (MS) dairy farmers of Eastern Uttar Pradesh in the year 2024, selected through multistage stratified purposive-cum-random sampling, using logistic regression analysis. Among these, the high insurance charges emerged as the most severe factor, increasing the odds of constraint by 17 times. The model was well-fitted as indicated by a Hosmer and Lemeshow test value of 0.201 and Nagelkerke R^2 of 0.326, explaining about 32.6 per cent of variance in constraints faced. The study concludes that targeted policy reforms are needed to address critical bottlenecks in the dairy sector. Overall, the findings reinforce the importance of a need-based and evidence-driven approach for inclusive rural development through dairy enterprise support.

INTRODUCTION

The rural livelihood is dependent on the integration of the crops as well as livestock rearing. To a significant extent it acts as a source of food and nutritional security (Mondal et al., 2022) along with being a promising income source to millions (Pal et al., 2017; Bahubalendra et al., 2025). As India is the largest milk producer (PIB, 2025), and have a significant contribution in agricultural GDP (Gross Domestic Product) and employment, particularly in the rural area. Due to lack of technical knowledge and inadequate literacy

(Ali et al., 2024) to cope up with growing societies and challenges, these enterprises are promising a continuous source of income (Bharne et al., 2025) and thereby facilitating the daily need and hence the rural economy. The rural economy, particularly the marginal-small (MS) category, owning less agricultural land are largely dependent on the animal interventions (Jatav, 2024c). Dairy farmers are the backbone of the dairy sector, fulfilling their own needs and the other non-farming population (Lepcha et al., 2023). Day by day shrinkage of the agricultural land, due to rapid urbanization and fragmentation in households, also pushes families

without any rigid income sources towards the dairy sectors (Maurya et al., 2023). And it is feasible also, since growing population needs nutrition and food (Mishra et al., 2025); which will require growth in the sector too. So, it is a promising sector in the future. Despite such a close tie with the dairy enterprise, the MS farmers face several disadvantages that restrict their economic growth in context of personal and social progress (Singh et al., 2024).

The prominent constraints faced by the MS dairy farmers are continuously suppressing them in income and growth point of view (Sahu et al., 2022). Some of the constraints are, inadequate dry fodder in off season, inadequate knowledge about balance feeding, high cost of concentrates, zero knowledge of latest technologies (Chandran & Podikunju, 2020), unavailability of HV bulls, lack of assistance/trainings from Krishi Vigyan Kendra (Maurya et al., 2024), high insurance charges, excessive paper work for credit, loss/death, infertility, lack of trained medical supervision (Patil et al., 2024), lack of proper marketing facilities (Das et al., 2014). To improve the profitability of dairy husbandry, especially in tribal communities, cultivation of fodder shrubs and trees on wastelands, and developing degraded lands (Singh et al., 2017). There are many more unrecognizable constraints that are unable to reach the proper solutions (Sahoo et al., 2022). These are suppressing the thoughts of other entrepreneurs also, if they are looking to be entering into the field. All of these are due to a lag between the policies intents and their field level implementation. Several schemes are continuously announced by the agencies promising the overall growth of individuals as well as the economy as a whole (Mandi et al., 2022). Institutional support systems are lacking in their reach at the grassroots level (Derville et al., 2023). Removing all these hurdles can push the potential of the enterprise and help in the overall growth. Removing these barriers can unlock the growth potential of small dairy farmers, enhance their livelihoods and contribute to inclusive rural development (Sahu et al., 2021). It also has the potential to generate employment, reduce vulnerability, and empower women in rural households (Acharya et al., 2022).

METHODOLOGY

The analysis is confined to the constraint variables of the marginal and small dairy farmers in eastern India particularly in Sant Kabir Nagar district of Uttar Pradesh in the year 2024. Multistage stratified purposive-cum-random sampling was adopted for the selection of districts, blocks, and villages. The study incorporates a quantitative approach in which the information is collected using a questionnaire in survey. Singarimbun study (Singarimbun & Effendi, 1995) was used as a reference. A sample size of 270 dairy farmers was selected using the Slovin formula (Asenahabi & Ikoha, 2023) from the population. At the first step, the reliability and dependability of the information collected with respondents were checked, then the identified variables of constraints with the MS dairy farmers were investigated by logistic regression using the SPSS software. LR is used to examine the relationship between the dependent (Pull back of the dairy farmers) and independent variables (constraints). The logit of dependent variable (Y) is predicted with the selected independent variable (X).

Logit = natural logarithm (ln) of odds of Y

Odds = ratio of probability of constraints to no constraints

Odds can be mentioned as probability of Y happening (Pi) and the probability of Y not happening (1 - Pi).

P_i = Probability of present constraints

$(1-P_i)$ = Probability of absent constraints.

Here, the dependent variable is binary in nature i.e., only two possible values; either Yes or No; and the covariates on the other hand, are used to refer to a group of independent factors.

Equation –

$$\text{logit (Y)} = \ln \frac{P_i}{(1-P_i)} \quad \dots \text{eq (1)}$$

$$= \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \mu \quad \dots \text{eq (2)}$$

Where,

$$P_i = (X_1 = x_1, X_2 = x_2, X_3 = x_3, \dots, X_{11} = x_{11})$$

$$= \frac{e^{\alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11}}}{1 + e^{\alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11}}}$$

Y = categorical variable (Pull back of the dairy farmers), X = categorical or continuous variable (Constraints faced by dairy farmers), α = intercept, β_i = regression coefficient, μ = unexplained error term

The variable descriptions used in the study are mentioned in Table 1.

RESULTS

District Sant Kabir Nagar holds most of the marginal and small (MS) farmers, as is likely to most of the other Indian states. Some of the selected respondents fall under the landless category, because of which they rely on allied agricultural practices, of which dairy practice is the most prominent one. Dairy farming ensures daily income and covers nutritional lacunae. But their adoption of this enterprise does not match the growth in relation. It is due to certain constraints faced by them in daily practices.

Table 1. Description of the variables selected for the study

Variables	Description	Units
P_i	Constraints	1 = Constraint exists 0 = No Constraint
α	Constant Intercept	
β_1 to β_{10}	Coeff. of Predictor variables	
β_1	Inadequate dry fodder in off off-season	A = Agree, D =Disagree
β_2	Inadequate knowledge about balanced feeding	A = Agree, D =Disagree
β_3	High cost of concentrates	A = Agree, D =Disagree
β_4	Zero knowledge of the latest Technologies	A = Agree, D =Disagree
β_5	Unavailability of HV Bulls	A = Agree, D =Disagree
β_6	Lack of assistance/training from KVKs	A = Agree, D =Disagree
β_7	High Insurance Charges	A = Agree, D =Disagree
β_8	Excessive Paperwork for Credit	A = Agree, D =Disagree
β_9	Loss/Death	A = Agree, D =Disagree
β_{10}	Infertility	A = Agree, D =Disagree
β_{11}	Lack of trained medical supervision	A = Agree, D =Disagree
μ	Error term affecting the dependent variable	

Some of the constraints faced by the dairy farmers include, Inadequate dry fodder in off season, Inadequate knowledge about balance feeding, High cost of concentrates, Zero knowledge of latest Technologies, Unavailability of hybrid variety Bulls, Lack of assistance/trainings from KVKs, High Insurance Charges, Excessive Paper Work for Credit, Loss/Death, Infertility, Lack of trained Medical Supervision. These problems resist the economic progress, yields and the morality of the dairy farmers. All of the above-mentioned issues studied are being grouped into two categories: A = Agree & D = Disagree.

Reliability and dependability test

To evaluate the dependability and consistency of the measurements scores derived from the surveys, this reliability was conducted. It is one of an appropriate statistical tool used in social analysis. The outcome of this tool is depending upon the consistencies between administrations and their effectiveness in what is intended to measure. This Cronbach's alpha test measures consistency of the selected parameters in the questionnaire or scale (Cronbach, 1951). The analysis is based on the values, which ranges from 0 to 1, indicating greater reliability while moving towards 1. In the results the Cronbach's alpha value is 0.620 and the scale is analyzed on the basis of the results obtained.

Table 2. Measure of internal consistency and comparison of means of the variables

Reliability Test		Hotelling's T-squared Test	
Cronbach's alpha (Raw)	0.620	Hotelling's T-squared	11400.896
Cronbach's alpha (Standardized)	0.638	F	1115.002
Variables	12	df ₁	11
		df ₂	270
		Significance	0.000

The differences between the means of any of the groups can be analyzed using the Hotelling's T-squared Test (Table 2). It employs a multivariate analysis, considering more than two variables in one go. Therefore, the dependent variables are considered for this multivariate analysis. The constraints of the dairy farmers are taken into account for it, and those were divided into two sections; one who faced some of the constraints (denoted as 1), while antagonistic to it, who didn't have any issues (denoted as 0). The presumed answers initially were that, there will be no significant difference between the means of the groups having all the dependent variables. Whereas, the alternative hypothesis was taken that, there is a significant difference between means of both the groups.

Factors affecting the dairy farmers

The factors which are affecting the dairy farmers' economic conditions are analyzed by the logistical regression. The factors are

believed to have the significant effect on their socio-economic conditions and are pilling factors against the economic developments and progress. The considered factors include: Inadequate dry fodder in off season, Inadequate knowledge about balance feeding, High cost of concentrates, Zero knowledge of latest Technologies, Unavailability of HV Bulls, Lack of assistance/trainings from KVKs, High Insurance Charges, Excessive Paper Work for Credit, Loss/Death, Infertility, Lack of trained Medical Supervision.

The considered factors are then categorized into two divisions, based on the dependent variables. The variable is considered as 1, if is the affecting variable to the farmers and if not, it is denoted by 0. All the categories of the aforementioned constraints are presented in Table 3; which shows that the model predicted accurately, the farmers categories.

Table 3. Problem classification matrix

Observed	Predicted		
	Overall faced constraints		Percentage corrections
	No constraints	Constraints	
Overall faced constraints			
No constraints	129	28	82.20
Constraints	63	60	48.78
Overall percentage	-	-	67.52

It reveals that 129 out of 157 dairy farmers were those who do not faced any constraints and 60 out of 123 were those who were encountered with the constraints.

Logistic regression (LR)

The suitability of the factors that were responsible for the pullback of the dairy farmers was checked using Logistic Regression. The factors such as, Inadequate dry fodder in off season, Inadequate knowledge about balance feeding, High cost of concentrates, zero knowledge of latest Technologies, Unavailability of HV Bulls, Lack of assistance/trainings from KVKs, High Insurance Charges, Excessive Paper Work for Credit, Loss/Death, Infertility, Lack of trained Medical Supervision are deployed in this LR model. The usefulness of the test model is understood by the high value of the Likelihood ratio, i.e., 472.355 (> 11). In the same pattern, the R-square value (Nagelkerke R-square) of 0.326 reveals that all the 11 factors collectively explain 32.6 per cent of the variance in the constraints confronted by the dairy farmers. Similarly, when the fitness of the LR model is studied by deploying the Hosmer & Lemeshow Test, it is found that the LR model is appropriate and best-fitted, supported and explained by the p-value of 0.201. From Table 4, we can depict the LR model as–

$$\text{logit (Y)} = -2.499 - 0.301 X_1 + X_2 + 0.305X_3 + 1.654X_4 + 0.209X_5 + 1.229X_6 + 2.779X_7 + 0.650X_8 + 1.249X_9 + 0.438X_{10} + 1.130X_{11} \quad \dots \text{eq (3)}$$

The above logit equation will be used to estimate the predicted value of the overall challenges faced by new farmers:

$$\text{Predicted logit (Y)} = \frac{1}{1 + e^{(-2.499 - 0.301 X_1 + X_2 + 0.305X_3 + 1.654X_4 + 0.209X_5 + 1.229X_6 + 2.779X_7 + 0.650X_8 + 1.249X_9 + 0.438X_{10} + 1.130X_{11})}} \quad \dots \text{eq (4)}$$

Table 4. Results from Logistic Regression

Variables	Coefficient	p-value	Odds ratio
Inadequate dry fodder in off season	-0.301	0.310	0.633
Inadequate knowledge about balance feeding	-1.000	0.375	0.386
High cost of concentrates	0.305	0.526	1.385
Zero knowledge of latest Technologies	1.654	0.030	5.128
Unavailability of HV Bulls	0.209	0.001	0.137
Lack of assistance/trainings from KVKs	1.229	0.009	3.214
High Insurance Charges	2.779	0.000	17.009
Excessive Paper Work for Credit	0.650	0.256	2.009
Loss/Death	1.249	0.050	3.449
Infertility	0.438	0.329	1.584
Lack of trained Medical Supervision	1.130	0.000	3.013
Constant	-2.499	0.000	0.079
-2 log likelihood	472.355	-	-
Omnibus test of model coefficients	77.342	-	-
Cox & Snell R Square	0.167	-	-
Nagelkerke R Square	0.326	-	-
Hosmer and Lemeshow Test	0.201	-	-

Inadequate dry fodder in off off-season

The variable X_1 , which focuses on the constraint of inadequate dry fodder in off-season, has a negative coefficient value i.e., -0.301. The results show a p-value of 0.310 (non-significant) and an odds ratio of 0.633. Although the odds ratio suggests a decreased likelihood of constraint due to this factor, the result is statistically insignificant. This implies that farmers facing fodder scarcity in the off-season are not significantly more constrained than others, possibly due to adaptation strategies like crop residue usage or fodder banks. This result is not statistically significant, which means this problem is not strongly related to whether a farmer is facing serious constraints overall. Farmers may have adapted by using crop residues or purchasing fodder during shortages. Therefore, they may not consider it a major hurdle.

Inadequate knowledge about balanced feeding

The Coefficient of the variable X_2 with its focus on the lack of proper knowledge on balanced feeding, has a Coefficient of -1.000, P-value: 0.375 (Not significant), and Odds Ratio of 0.386. The outcome reveals that there is a reduced probability of farmers who do not know how to feed the chickens efficiently reporting overall constraints; nevertheless, the outcome is not significant. It can be because of the low awareness itself, perhaps farmers do not regard this as a constraint because of knowledge gaps. The value of the odds ratio is less than one, indicating that the individuals who are not aware of the knowledge of balanced feeding practices will fail to appreciate its significance and therefore fail to note it as an issue. Not all farmers have been trained in the management of the feed, and thus they may not even be aware that this is a problem to their milk yield.

High cost of concentrates

The result of the variable X_3 , which concentrates on the high cost of concentrates is a positive coefficient number of 0.305, P

value number 0.526 (significant) and odds ratio of 1.385. Nevertheless, although the odds ratio indicated a more probable occurrence of constraints because of high concentrate prices, the impact is not notable in a significant way. It can mean that cost will be a factor but it does not equally restrict all smallholders. It suggests that there could be more constraints based on high-cost feed but the implication is not profound. Some may opt to use less or switch to cheap methods and this will not have direct effect on constraints immediately.

Zero knowledge of the latest technologies

The results of this factor are each of the coefficient that is 1.654 and significant p-value (0.03) and an odds ratio of 5.128. It is a very important limitation. The farmers who do not know about the modern technologies have five times bigger chances of having severe limitations. This indicates the digital and technical gap in the productive and quality practices and management in dairy farming. Without any knowledge of modern tool, tools, practices in the dairy farm, farmers stand five times more likely to experience major problems.

Unavailability of HV bulls

The consequences of the constraints are: Coefficient = 0.209, a highly significant p-value = 0.001, and 0.137 as the odds ratio. Although the relationship is statistically significant, the value of the odds ratio that is less than one implies the existence of a counterintuitive relationship. This could be a subject of additional research - possibly the variable coding was flipped, or the local practices counteract the effect of this limitation. Although the results are statistically significant, the odds ratio is very small, and it may be due to improper interpretation or coding error.

Lack of assistance/training from KVKs

This variable X_6 which is concerned with the absence of institutional back-ups in the form of Krishi Vigyan Kendras, has a Coefficient of 1.229, p-value: 0.009 (Significant), and Odds Ratio of 3.214. The likelihood of untrained farmers reporting some constraints is 3.2 times that of the trained ones, demonstrating the direct necessity of conducting capacity building and extension revisions. Farmers who do not get aid and training from Krishi Vigyan Kendras have a risk of facing issues more than three times that of others.

High Insurance Charges

This variable X_7 , which focus on the constraint of high insurance charges, has Coefficient of 2.779, p-value: 0.000 (Highly Significant) and Odds Ratio of 17.009. This is the strongest constraint. Farmers perceiving insurance premiums as high are 17 times more likely to experience significant constraints. The current structure of livestock insurance is clearly unaffordable or inaccessible for smallholders, requiring immediate policy revision. Farmers who face high insurance premiums are more likely to face constraints.

Excessive paper work for credit

The present variable X_8 , holds the obtained results of coefficient (0.650), non-significant p-value of 0.256 and odds ratio

of 2.009. Although not statistically significant, the odds ratio indicates a tendency toward higher constraint for farmers facing cumbersome credit formalities. This suggests that institutional bottlenecks still exist, but variability across banks or regions may dilute the statistical effect. X_8 variable is not statistically significant, but still shows a trend toward increased constraints due to complicated loan processes. Small farmers may find formal banking paperwork difficult or time-consuming, leading to delays or denial of credit.

Loss/death

The variable X_9 , has the coefficient of 1.249, p-value (0.050) and odds ratio of 3.449 in the analysis. This factor is on the edge of statistical significance and shows a strong practical effect. Farmers reporting animal loss are 3.4 times more likely to face compounded constraints, revealing gaps in veterinary care, insurance coverage, and risk management. Just at the threshold of significance in this factor farmers who experienced animal death are over three times more likely to face other challenges.

Infertility

This factor has coefficient of 0.438, a significant p-value (0.329), and odds ratio of 1.584. Despite an increased odds ratio, infertility does not show a significant impact in the model. Still, reproductive health issues remain critical at the field level, and may be under-reported or conflated with other problems. While infertility does affect dairy operations, its impact here isn't strong statistically. Farmers might accept delayed pregnancies as normal or lack awareness about fertility treatments.

Lack of trained medical supervision

This factor has results of coefficient of 1.130, highly significant p-value (0.000) and odds ratio of 3.013. This is a major constraint. Farmers without access to trained veterinary personnel are three times more likely to face difficulties. This supports arguments for strengthening doorstep veterinary care and para-vet outreach in remote areas.

DISCUSSION

While addressing the issues in the dairy enterprises, it was needed to explore and analysed the key constraints that were hindering the growth of small and marginal dairy farmers (Gupta et al., 2020). As per the results, there was a significant difference between the means of both the group variables, because $0.000 < 0.05$ in the significance calculations in the measurement of internal consistency and comparison of means of the variables. The factors which were affecting the dairy farmers economic conditions were analyzed by the logistical regression and it was found that the model was predicting the overall accuracy percentage of 67.52 per cent. The factors such as, Inadequate dry fodder in off season, Inadequate knowledge about balance feeding, High cost of concentrates, zero knowledge of latest Technologies (Kumar et al., 2021), Unavailability of HV (Hybrid Variety) Bulls, Lack of assistance/trainings from KVKs, High Insurance Charges, Excessive Paper Work for Credit, Loss/Death, Infertility (Adhikari et al., 2020), Lack

of trained Medical Supervision (Nagrle, 2015) were deployed in this LR model. The usefulness of the test model was understood by the high value of the Likelihood ratio. The R square value showed that all the 11 factors collectively explained the variance in the constraints confronted by the dairy farmers. The LR model was appropriate and best-fitted, supported and explained by the p-values. The absence of a significant difference between the predicted and observed results indicates that the regression model is suitable for further analysis. Among the factors studied, it was revealed that the few factors viz., dry fodder availability in off-season, inadequate knowledge of balance feeding, high cost of concentrate, excessive paperwork for credit, and infertility, were least affecting the MS dairy farmers (Dhinds et al., 2014). Major concerns were technology aids in the enhancement of productivity, health monitoring and cutting down on expenses. In its absence, small farmers were not be able to get out of their old ways of doing things. Similarly, Lack of good breeding bulls was found added to problems. At the field level it was seen that lack of good access to quality semen or bulls was a factor that constraints productivity. For trainings, Farmers cannot develop better unless they are exposed to new ideas, practices and methods of doing things. So, KVKs were found the main source of farmer education (Kholia & Bhardwaj, 2024). Expensive livestock insurance has always been a burden to the farmers. Many small farmers found avoiding it, leaving them vulnerable to loss from death or disease. In the same way the loss of even one dairy animal was seen as directly reducing the income and increasing emotional and financial stresses (Saravanan et al., 2021). Lastly, the farmers who were not having access to trained veterinary help were three times more constrained. Lack of timely treatment caused worsening health issues in animals, reducing productivity and increasing mortality (Singh et al., 2017).

CONCLUSION

The present study aimed to identify key constraints that hinder the progress of small and marginal dairy farmers, using logistic regression analysis. The findings provide insights into the severity and significance of various challenges in the dairy sector, which directly impact profitability and sustainability of rural livelihoods. Among the numerous challenges studied, five factors emerged as statistically significant and practically crucial. These constraints increase the likelihood of farmers facing multiple hardships, thus creating a cycle of low income, productivity, and poor resilience to shocks. High insurance charges, in particular, showed the strongest influence, suggesting an urgent need to restructure livestock insurance schemes to be more affordable and accessible. From a policy perspective, these results emphasize the importance of farmer education, veterinary infrastructure, accessible credit, technology diffusion, and affordable insurance products. By addressing the challenges, the dairy sector can be a powerful vehicle for inclusive rural development in India.

DECLARATIONS

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

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

The authors declare that during the preparation of 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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Constraints in Adopting Improved Chickpea Cultivation Practices in Ballia, Uttar Pradesh

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HIGHLIGHTS

- Non-availability of agricultural inputs at the proper time (92.78 MPS) was the most critical constraint limiting effective chickpea cultivation.
- Knowledge-related barriers, such as Lack of information about improved chickpea varieties (89.45 MPS) and Lack of training in scientific chickpea production (88.35 MPS), significantly affected technology adoption.
- Economic constraints, especially the High cost of seed, fertilizers, insecticides, and implements (84.67 MPS), restricted investment in improved practices.
- Social and environmental challenges like the Grazing animal problem (86.98 MPS) and Labour shortage during peak season (82.67 MPS) further hindered productivity.

ARTICLE INFO

Keywords: Technology adoption, Agricultural constraints, Input availability, Farmer training, Extension services.

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ABSTRACT

Despite favourable agro-climatic conditions in eastern Uttar Pradesh, chickpea productivity remains below potential due to multiple adoption barriers. This study investigated the constraints faced by chickpea growers in Ballia district, Uttar Pradesh, during the Rabi season of 2024–25. Using multistage random sampling, 160 farmers from four blocks and sixteen villages were surveyed with structured interviews. The most pressing constraint was the non-availability of agricultural inputs at the proper time, followed by knowledge-related gaps such as a lack of information about improved chickpea varieties and a lack of training in scientific chickpea production. Economic factors such as the high cost of seed, fertilisers, insecticides, and implements, and institutional issues like the non-availability of required seeds in cooperative societies also ranked high. Environmental and social issues—particularly the grazing animal problem and labour shortages during peak seasons further complicated technology adoption. Lower-ranked but still relevant constraints included limited exposure to demonstrations, poor market access, and gender barriers in extension outreach. These findings highlight the complex interplay of technical, economic, institutional, and environmental factors in adoption behaviour. The study recommends a multi-dimensional approach involving timely input delivery, capacity building, improved infrastructure, and targeted policy interventions to enhance chickpea productivity and sustainable adoption of improved cultivation practices.

INTRODUCTION

Chickpea (*Cicer arietinum*), often referred to as the “meat of the poor,” plays a critical role in India’s agriculture and nutrition due

to its high protein content (~25%) and soil-enriching properties through biological nitrogen fixation. As a major pulse crop, chickpeas contribute nearly 50 per cent of India’s total pulse production, with

India accounting for over 70 per cent of global chickpea output (Singh et al., 2020). Uttar Pradesh is one of the top chickpea-producing states, with Ballia district being an important region due to its favourable agro-climatic and soil conditions (Rajbhar et al., 2018). Despite these advantages, the region suffers from suboptimal productivity, largely due to low adoption of improved farming practices and limited awareness among farmers. Studies confirm that variables such as education, income, landholding size, and extension contact significantly influence knowledge and adoption of chickpea technologies (Chaudhary et al., 2014; Nain et al., 2014; Nain et al., 2015).

In Ballia and similar districts, major constraints include lack of technical knowledge, poor access to quality seeds, inadequate irrigation, and weak extension services. In central Uttar Pradesh, 72 per cent of farmers were marginal landholders and over 60 per cent had low income, which correlated with low adoption levels (Rajbhar et al., 2020). However, demonstration projects in Uttar Pradesh have shown significant gains in yield (up to 60% more income) and adoption when improved varieties and complete technological packages are introduced (Singh & Singh, 2013). For example, adoption of STCR-based nutrient management increased yields by 37 per cent and improved soil fertility (Singh et al., 2021). Similarly, frontline demonstrations revealed a technology gap of up to 8.1 q/ha, highlighting the need for more effective knowledge transfer (Singh et al., 2020). Studies have also shown that extension training (e.g., by Krishi Vigyan Kendras) significantly improves knowledge and adoption, especially among farmers with better access to training and information sources (Meena et al., 2015).

The present study investigates the constraints faced by chickpea growers in Ballia district of Uttar Pradesh, a region known for its favourable agro-climatic conditions for rabi pulse cultivation. Using a structured interview schedule and multistage random sampling, the study systematically examines the knowledge, adoption level, and challenges associated with improved chickpea production technologies. The insights derived from the study aim to support policymakers, researchers, and extension personnel in formulating targeted strategies to overcome these barriers. By addressing the identified constraints, the study aspires to enhance chickpea productivity, promote scientific farming practices, and strengthen the overall pulse production system in the region.

METHODOLOGY

The study was carried out during the Rabi season of 2024–25 in the Ballia district of Uttar Pradesh, India. The region features a subtropical climate conducive to chickpea cultivation and is representative of eastern Uttar Pradesh's agro-ecological conditions. A multistage random sampling technique was employed to select the study respondents. In the first stage, four blocks were randomly selected from the district. In the second stage, sixteen villages were selected from these blocks using simple random sampling, with proportional allocation based on the size of each village. In the final stage, a sample of 160 chickpea farmers was selected using proportional allocation, with eligibility criteria including the cultivation of at least half a bigha (approximately 0.125 acres) of chickpea. Primary data were collected through personal interviews using a pre-tested and structured interview schedule. The data were subsequently coded, tabulated, and analysed using the Statistical

Package for the Social Sciences (SPSS). To identify and prioritise the constraints faced by farmers in adopting recommended chickpea production practices, a four-point Likert-type rating scale was employed. The constraints were then ranked according to their mean percent scores (MPS).

RESULTS

The data in Table 1 revealed that the constraint “Non-availability of agricultural inputs at proper time” (92.78 MPS) was the most significant constraint perceived by chickpea growers in the study area. This issue was ranked first and highlights the urgent need for a timely supply of critical inputs to support effective cultivation. The second most important constraint, “Lack of information about improved chickpea varieties” (89.45 MPS), indicates a major knowledge gap among farmers regarding the use of high-yielding or resistant varieties. It was followed closely by “Lack of training in scientific chickpea production” (88.35 MPS), which ranked third, reflecting a lack of capacity-building and skill enhancement among the farming community.

The constraint “High cost of seed, fertilizers, insecticides, and implements” (84.67 MPS) stood at fourth position, indicating that economic limitations continue to restrict the adoption of improved practices. The fifth-ranked constraint was “Non-availability of required seeds and agro-chemicals in cooperative societies” (82.89 MPS), emphasizing issues in local institutional support systems. Interestingly, the “Grazing animal problem” (86.98 MPS) emerged as the sixth major constraint, showing the impact of stray animals on crop productivity. “Labour shortage during peak agricultural season” (82.67 MPS) was ranked seventh, highlighting seasonal workforce challenges. Similar findings have been reported by Tiwari et al., (2020) & Sengar et al., (2020).

Other notable constraints included “Lack of knowledge about plant protection measures” (74.53 MPS, Rank VIII), “Limited access to extension services and technical advice” (70.25 MPS, Rank IX), and “Market is far from the village” (64.67 MPS, Rank X). Constraints like “Lack of irrigation resources” (61.67 MPS), “Inadequate exposure to demonstrations” (67.50 MPS), and “Lack of awareness about cooperative societies” (63.10 MPS) were ranked lower but still represented meaningful barriers to full adoption. The least significant constraints identified were “Social resistance to new practices” (68.90 MPS, Rank XVII), “Gender barriers in accessing training and inputs” (66.20 MPS, Rank XVIII), and “Risk of crop damage due to erratic climate or pests” (72.50 MPS, Rank XIX), which although ranked lower, suggest emerging challenges that may intensify under changing socio-economic and environmental conditions. Sharma et al., (2024) report similar findings.

DISCUSSION

The analysis of constraints faced by chickpea growers in Ballia district revealed a wide range of interrelated issues that collectively hinder the effective adoption of improved production technologies. The most critical constraint identified was the non-availability of agricultural inputs at the proper time (92.78 MPS), underscoring the inefficiencies in supply chain and distribution systems. Knowledge-related constraints, such as a lack of information about improved chickpea varieties (89.45 MPS) and insufficient training

Table 1. Constraints in the adoption of recommended cultivation practices of chickpea.

S.No.	Constraints	MPS	Rank
A.	Input & Resource Related Constraints		
1	Non-availability of agricultural inputs at the proper time	92.78	I
2	High cost of seed, fertilizers, insecticides, and implements	84.67	IV
3	Non-availability of required seeds and agrochemicals in cooperative societies	82.89	V
4	Non-availability of soil testing facilities and training for seed & soil treatment	78.89	VII
5	Lack of irrigation resources (electricity and water)	61.67	XI
B.	Knowledge & Training Related Constraints		
6	Lack of information about improved chickpea varieties	89.45	II
7	Lack of training in scientific chickpea production	88.35	III
8	Lack of knowledge about plant protection measures	74.53	VIII
9	Limited access to extension services and technical advice	70.25	IX
10	Inadequate exposure to demonstrations and field visits	67.50	XII
6	Lack of information about improved chickpea varieties	89.45	II
7	Lack of training in scientific chickpea production	88.35	III
C.	Infrastructural & Institutional Constraints		
11	Market is far from the village	64.67	X
12	Lack of proper transport facilities	69.83	XIII
13	Inadequate storage and warehousing facilities	66.75	XIV
14	Delayed or inefficient input supply chains	65.35	XV
15	Lack of cooperative society awareness and support	63.10	XVI
D.	Social & Environmental Constraints		
16	Grazing animal problem	86.98	VI
17	Labour shortage during peak agricultural season	82.67	VII
18	Social resistance or unwillingness to adopt new practices	68.90	XVII
19	Gender barriers in accessing training and inputs	66.20	XVIII
20	Risk of crop damage due to erratic climate or pests	72.50	XIX

in scientific chickpea production (88.35 MPS), also ranked among the top, pointing to serious gaps in farmer education and extension outreach. Economic barriers, particularly the high cost of quality seeds, fertilizers, and pesticides (84.67 MPS), continue to discourage investment in advanced practices, while infrastructural deficiencies such as distant markets, poor transport, and inadequate storage limit the profitability and scalability of chickpea cultivation. Social and environmental challenges, especially the grazing animal problem (86.98 MPS) and labour shortages during peak seasons (82.67 MPS), further compound the difficulties.

These findings are consistent with studies from similar regions in Uttar Pradesh, such as Auraiya and Bundelkhand, where technical constraints (e.g., lack of good-quality seeds and information), financial challenges (e.g., cost of inputs), and socio-environmental issues (e.g., labour shortages and pest problems) were also found to significantly hinder chickpea production (Singh et al., 2016; Gireesh et al., 2019; Sengar et al., 2020). These findings indicate the need for a holistic and multi-pronged approach involving timely input delivery, improved extension services, targeted subsidies, better market access, and localized infrastructure development. Strengthening institutional support and addressing socio-environmental barriers will be key to enhancing chickpea productivity and promoting sustainable pulse cultivation in the region.

CONCLUSION

Farmers in Ballia district face major challenges such as delayed input supply, lack of technical knowledge, high input costs, and limited access to institutional support, all of which hinder the

adoption of improved chickpea production practices. These findings highlight the urgent need for targeted interventions, including timely delivery of agricultural inputs, enhanced extension services, capacity-building programs, and affordable credit mechanisms. Addressing these interlinked constraints can significantly improve chickpea productivity, farm profitability, and rural livelihoods. The study reinforces the critical role of institutional support and farmer-focused strategies in bridging adoption gaps and promoting sustainable pulse cultivation in eastern Uttar Pradesh.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the farmer respondents 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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Perceived Benefits and Pre-Design Environmental Impact Assessment of Eco-Friendly Ornament Development

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HIGHLIGHTS

- Environmental safety is the most influential driver for advocating eco-friendly ornaments among rural consumers.
- Design-stage sustainability considerations remain underemphasized despite expressed environmental motivations.
- Energy saving and fossil fuel alternatives are the most perceived ecological benefits of eco-friendly products.

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ABSTRACT

The study examined the environmental benefits and pre-design impact assessments of eco-friendly ornaments in rural Uttar Pradesh, focusing on Ayodhya district. A sample of 240 respondents was selected from 24 villages using multistage random sampling. Data were collected through structured interviews, surveys, and direct observations, and analyzed using descriptive statistics, chi-square tests, and Student's t-test. The results, conducted in 2024-2025, show that 58.75 per cent of respondents supported eco-friendly ornaments to promote environmental safety ($\chi^2 = 191.95$, $p < 0.05$). However, when it came to the integration of environmental considerations during the design phase, durability (35.41%) was the most cited factor, but differences were not statistically significant ($t = 0.167 < 3.182$). In terms of ecological benefits, energy saving (40.41%) and fossil fuel alternatives (30.41%) were the most recognized advantages, with statistical significance ($\chi^2 = 48.61$, $p < 0.05$). These findings highlight a strong environmental motivation among consumers in rural areas, although sustainability is not fully integrated into the early stages of product design. The study emphasizes the need for interventions that raise awareness and build capacity to ensure that sustainability becomes a key consideration in the design process, ultimately promoting more environmentally responsible ornamentation practices in rural India.

INTRODUCTION

In recent years, the global emphasis on sustainable development has catalyzed a significant shift towards environmentally responsible consumption and production practices. Among the various sectors impacted by this movement, eco-friendly ornaments have gained substantial attention as alternatives to

conventional accessories traditionally crafted from synthetic or non-renewable materials (Pasaribu et al., 2022). These ornaments, designed from biodegradable, recyclable, or locally sourced materials, embody a fusion of aesthetic appeal, ethical responsibility and environmental stewardship. This development holds particular relevance for rural India, where traditional craftsmanship intersects with emerging ecological values (Austria et al., 2022). While eco-

conscious purchasing behaviors have become increasingly prominent in urban areas, there remains a dearth of research focused on rural consumers, whose preferences are shaped by a unique blend of cultural traditions, economic limitations, and localized environmental challenges (Kumari et al., 2025). Rural communities, especially women artisans, play an integral role not only in the production of such sustainable ornaments but also in the dissemination of eco-friendly practices. These artisans, often deeply rooted in their local environments, contribute significantly to the promotion of sustainable ornamentation within their communities (Imrankhan et al., 2025). However, the extent to which environmental factors influence their design decisions, and how these decisions are perceived in terms of ecological benefits, remains underexplored in the academic literature (Jin et al., 2024).

This study seeks to fill these gaps by examining two primary areas of interest: first, the perceived environmental benefits of eco-friendly ornaments among rural consumers, and second, the environmental impact assessments conducted prior to the design and creation of these products. Through a focused analysis of consumer behavior and sustainability awareness in the Ayodhya district of Uttar Pradesh, this research aims to provide a comprehensive understanding of eco-consumerism within rural contexts. The findings are intended to inform sustainable design interventions, support policy alignment with grassroots sustainability efforts, and promote the growth of environmentally responsible consumer cultures in rural India (Sonu & Jha, 2025). In rural India, traditional ornament crafting plays a key role in the cultural and economic life of communities. Despite facing challenges such as limited access to sustainable knowledge and eco-friendly practices, rural artisans' strong connection to the land and local resources can provide a foundation for promoting environmentally friendly alternatives. This research explores how these traditional practices can be aligned with ecological values to support the development of eco-friendly ornaments. By assessing the environmental benefits recognized by consumers and the pre-design impact assessments made by artisans, the study provides valuable insights into integrating sustainability into ornament design. The findings aim to promote the adoption of environmentally responsible practices among rural artisans and consumers, encouraging the growth of an eco-conscious ornamentation industry in rural India. While there is a shift toward eco-conscious consumption in these areas, integrating sustainability into the design stage of ornament production remains underdeveloped and requires attention. The study highlights the need for interventions that bridge the gap between environmental awareness and the practical application of sustainable design principles, contributing to the long-term ecological and economic sustainability of rural craftsmanship.

METHODOLOGY

This research, conducted in 2024-2025, adopts a qualitative, descriptive, and cross-sectional design to assess the perceived environmental benefits and pre-design environmental impacts of eco-friendly ornaments in rural Uttar Pradesh, India. The study involved 240 respondents aged 18 and above, selected using a multistage random sampling method from 24 villages across four administrative blocks in Ayodhya district. The selection of blocks was based on

their proximity to eco-friendly ornament markets and their involvement in sustainable initiatives. Participants were chosen from those who had shown interest in or had previously purchased eco-friendly ornaments, ensuring a representative sample.

Data collection was carried out through structured interviews, direct observations, and surveys. The interview schedule was self-developed and pre-tested with a pilot group of 20 respondents to refine the tool and ensure clarity and reliability. Ethical considerations were rigorously followed by obtaining verbal consent from participants, explaining the research's academic purpose, and ensuring confidentiality.

For data analysis, both descriptive and inferential statistical methods were employed. Descriptive statistics, such as frequency distributions, means, and standard deviations, were used to summarize the data. The chi-square test (χ^2) was used to explore relationships between categorical variables, while the Student's t-test (assuming equal variances) was applied to compare groups regarding environmental perceptions. The expected frequencies (E_i) for the chi-square test were calculated using the formula:

$$E_i = \frac{\text{Row total} \times \text{Column total}}{\text{Grand total}}$$

Where, E_i = Expected frequency for each cell, Row Total = Total of the specific row, Column Total = Total of the specific column, Grand Total = Total of all observations in the table

Data analysis was conducted using SPSS Version 26, ensuring robust statistical validation of the findings. These methodologies were selected to ensure the study's rigor, reliability, and relevance to understanding the attitudes of rural consumers toward eco-friendly ornamentation and sustainable practices.

RESULTS

To understand the multidimensional aspects influencing the adoption and advocacy of eco-friendly ornaments, the study assessed motivational factors, design-stage environmental considerations, and perceived ecological benefits. The findings offer key insights into sustainability-related behaviours within rural communities.

A substantial proportion of respondents (58.75%) cited the promotion of a safe environment as the most influential factor (Table 1). Product utilization was selected by 12.50 per cent of the respondents, followed by economic savings (10.00%) and other motivations (7.91%). The chi-square test produced a value of 191.95 ($df = 3$, $p < 0.05$), indicating a statistically significant variation in the distribution. These results suggest that environmental safety is

Table 1. Distribution of respondents based on their reasons for advocating the promotion of eco-friendly ornaments

Factors	Percentage	$(O_i - E_i)^2$	$(O_i - E_i)^2 / E_i$
Safe environments	58.75	7656.25	143.11
Save economy purpose	10.00	870.25	16.27
Product utilization	12.50	552.25	10.32
Other	7.91	1190.25	22.25
Total	100		191.95

Table 2. Distribution of the evaluation of the environmental impact prior to designing and crafting eco-friendly ornaments.

Environmental Impact	Percentage	d.f	t_{cal}	T_{tab} (5%)
Durability	35.41	3	0.167	3.182
Sometime	31.66			
Consumer demand	16.66			
Never	16.25			

the dominant reason among respondents for supporting eco-friendly ornaments.

In the evaluation of environmental impact prior to the design and crafting of eco-friendly ornaments, consumer demand emerged as a significant factor, cited by approximately 16.66 per cent of the respondents. While this category may not directly refer to traditional environmental factors, consumer demand plays a crucial role in shaping the sustainable practices of businesses and artisans. When consumers support sustainable jewelry brands, they actively contribute to the reduction of waste and the promotion of recycled materials. For example, 4 Ocean bracelets, made from recycled ocean plastics, exemplify how consumer demand can help repurpose waste materials into new raw materials for ornament creation, simultaneously cleaning up the oceans. This shift in consumer preference encourages artisans and companies to adopt more sustainable practices, ultimately contributing to the reduction of environmental harm. However, the t-test results ($t = 0.167$) show that the observed differences in responses regarding the evaluation of environmental impact were not statistically significant, with a tabulated value of 3.182 at the 0.05 level of significance ($df = 3$). This suggests that while consumer demand is an important consideration, it is not the most influential factor in the environmental impact assessments made by artisans during the design phase.

As shown in Table 3, the most widely acknowledged environmental benefit of eco-friendly products was energy saving (40.41%). This was followed by recognition of their role as an alternative to fossil fuels (30.41%), awareness of their connection to non-renewable resource conservation (11.25%), and other factors (17.91%). The calculated chi-square value of 48.61 ($df = 3$, $p < 0.05$) was significantly higher than the critical value, indicating that differences among categories were statistically significant.

Table 3. Distribution of the Environmental Benefits of Eco-Friendly Products

Benefits	Percentage	$(O_i - E_i)^2$	$(O_i - E_i)^2 / E_i$
Save energy	40.41	1369	22.82
Alternative to fossil fuel	30.41	169	2.82
Nonrenewable resources	11.25	1089	18.15
Other	17.91	289	4.82
Total	100		48.61

DISCUSSION

The present study explores the socio-behavioural and environmental dynamics surrounding the adoption and advocacy of eco-friendly ornaments among rural communities. The findings reveal that ecological consciousness strongly influences consumer

motivation, with a majority of respondents identifying environmental safety as the primary driver for promoting such products (Tran et al., 2022). This aligns with prior research emphasizing that rural populations, despite limited exposure to structured environmental campaigns, often demonstrate an intuitive alignment with eco-conscious practices due to their close dependence on natural ecosystems (Carranza et al., 2023). The dominance of “safe environments” as a motivating factor (58.75%) underscores a growing perception of environmental sustainability as a core value within grassroots consumption (Yusuf et al., 2023), who assert that the integration of green ethics into lifestyle decisions is gaining traction in Indian semi-urban and rural settings. The statistically significant chi-square result ($\chi^2 = 191.95$, $p < 0.05$) further reinforces the non-random distribution of motivations, highlighting a definitive preference for environmental well-being over purely economic or utilitarian benefits (Sarstedt et al., 2020).

In contrast, the evaluation of environmental considerations during the design phase yielded statistically insignificant variation ($t = 0.167 < t_{crit} = 3.182$), suggesting a relatively uniform distribution of responses across categories. Although durability (35.41%) emerged as the most frequently cited criterion, the overlap with material availability (31.66%) indicates that design choices may be more practical than principle-driven. This finding diverges from earlier studies (Sanyal et al., 2014), which emphasized proactive environmental design thinking among eco-entrepreneurs. The low t-value implies that while environmental impact is acknowledged post-consumption, it is not yet fully integrated into design-stage decision-making, pointing to a potential knowledge-action gap. The third component of the analysis, perceived environmental benefits, provides further validation of consumer awareness. Energy conservation (40.41%) and fossil fuel alternatives (30.41%) were cited as primary advantages of eco-friendly products. The significant chi-square result ($\chi^2 = 48.61$, $p < 0.05$) supports the presence of meaningful differences in how these benefits are understood and prioritized among rural consumers (Krishnakumar & Lajith, 2023). Notably, only 11.25% of respondents recognized connections to non-renewable resource conservation, suggesting that while awareness exists, it may be limited to more tangible and immediate outcomes like energy efficiency (Siddique & Rajput, 2022). Taken together, these results suggest a layered awareness among rural consumers where environmental advocacy is a conscious choice, but environmental integration into design and production stages remains fragmented (Salem & Chaichi, 2018). This partial disconnect may be attributed to limited access to sustainable design knowledge or insufficient engagement with ecological literacy programs. Furthermore, the influence of culturally embedded values such as frugality, resourcefulness, and communal well-being appears to strengthen the pro-environmental orientation, though not necessarily with scientific framing (Kumar et al., 2024). The study contributes to the growing discourse on rural environmental behaviour by bridging attitudinal perception with statistical validation. It indicates that while ecological motivation is robust at the advocacy level, further sensitization is needed at the creative and production level. Future research should explore intervention strategies that translate environmental intent into design-led innovation, particularly within artisanal and informal markets.

CONCLUSION

The study establishes that environmental safety is the most influential factor driving the advocacy of eco-friendly ornaments among rural consumers, highlighting a growing environmental consciousness at the grassroots level. However, the integration of environmental considerations during the design phase remains limited, with durability cited most frequently but lacking significant variation. This suggests that while consumers recognize ecological benefits such as energy saving and fossil fuel alternatives, these motivations are not fully reflected in early-stage product development. The findings underscore the need for targeted awareness and capacity-building interventions to bridge the gap between environmental intent and sustainable design practices. Promoting ecological literacy and design-oriented training can enhance rural sustainability efforts and support the broader goal of environmentally responsible consumption and production.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the farmer respondents 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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Constraints Faced by Farmers in Adapting to Climate Change in North Bihar

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HIGHLIGHTS

- Small and fragmented landholdings significantly restrict farmers' capacity to adapt to climate change.
- Lack of accuracy and untimely weather forecasts limits informed decision-making and hinders risk management efforts.
- High dependency on monsoon due to costly irrigation and lack of technical training increases vulnerability to climate variability.
- Financial constraints such as high input costs, delayed credit, and low savings reduce farmers' adaptive capacity and resilience.

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Keywords: Constraints, Climate change, Garrett ranking, Adaptation, Variability, Climate resilient, Adaptive capacity, Vulnerability.

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ABSTRACT

The study was conducted in 2025 in North Bihar to investigate the challenges faced by farmers in adapting to climate change. Districts Darbhanga and Sitamarhi were purposively chosen on the basis of high vulnerability to climate change. To analyze the constraints faced by farmers, 192 respondents were selected randomly from selected villages. Farmers were surveyed through personal interviews, and data were analyzed using Garrett's ranking technique to prioritize the constraints hindering adaptation to climate change. The constraints were divided into four categories, i.e., socio-personal constraints, institutional constraints, technical constraints, and financial constraints. The analysis revealed that socio-personal constraints, such as small size fragmented landholdings, and increasing labour scarcity, whereas institutional constraints such as lack of accurate and untimely information about weather forecast and poor extension service on climate risk management were major constraints faced by farmers in adapting to climate change in north Bihar. Furthermore, the highly dependent nature of farmers on the monsoon and the lack of training on climate-smart agriculture practices were ranked as major technical constraints, whereas the high cost of inputs and the non-availability of untimely inputs were financial constraints faced by farmers.

INTRODUCTION

In India, agriculture is one of the most significant economic sectors, providing food and a means of livelihood for about 60 per cent of the country's population. Agriculture and climate are mutually dependent. Climate change affects agriculture both directly and indirectly in India (Vijayabhinandana et al., 2022). Changes in cropping patterns, agricultural productivity, profitability, supply, and trade are only a few of the major economic impacts of climate change on agriculture. Due to rising temperatures, agricultural production is expected to decline by 2050 in the Himalaya region

will lead to food insecurity (Bharat et al., 2022). In past years, it has been predicted that, with the rise in temperature by 2.5°C to 4.9°C, the yield of rice and wheat will drop by 32 to 40 per cent and 41 to 52 per cent, respectively (Chouksey et al., 2021). Despite the fact that climate change has happened globally, its effects frequently differ from region to region. Bihar is among the most climate-sensitive states in India because of its geographic location, unpredictable hydrometeorology, dense rural population, and poverty (Sattar et al., 2021). Due to the yearly floods in the northern part of Bihar and the droughts in the southern part, the state is particularly vulnerable to hydro-meteorological disasters.

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According to vulnerability analysis done by the Indian Council of Agricultural Research (ICAR) with the support of the National Innovation on Climate Resilience Agriculture (NICRA) programme, Bihar is most susceptible to the impacts of climate variation (Singh et al., 2024). Research report on national climate vulnerability assessment published by Department of Science and Technology in 2021, about 80 per cent (31 out of 38) district in Bihar are among top 25 per cent most vulnerable district in the country. According to available evidence, the vulnerability of Bihar's agriculture to climate change is likely to be more prominent in the future. Agriculture is the mainstay of the Bihar economy, employing 77 per cent of the workforce. Floods, heat waves, and other extreme weather conditions will have a detrimental effect on agricultural crops, cattle health, and productivity.

To cope with extreme weather, adaptation strategies are important. Adaptations are defined as adjustments in human or natural systems in response to real or anticipated climate stimuli, which moderately harm or exploit beneficial opportunities (IPCC, 2007). To deal with changing weather events, strategies for adaptation include adjusting planting dates, water-saving methods, prudent fertilizer management, etc. (Shanabhoga et al., 2020; Brar et al., 2020). Adapting to the changing climate presents a variety of constraints for farmers. They must overcome a variety of obstacles, including institutional ones like inadequate extension services and restricted credit availability, personal ones like low literacy and dispersed landholdings, and technical ones like ignorance of climate-smart practices. Their capacity to adapt is further hampered by weather-related problems such as inaccurate forecasts, shifting rainfall patterns, high input costs, and a lack of workers (Naik et al., 2022; Singh et al., 2023). This study highlights the major constraints face by the farmers in the study area.

METHODOLOGY

The study was carried out in North Bihar's Darbhanga and Sitamarhi districts, which were purposively chosen on the basis of high vulnerability to climate change according to vulnerability analysis done by ICAR with the support of NICRA programme. In the second stage, the Alinagar and Hanuman-nagar block of Darbhanga district and Dumra and Riga block of Sitamarhi district were selected by random sampling technique for the study. From each selected block, four villages were selected using a random sampling technique making a total of 16 villages.

To analyze the constraints faced by farmers in adapting the climate change 12 respondents were selected randomly, from each village constituting a total sample size of 192. The constraints were classified as personal, institutional, technical and financial based on the review of literature. From the listed constraints, respondents were asked to give higher ranks to the most severe one and last rank to the least severe one. Among the various methodologies as suggested by Gupta et al., (2020), ranking of constraints was done with the help of Henry Garrett's Ranking Technique. For this, the percent position of each rank is calculated with the help of following formula:

$$\text{Percent position} = 100 (R_{ij} - 0.5) / N_j$$

Where, R_{ij} = Rank given for the i^{th} variable by j^{th} respondent,
 N_j = Number of variable ranked by j^{th} respondents

With the help of Garrett's table given by Garrett and Woodworth (1969), the percent position estimated is converted into scores. Then for each constraint, the score of each individual was summed up and divided by total number of respondents for each constraint to get mean value. The constraint with the highest mean value was the most important one and ranked I.

RESULTS

The data from Table 1 shows that among the personal constraints, 'small size fragmented land holdings' was ranked 'I' with a Garrett score of 65.34, followed by 'Increasing labour scarcity' was ranked 'II' with a Garrett score of 58.14, 'Inadequate knowledge about climate change coping strategies' was ranked 'III', and inability to take risk was ranked 'IV' with a Garrett score of 56.25 and 52.74, respectively

Among the institutional constraints as perceived by the respondents, 'Lack of accurate and untimely information about weather forecast and climate change' was the most significant constraint (61.09). 'Poor extension service on climate risk management' ranked 'II' with a Garrett score of 59.89, followed by 'Lack of market access' was ranked 'III' with a Garrett score of 54.20 and 'Lack of support from line departments' was found to be the least important institutional constraint (51.45).

It is evident from Table 1 that among technical constraints faced by farmers in adapting to climate change, 'highly dependent on monsoon' was ranked 'I' with a Garrett score of 61.07. 'Lack of technical know-how on climate change', 'High cost of irrigation facilities' and 'Poor reliability of climate forecast' were ranked 'II',

Table 1. Constraints faced by the farmers in adapting to climate change

Constraints	Garrett Score	Rank
<i>Personal constraint</i>		
Small size fragmented landholdings	65.38	I
Inadequate knowledge about climate change coping strategies	56.25	III
Increasing labour scarcity	58.14	II
Inability to take risk	52.74	IV
<i>Institutional constraint</i>		
Poor extension service on climate risk management	59.89	II
Lack of accurate and untimely information about weather forecast and climate change	61.09	I
Lack of Market access	54.20	III
Lack of support from line department	51.45	IV
<i>Technical constraints</i>		
Highly dependent on Monsoon	61.07	I
High cost of irrigation facilities	56.53	III
Lack of training on climate smart agriculture practices	58.13	II
Poor reliability of climate forecast	51.32	IV
<i>Financial constraints</i>		
High cost of inputs	68.15	I
Short of savings	38.65	IV
Non-availability of untimely inputs (seeds, pesticides, fertilizers, etc.)	45.41	II
Delay in sanctioning credit	42.67	III

'III' and 'IV' with a Garrett score of 58.13, 56.53, and 51.32, respectively.

It is indicated from Table 1 that 'High cost of inputs' was ranked the most severe financial constraint ranked 'I' with a Garrett score of 68.15, followed by 'Non-availability of untimely inputs' was ranked 'II' with a Garrett score of 45.41, 'Delay in sanctioning credit' and 'Short of savings' were ranked as 'III' and 'IV' financial constraints in adapting to a changing climate, with a Garrett score of 42.67 and 38.65, respectively.

DISCUSSION

The multifaceted constraints were identified in the adaptability of farmers to climate change in North Bihar through survey data and farmers' insights. Farmers have small and fragmented land holdings due to the nuclear family and low annual income. Singh et al., (2015) in their study in Bihar reveal that small and scattered land holdings reduce economies of scale, limit access to credit, and challenging to adapt various coping measures to climate change. Labour scarcity hinders farmers' climate adaptation by limiting their ability to implement resilient practices, adopt new technologies, and respond to climate related shocks (Ashoka et al., 2022). Adequate knowledge about climate change coping strategies enables farmers to implement adaptive measures, ultimately supporting farmers' livelihood and food security (Ghanghas et al., 2015; Chouksey et al., 2020; Mishra et al., 2024).

Inaccurate weather forecast hinders farmers' climate adaptability, causing crop losses and poor decision-making. Untimely and precise forecasts enable informed choices, reducing risks and enhancing resilience to climate change. Similarly, in the study by Shelar et al., (2022), access to reliable weather data is crucial for farmers to manage climate related challenges and ensure sustainable agricultural practices. Poor extension services on climate risk management can hinder farmers' ability to adapt to climate change leading to increased vulnerability to climate-related shocks and stresses. As reported by Shanbhoga et al., (2023), the improvement of field extension services, especially on climate risk management, can improve farmers' ability to adapt to climate related innovations. In the study of Roy et al., (2023) in Bihar reports that unfavorable weather circumstances like droughts and floods can destroy crops, reduce the appropriate supply of agricultural products, and eventually affect the selling of agricultural commodities. Furthermore, unstable demand and low prices can discourage farmers from investing in sustainable practices, exacerbating their vulnerability to climate change. Lack of support from the line department in Bihar is due to a shortage of officials, staff, and lack of unity of command on officers of the line department (Singh et al., 2015). Support from line departments can significantly enhance farmers' capacity for climate adaptation by providing essential services such as extension, technical assistance and input supply.

In study done under the Central Research Institute for Dryland Agriculture on Promising Climate Resilient Technologies for Bihar (Singh et al, 2024) reported that 60 per cent to 70 per cent of agriculture is highly dependent on rainfall. The erratic monsoon is responsible for making Bihar agriculture particularly vulnerable to fluctuations in monsoon patterns (Singh et al., 2014). Saha et al.,

(2019) & Mishra et al., (2024) highlight the need for specialized training programmes and found that farmers who receive regular training faced fewer problems in adopting climate smart agricultural practices. Unavailability of water storage structures makes farmers more dependent on monsoon. This can lead to reduced crop yields, decreased productivity, and financial strain, ultimately limiting their ability to invest in climate-resilient practices. Unawareness of the farmers about the shift in meteorological circumstances and poor reliability on weather forecasts can lead to poor planning and decision-making, making farmers more vulnerable to crop damage or loss, and decreased productivity (RaviKumar et al., 2015; Adhikari et al., 2022; Kumar et al., 2023).

In the study of Namdeo et al., (2023), the high cost of inputs encountered by farmers was the major constraint in adapting climate-resilient practices. The high cost of agricultural inputs such as seeds, fertilizers, equipment, and untimely unavailability can limit farmers' ability to invest in climate-resilient practices and technologies, making them more vulnerable to climate-related shocks. The problems of agricultural finance are manifold and complex. Farmers face the problem of credit non-availability in time, document expense, expensive procedure, and high rate of interest (Subramanian et al., 2017). Delayed credit can hinder farmers' ability to adapt to changing climate conditions, ultimately affecting their productivity, income and resilience. A lack of savings can significantly affect farmers to invest in climate-resilient practices, new technologies, or essential inputs that can improve productivity, making it challenging to sustain their livelihoods and respond to emerging challenges (Naik et al., 2022).

CONCLUSION

The study highlights the multifaceted challenges faced by cultivators in North Bihar in adjusting to climate shifts. These challenges are interrelated and call for a holistic and multi-level response. Addressing these challenges requires integrated efforts such as strengthening extension services, promoting climate-resilient farming practices, improving weather forecasting systems, and ensuring untimely access to inputs and credit. Moreover, policy interventions that prioritize smallholder farmers, invest in rural infrastructure, and integrate local knowledge with scientific innovations are crucial for long-term sustainability. Empowering cultivators through training and institutional support is essential to enhance their ability to cope with climatic variability and secure sustainable agricultural livelihoods.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the farmer respondents 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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Bridging the Digital Divide: Constraints to Digital Literacy Among Joint Liability Groups Women Farmers in Kerala

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HIGHLIGHTS

- Limited training opportunities emerged as the most critical barrier to digital literacy.
- Economic factors, particularly internet costs, significantly constrained access.
- Lack of mentorship and limited institutional initiatives weakened adoption.
- Educational and economic barriers emerged as the most severe dimensions.
- Holistic interventions are required to address interconnected barriers.

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Keywords: Digital literacy, Women farmers, Joint liability groups, Constraints, Garrett ranking, Kerala.

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ABSTRACT

Digital literacy remains a critical determinant of women farmers' ability to participate in and benefit from emerging agricultural innovations. Among women farmers in Joint Liability Groups (JLGs) in Kerala, multiple barriers continue to limit their effective digital engagement. To capture these constraints, data were collected from 280 respondents across 14 districts during April-May 2025 using a structured interview schedule supplemented by focus group discussions. Constraints were prioritised through Garrett's ranking technique. The findings revealed that limited training opportunities emerged as the most severe barrier (mean score 64.66), followed by high internet costs (56.28), lack of local mentorship (56.03), and insufficient government initiatives for digital adoption (55.35). Other important challenges included non-customised training programs (55.27), low digital proficiency (55.12), complex digital interfaces (54.82), dependence on family members (51.78), low motivation (50.59), and language barriers in training materials (48.40). The findings indicate that digital exclusion among JLG women farmers arises from interlinked educational, economic, infrastructural, and socio-cultural constraints. The study emphasises the need for gender-sensitive and context-specific training, affordable internet access, community-based mentorship, and targeted policy support to strengthen digital literacy and empower women farmers in Kerala's agrarian economy.

INTRODUCTION

Digital technologies are increasingly recognised as transformative tools in agriculture, driving improvements in productivity, efficiency, and sustainability (Pretty, 2018; Liakos et al., 2018). Precision farming (Gebbers & Adamchuk, 2010), AI-driven decision-support systems, blockchain-enabled supply chains

(Kamilaris et al., 2019), and IoT-based monitoring solutions exemplify innovations that reshape global farming practices. Yet, the benefits of this digital revolution remain unevenly distributed, particularly in developing economies where digital divides persist (Fuglie, 2018; World Bank, 2022). In India, where agriculture sustains nearly 55 per cent of the workforce and contributes about 18 per cent to national GDP (MoA&FW, 2023), bridging this divide

is vital to achieve the projected 70 per cent increase in food production required to meet future demand (FAO, 2023). Persistent disparities in access, affordability, and capacity continue to exclude smallholders and women farmers from fully benefiting from digital agriculture initiatives.

The gender dimension of this divide is particularly pronounced in India's agrarian economy. Women constitute nearly one-third of the agricultural workforce and almost half of self-employed farmers (NSSO, 2019), but face structural disadvantages such as limited land ownership (Agricultural Census, 2016), wage gaps of 20–30 per cent compared to men (ILO, 2022), and the “triple burden” of household, farm, and community responsibilities (Rao, 2012). The digital gap compounds these inequalities: only 8.5 per cent of rural women possess basic digital literacy compared with 17.1 per cent of rural men (MoSPI, 2019). Barriers include low smartphone ownership (GSMA, 2022), sociocultural restrictions (Gurumurthy et al., 2016), and the absence of gender-responsive agricultural content (Priya et al., 2021). Extension research demonstrates that targeted, gender-sensitive interventions reduce these gaps. Sharma & Singh (2022) show that digital inclusion initiatives improve women's access to agricultural information, while Singh et al. (2023) report that ICT-enabled extension services reduce structural and knowledge barriers when inclusively designed. Pal et al., (2015) reported that difficult terrain and poor connectivity in hilly areas, an unorganized farming community, lack of interest in farming due to uneconomic holding, and poor financial condition of the farmers were the prime constraints encountered by the agriculture extension officers.

Kerala provides a compelling case for examining these dynamics. Despite its high literacy rate (94%; Census, 2011), advanced digital infrastructure such as the Kerala Fibre Optic Network (KFON), and the Kudumbashree movement that mobilises over three million women (Kudumbashree Mission, 2023), significant disparities persist among women farmers in Joint Liability Groups (JLGs). This study, therefore, identifies and prioritises the constraints to digital literacy among JLG women farmers in Kerala, with the broader aim of outlining pathways to bridge the gendered digital divide and strengthen women's capacity to leverage opportunities in digital agriculture.

METHODOLOGY

The study was carried out across all 14 districts of Kerala to ensure comprehensive representation. Kerala hosts 96,177 Joint Liability Groups (JLGs) under Kudumbashree, involving 439,255 women farmers cultivating 21,457 hectares. Among these, Thrissur, Wayanad, and Kannur account for the largest share of JLGs, while Kollam and Palakkad represent smaller proportions. This extensive presence underscores their institutional significance and justified their selection as the unit of study. From each district, five JLGs were randomly chosen, and four members from each were selected, yielding 20 respondents per district and 280 in total. This two-stage sampling design ensured representation of multiple groups within each district, capturing both intra-group and inter-district variation. Such an approach prevented over-reliance on single groups and provided more reliable insights into the digital literacy scenario of JLG women farmers. JLGs were considered particularly

appropriate as they receive strong institutional backing, greater opportunities for capacity building, and play a vital role in women's empowerment and livelihood security, making them an ideal setting to examine digital literacy constraints in farming contexts.

Primary data were collected through a pre-structured interview schedule designed to capture constraints across diverse dimensions, including access and infrastructure-related barriers, individual challenges, socio-cultural restrictions, capacity-building limitations, policy and institutional issues, technological difficulties, and psychological factors. To supplement and validate these findings, focus group discussions (FGDs) were conducted in each district, offering qualitative insights and triangulation of results. These sessions provided greater depth in understanding socio-cultural dynamics, affordability concerns, infrastructural gaps, and institutional shortcomings.

The list of constraints was finalised through expert consultation and a review of relevant literature. Garrett's ranking technique was then used to prioritise the identified factors. Garrett's method (Garrett & Woodworth, 1969) ensures uniformity in score distribution and facilitates clear prioritisation, even when the number of items or ranking patterns varies. Using the Garrett table, the calculated per cent positions were converted into scores. The individual scores for each factor were aggregated and divided by the total number of respondents to determine the mean scores.

RESULTS

The data in Table 1 reveal that the most critical constraint was limited training opportunities (Mean score: 64.66), highlighting the inadequacy of structured and localised training for women farmers. This result is in line with earlier findings by Mittal et al., (2017) & Kumar et al., (2025), who emphasised that training gaps are a major impediment to digital literacy among rural populations.

The high cost of internet services and recharges (56.28) was the second most pressing constraint. Affordability issues continue to limit consistent internet use, as also observed by Mukherjee et al., (2023) in their assessment of barriers to digital adoption in Indian agriculture. The lack of local mentorship (56.03), ranked third, indicates the absence of peer or community guidance in digital adoption, similar to the observations of Sen (2015), who noted that localised support networks are vital in encouraging rural women's engagement with technology. Institutional and policy-related issues were also prominent. Limited government initiatives for promoting digital adoption in agriculture (55.35) and non-customised programs (55.27) were ranked fourth and fifth, respectively. These results are in line with Heeks (2018), who argued that top-down digital interventions often fail to align with grassroots realities. Low digital proficiency (55.12) and complex digital interfaces (54.82) further constrained adoption, which is consistent with the findings of Schnebelin (2022), who emphasised that user-unfriendly applications discourage participation among farmers with low literacy levels. Psychological and social barriers were ranked in the middle order. Dependence on family members (51.78) and low motivation levels (50.59) reflect attitudinal and autonomy-related challenges, as reported by Chakraborty & Gupta (2019). Language barriers in training materials (48.40) also affected digital literacy efforts, confirming the importance of localised content highlighted

Table 1. Constraints faced by JLG women farmers in improving digital literacy

S. No.	Statements	Mean Score	Rank
<i>Access and Infrastructure-Related Constraints</i>			
1.	Limited Internet Penetration	33.77	15
2.	Unstable Network Infrastructure	41.75	12
3.	High costs associated with internet services and recharges	56.28	2
<i>Individual-Level Constraints</i>			
4.	Low Digital Proficiency	55.12	6
5.	Fear of Technology	38.63	14
6.	Physiological problems (e.g. eye strain) related to technology use	40.66	13
<i>Social and Cultural Constraints</i>			
7.	Lack of Local Mentorship	56.03	3
8.	Cultural Barriers	41.95	11
<i>Educational Constraints</i>			
9.	Limited Training Opportunities	64.66	1
10.	Language Barriers in Training Materials	48.4	10
<i>Technological Constraints</i>			
11.	Complex Digital Interfaces	54.82	7
<i>Policy and Institutional Constraints</i>			
12.	Limited government initiatives for promoting digital adoption in agriculture	55.35	4
13.	Non-Customized Programs	55.27	5
<i>Psychological Constraints</i>			
14.	Low Motivation Levels	50.59	9
15.	Dependence on Others/ family members	51.78	8

by Landmann et al., (2021). Lower-ranked constraints included cultural barriers (41.95), unstable network infrastructure (41.75), physiological challenges such as eye strain (40.66), fear of technology (38.63), and limited internet penetration (33.77). While these were not considered as critical as training or cost-related issues, they still contribute to digital exclusion, consistent with the findings of Ziegler (2021) and Rahman et al., (2023), who noted that both

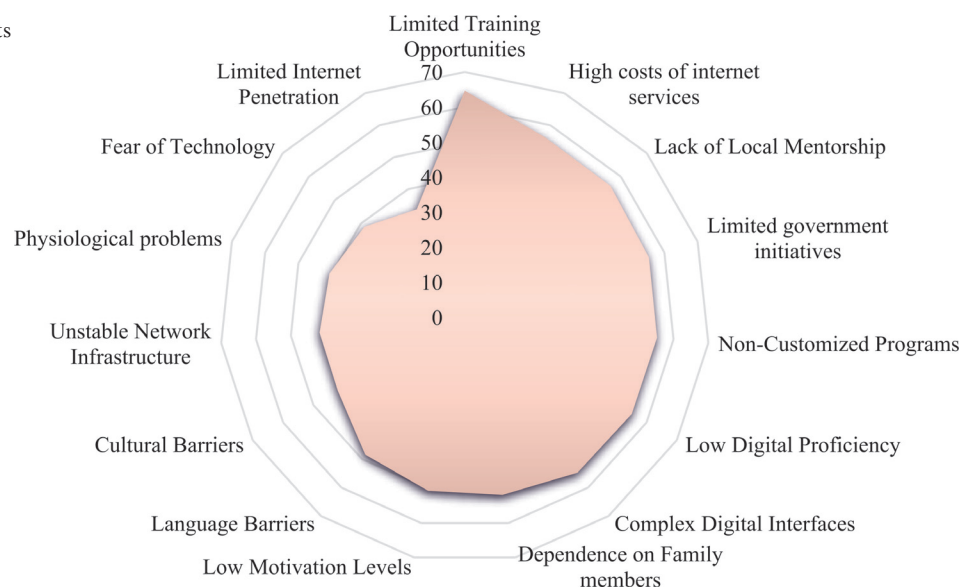
infrastructural and psychological limitations hinder rural women's ability to fully engage with digital technologies.

The radar chart (Figure 1) further illustrates how these constraints cluster into seven dimensions—educational, economic, social and cultural, technological, policy and institutional, infrastructural, and psychological. Educational and economic constraints were ranked highest, followed by policy-related barriers, suggesting that skill-building and affordability are the most immediate areas requiring intervention.

DISCUSSION

Educational barriers dominate the findings, with limited training opportunities emerging as the foremost constraint. This supports Mittal et al., (2017) & Kumar et al., (2025), who emphasise that the absence of structured and context-specific programmes restricts women farmers from acquiring essential digital competencies. Landmann et al., (2021) also note that without targeted training, rural women remain excluded from meaningful digital participation, highlighting the need for farmer-centred and localised learning approaches. Economic barriers, particularly the high cost of internet services, further intensify exclusion. As Mukherjee et al., (2023) observe, affordability strongly determines access to digital technologies in rural India. Unless addressed through subsidised data packages, public Wi-Fi facilities, or community-based digital hubs, financial barriers continue to prevent smallholders and women farmers from sustained engagement with digital tools.

Social and cultural factors add another layer of exclusion. The absence of mentorship and women's dependence on family members reduces autonomy, reflecting the gendered dynamics described by Sen (2015); Chakraborty & Gupta (2019). Establishing peer-led literacy groups and community mentors could provide role models and context-specific guidance. Institutional shortcomings aggravate the problem, as limited government initiatives and non-customised programmes often fail to align with grassroots realities. Heeks (2018) warns that standardised interventions rarely succeed without local adaptation, while Priambodo et al., (2024) find that women benefit more from programmes designed to meet their specific needs.

Figure 1. Radar chart of ranked constraints to digital literacy among JLG women farmers in Kerala

Technological, psychological, and infrastructural barriers further constrain digital adoption. Complex interfaces, fear of technology, and low motivation reduce women's confidence, as highlighted by Schnebelin (2022); Ziegler (2021) & Rahman et al., (2023). Meanwhile, unstable connectivity and limited internet penetration remain challenges in remote regions of Kerala despite initiatives such as KFON. Addressing these interconnected barriers requires integrated, gender-sensitive strategies that combine affordable internet, farmer-oriented training, peer mentorship, and inclusive extension services. Such interventions are essential for enabling women farmers to leverage digital technologies for improved productivity, market access, and empowerment in Kerala's agrarian economy.

CONCLUSION

The digital literacy among JLG women farmers in Kerala is constrained by multiple interlinked factors spanning educational, economic, social, technological, institutional, psychological, and infrastructural dimensions. Limited training opportunities and high internet costs emerge as the most critical barriers, followed by inadequate mentorship, low digital proficiency, and poorly aligned institutional initiatives. While infrastructural challenges such as unstable connectivity and limited internet penetration remain important, socio-cultural restrictions and low motivation further reduce women's autonomy in digital adoption. Addressing these constraints requires integrated, gender-sensitive, and context-specific strategies that combine affordable internet access, skill-building through localised training, community-based mentorship, and inclusive policy support. By strengthening digital capacities, women farmers can more effectively engage with agricultural technologies, improve productivity, and enhance resilience in Kerala's agrarian economy. Bridging the gendered digital divide is therefore essential not only for empowering women but also for ensuring equitable and sustainable agricultural development.

DECLARATIONS

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

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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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