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-Editor

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CONTENTS

Agricultural Value Chain Extension: A Comprehensive Strategy beyond Production and Market Access

Sanjay Kumar Agrawal, IAS

ABSTRACT

Agriculture is undergoing rapid changes due to globalization, climate change, changing consumer preferences, food safety requirements and need for market linkages. These changes have shifted the focus of agriculture from merely increasing production towards improving profitability, competitiveness and sustainability. Farmers are now required to maintain quality standards, reduce post-harvest losses, undertake value addition and respond to changing market demand. However, majority of the small and marginal farmers have limited access to resources, infrastructure, and information and possess poor bargaining power to participate effectively in modern markets. This creates a need to move agricultural extension beyond a production-centred approach towards a value chain-based approach. A value chain involves different actors and activities from input supply and production to processing, marketing and consumption, where each activity influences the quality, cost, safety, marketability and final value of the product. Therefore, agricultural extension is evolving to support farmers and other actors throughout the value chain by facilitating technical guidance, institutional linkages, entrepreneurship development, value addition and market linkages. The approach is comprehensive and requires better coordination among farmers, FPOs, processors, warehouse operators, financial institutions, research organisations, extension agencies and private organisations. In such a system, the extension professional has a broader role as a value-chain facilitator rather

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than only a technology-transfer agent. FPOs, digital technologies, post-harvest infrastructure, market linkages, capacity building and public-private partnerships can further support farmers' participation in agricultural value chains. Thus, a value chain-based extension approach can help in improving coordination among different stakeholders, reducing transaction costs, increasing value addition and market access leading to improved farmers income and livelihoods.

Key words: Agricultural extension, agricultural value chain extension approach, its components, institutional arrangements, market led extension

Introduction

The contemporary agricultural landscape is undergoing rapid transformation due to globalization, climate change, technological innovations, changing consumer preferences, food safety regulations and strengthening integration of domestic and global markets. These developments have shifted the focus of high value agriculture from merely increasing production to improving profitability, competitiveness and sustainability. Farmers today must comply with quality standards, adopt value addition practices, reduce post-harvest losses, respond to market demand and integrate with increasingly complex and profitable supply chains. Consequently, agricultural development strategies have evolved from production-oriented approaches to market-led extension, with emphasis on market information, price intelligence, consumer demand and marketing skills (Christoplos, 2010 and Kumar et al., 2012).

Agricultural extension has been recognised as a means to facilitate this transformation if revived to make services demand driven which implies making extension more responsive and accountable to the need of all the farmers (Birner and Anderson, 2007). The shift from production-centric to demand driven-extension is expected to improve orientation of farmers towards market and consumer needs. Though, in the changed agricultural landscape with lot many challenges and opportunities, there is a need for interventions to go beyond production and marketing to ensure enhanced farmers' income.

The extension system in developing / underdeveloped countries is production orientated with inadequate attention on processing, value addition and marketing, though there is need for a balanced approach for introducing competitiveness in value chain activities (Manteaw et al., 2020). Thus, the traditional production centric approach in agricultural extension may not be sufficient for income enhancement and necessitates a shift to a value chain extension approach which focuses on facilitation at various stages of value chain to enhance profitability (Shukla et al., 2026). The extension should move beyond production centric advisory services to market orientation, leadership,

digital literacy, collective action and business competencies to enable farmers organisations to avail value chain opportunities (Praphavathi et al., 2023). The participation of farmers in organised retail supply chains is influenced by factors like assured price, quality, access to market information and finance, highlighting the role of extension as an integrator and facilitator that link farmers with other value chain actors (Nandi et al., 2017). Farmers need support throughout agricultural value chain, from input supply and production to post-harvest management, processing, value addition, quality assurance, logistics, finance, and market linkages.

Against this backdrop, the present paper attempts to improve the understanding on the need for a shift in focus of agricultural extension from production-central Centric to value chain based approach to support the transformation which Indian agriculture is undergoing. The paper focuses on the concept of value chain based agricultural extension and its key components and different value chain actors. The paper also speaks about the policy suggestions to strengthen the existing agricultural extension system which is efficient, inclusive and resilient with ability to enhance farmers' income and agricultural competitiveness.

Need for paradigm shift towards value chain extension

The majority of Indian farmers operate on small and marginal landholdings and few challenges are there regarding the scale, resources, infrastructure and information required to participate effectively in modern markets (Sharma et al., 2021). Farmers can no longer depend solely on increasing production to improve their incomes but need to understand the way their produce is harvested, handled, graded, stored, processed, transported, branded and marketed and also the means to reduce the cost of production and manage risk associated with production. Value chain extension can help overcome these constraints by promoting collective action, strengthening FPOs, facilitating business partnerships and providing knowledge about value-addition opportunities. It can also help farmers move away from supply push production towards planning production according to identified market demand, quality requirements and consumer preferences.

A value chain is a set of activities carried out by actors (input dealers, producers, processors, transporters, wholesalers, retailers, and consumers) to deliver a product or service from conception to end use. Value Chain Development (VCD) has emerged as a comprehensive framework for analyzing and improving agricultural systems (Singh et al., 2025). A value chain perspective emphasizes the interconnectedness of multiple actors. Instead of focusing solely on on-farm productivity, value chain development seeks to enhance efficiency and equity across the entire chain (Prasanna et al., 2025). A value chain is not merely a linear

movement of produce from the farmer to the market. It is an interconnected process in which each activity influences the quality, cost, safety, marketability and final value of the product. Decisions concerning seed selection, production practices and harvesting influence the quality of produce available for grading, storage and processing. Similarly, packaging, branding, market promotion and consumer satisfaction determine demand and influence future production decisions.

Value chain approach to agricultural extension

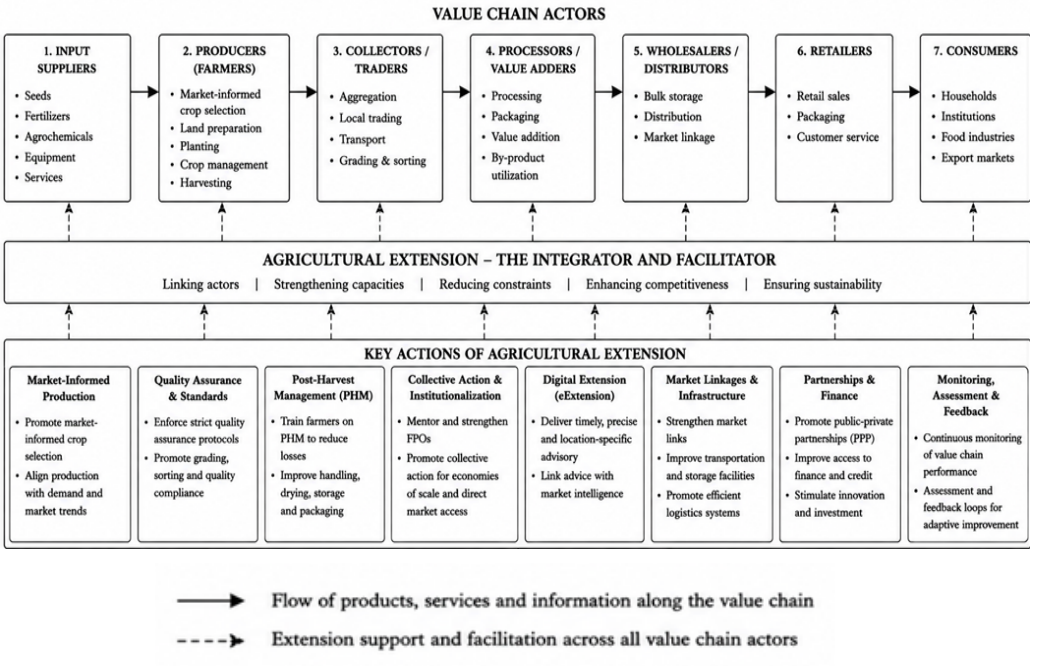
In the process of evolution of the agricultural extension from production to market linkage to organising famers and empowering them to develop into micro – enterprises to conservation of resources, the FARMERS have been central to the theory and practices of the concept. However, the value chain development is going to be central to the concept of agricultural transformation so as to bring focus on actors other than farmers as well. It is value chain approach that will facilitate integration of various actors of the chain with the concept of agricultural extension and reposition itself to advice various actors of the chain, other than the farmers. This emphasises on the need of a multi – actor agricultural extension system which is capable of addressing the challenges faced by different actors of the agricultural value chain leading to optimal value realisation by each player including farmers (Ammani and Abdullahi, 2015). An example of potato value chain in India speaks about the comprehensive support offered by the firm to the farmers covering, technical extension, monitoring, assured market and prices, access to credit and inputs and insurance. The arrangement is facilitated by the vendors and people (identified by the firm) to establish coordination between farmers and the firm.

The agricultural value chain begins with the provision of quality inputs such as seeds, fertilizers, machinery and credit. It then progresses through production, harvesting, post-harvest handling, grading, storage, transportation, processing, packaging and branding and marketing before the product reaches the consumer. Every stage provides opportunities for reducing losses, improving quality, adding value and increasing farmers' incomes. Therefore, agricultural extension should no longer be confined to production enhancement and strategies to market the surplus efficiently but should facilitate technical guidance, institutional linkages, entrepreneurship development, value addition and market integration throughout the value chain.

Value chain approach extends the conventional role of agricultural extension beyond technology dissemination and market facilitation by promoting collaboration among farmers, Farmer Producer Organizations (FPOs), input suppliers, processors, traders, financial institutions, private enterprises and

consumers. It also focuses on developing farmers' entrepreneurial capacity, strengthening farmer producer organizations, facilitating value addition, improving access to finance and digital technologies, promoting quality standards, traceability, developing efficient market and business linkages (Figure-1). By addressing constraints across the entire value chain rather than only the ones experienced at the production or marketing stage, value chain extension contributes to better planning, higher productivity, reduced transaction costs, enhanced competitiveness and improved profits leading to sustainable livelihood improvement.

Figure 1. General value chain appraoch in agricultural extension



Source: Manteaw et al. (2020); and Shukla et al. (2026) and Ammani & Abdullahi, 2015 and references therein, like Aderibigbe, et al. (2007), Akpokodje et al. (2001), Erenstein et al. (2003), UNEP (2005 and USAID (2009)

In this context, value chain based extension approach represents a strategic shift beyond production-support and market-led extension by positioning extension services as facilitators for development of inclusive value chain rather than merely providers of production technologies or market information to its stakeholders (Ferroni & Zhou, 2012 and FAO, 2014).

Component of value chain extension approach

1. Input Supply and Production: The value chain begins with timely access to quality seeds, fertilisers, crop-protection inputs, machinery, credit and technical information.
2. Harvesting and Post-Harvest Handling: Harvesting at the appropriate stage of maturity is essential for maintaining product quality and reducing losses. Post-harvest activities include cleaning, drying, grading and sorting.
3. Storage and Transportation: Scientific storage protects produce from moisture, pests, contamination and deterioration. Efficient transportation reduces transit losses and ensures that products reach processors and markets on time. Extension agencies can connect farmers and FPOs with warehouses, cold-storage units, pack houses, refrigerated transportation and other logistical services. Farmers and other players need to be oriented about the changes like electronic negotiable warehouse receipt (e-NWR) system.
4. Processing: Processing transforms agricultural produce into products with greater utility, shelf life and market value. Examples include converting cereals into flour, oilseeds into edible oil, fruits into juice or pulp, milk into processed dairy products and spices into cleaned and packaged products. Extension personnel can facilitate training on the importance of processing and processing technologies, enterprise development, food-safety compliance and access to government schemes.
5. Packaging and Branding: Suitable packaging protects the product and improves convenience, appearance and shelf life. Branding and labelling help create product identity and communicate information concerning origin, quality and certification. Extension organisations can assist farmers and FPOs with market assessment, packaging selection and digital promotion
6. Consumer Feedback and Production Planning: Consumer preferences regarding quality, price, taste, convenience, safety and sustainability influence demand. Extension systems should facilitate the collection and sharing this information with farmers and FPO.

Agricultural Extension in India

The agricultural development efforts in India after the independence were supported through a series of programs such as Grow More Food Campaign (GMFC, 1947), Community Development Programme (CDP, 1952), National Extension Service (NES, 1953), Intensive Agricultural District Programme

(IADP, 1961) and Intensive Agricultural Area Programme (IAAP, 1964-65). The agricultural extension support was extended through initiatives like National Demonstrations (1965), Farmers Training Centres (FTC, 1966), Small and Marginal Farmers Development Agencies (SFDA, 1971), Krishi Vigyan Kendra (KVK, 1974), and Lab-to-Land Programme (1979) during green revolution period (DFI, 2017). Training and Visit (T&V) extension system was observed to be effective in potential irrigated areas leading to good effect impact on productivity and income among farmers. Subsequently, decentralised system was experimented with to address issues related to lack of integration of programs among different departments, weak research-extension linkages and various other constraints faced by the system (Glendenning & Babu, 2011 and Singh, 2006).

The 'Agricultural Technology Management Agency (ATMA)' represents a shift in agricultural extension from a top-down approach towards a decentralised, demand-driven and participatory system. The component was launched in 2005-06 under the Centrally Sponsored Scheme, 'Support to State Extension Programmes for Extension Reforms'. Inherent issues of capacity and culture of public sector agriculture extension in India; limits the ability of the concept to fulfil its objectives (Glendenning & Babu, 2011). The scheme supports the efforts of state governments to provide farmers with access to improved agricultural technologies and good agricultural practices in agriculture and allied sectors. Its activities include farmer training, demonstrations, exposure visits, Kisan Melas, Farmer-Scientist Integration and farm schools. ATMA also facilitates the formation and strengthening of 'Farmer Interest Groups' and 'Farmer Producer Organisations' and supports entrepreneurship development and market-oriented training. It can therefore serve as an important institutional platform for implementing value chain extension at the district level by facilitating coordination among different public and private organisations. ATMA model is considered a key concept for decentralising decision making to the local level. Owning to it's structure, it promotes coordination both among the government agencies and among the public, private and development organisations (Birner & Anderson, 2007).

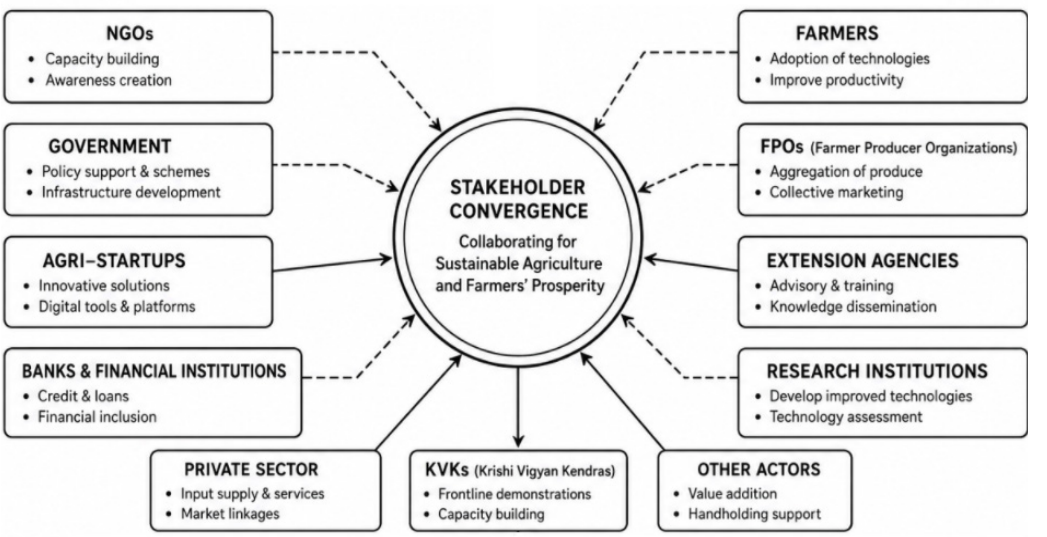
Institutional Arrangements

Agricultural value chain development requires coordination from input suppliers, farmers, FPOs, processors, transporters, warehouse operators, wholesalers, retailers, exporters, financial institutions, research organisations, extension agencies and consumers. Each performs a specialised function, but the efficiency of the overall chain depends on the strength of the relationships among them calling for the need for them to work in tandem. The government

extension agencies provide technical guidance, training, policy support and access to development schemes. Para-extension workers and lead farmers provide locally accessible advisory services and promote farmer-to-farmer learning. FPOs aggregate produce, improve bargaining power and facilitate collective purchase, grading, storage, processing and marketing. Non-governmental organisations support community mobilisation and institutional development, while private-sector organisations provide inputs, technologies, processing facilities, logistics and market linkages. Financial institutions facilitate access to credit, and research organisations generate technologies and quality-management practices.

In this ecosystem, the extension professional serves as a value-chain facilitator rather than only as a farm-level technology-transfer agent and therefore, need to have a complete understanding of the complete entire ecosystem in terms of stakeholders and institutional arrangement available to for realising the maximum profits from the chain (Figure-2). The extension role extends from helping farmers obtain appropriate inputs to facilitating production planning, collective action, value addition, business development, quality compliance, market linkage and consumer feedback. Effective coordination among these stakeholders can improve productivity, reduce transaction costs, expand market access and support sustainable and inclusive agricultural development.

Figure 2. Emerging institutional arrangement for agricultural extension in India



Source: Partly drawn from Mall et al., 2025

Different approaches for value chain orientation of extension

This section deals with some of the approaches which can be used to provide value chain orientation to the agricultural extension system existing in India.

Farmer Producer Organization (FPO)

Small and marginal farmers need extra support because of low marketable surplus, limited bargaining power, input costs and mechanical challenges. Farmer Producer Organisations provide an institutional mechanism through which such farmers can undertake different activities collectively. FPOs can reduce transaction costs, improve economies of scale and strengthen farmers' negotiating position in input and output markets. The role of an FPO can extend across the entire agricultural value chain from the input stage to the post-harvest stage. After harvesting, it can facilitate collective cleaning, drying, sorting, grading, storage and transportation. FPOs may also establish processing units, develop packaged and branded products, obtain quality certification and supply products to bulk and organised buyers and establish linkage with digital marketplaces. Agricultural extension organisations play an important role in mobilising farmers, facilitating FPO formation and strengthening their technical, organisational and entrepreneurial capacities. FPOs can function as intermediaries between individual farmers and other value-chain actors. Thus, FPOs provide an important platform for integrating smallholders into organised and higher-value agricultural markets. At present, more than 40,000 farmers' organisations are working in India under different arrangements. Some of these organisations have specialised in specific commodities and established direct linkage with bulk buyers and processors by avoiding intermediaries.

Technology Interventions in Crop Value Chains

Technologies are influencing how a commodity is produced, handled, stored, transported and marketed. There are different initiatives employing blockchain and IoT to manage the supply chain of perishables. Likewise, various mobile apps under private and public set-up are available to facilitate marketing of agricultural produce. Market intelligence systems provide timely information on prices, demand, weather, and consumer preferences, enabling farmers to make market-oriented production and marketing decisions. Digital platforms such as e-NAM improve market access, price discovery, and transparency. Drones and remote support assessment of crop quality and expected yields and facilitate traders and agro-industries in planning their procurement more efficiently. However, the usefulness of tools depends on accessibility, affordability, local relevance and interaction with farmers and FPOs with respect to various technologies available such as AI, IoT, blockchain, and traceability, drone,

remote sensing, e-NAM, digital payments and incorporating the information into production and marketing decisions.

Industrial Linkage

Industrial linkages play an important role in transforming agricultural produce into higher-value products and expanding market opportunities for farmers. Linkages with mills, food-processing units, dairy plants, cold-chain enterprises, exporters, retailers and agri-MSMEs can help farmers move beyond the sale of raw produce and participate in more profitable markets. Micro food-processing enterprises, self-help groups, cooperatives and FPOs can promote local-level value addition, rural employment and entrepreneurship. Programmes such as the Micro Food Processing Enterprises Scheme can support technology upgradation, product-quality improvement, branding and enterprise formalisation. Extension personnel can facilitate linkages among farmers to assist with enterprise selection, business-plan preparation, financial linkage, technology assessment and the establishment of suitable primary processing facilities, and integrating the same with industry.

Improvement of Post-Harvest Infrastructure

Post-harvest infrastructure may include village-level collection centres, drying yards, mechanical drying units, pack houses, grading and sorting lines, scientific warehouses, silos, cold-storage facilities, ripening chambers, refrigerated vehicles, primary processing centres, testing laboratories and packaging units. The type of infrastructure required depends on the commodity. The availability of infrastructure alone does not ensure its effective utilisation. Farmers and FPOs require technical knowledge regarding maturity assessment, harvesting methods, drying, moisture management, grading, storage conditions, cold-chain handling and inventory management. Accordingly, extension agencies should train farmers, organise regular capacity-building programmes for farmers, FPOs and rural entrepreneurs on post-harvest management, scientific storage, warehouse management, quality standards and value-addition practices.

Building Capacity of Farmers and Extension Personnel

Entrepreneurship and skill development are essential for fostering innovation and competitiveness in agricultural value chains. Agri-start-ups, food processing enterprises, women-led self-help groups, and rural micro, small, and medium enterprises (MSMEs) encourages for value addition and employment. Capacity-building programmes should therefore, extend beyond production technologies to post-harvest management, food safety standards, packaging technologies, digital marketing, and business management. Farmers require knowledge and skills related to quality-oriented production, appropriate harvesting,

post-harvest handling, grading, scientific storage, market information, digital platforms and financial decision-making.

Improving Market Linkages

Efficient market linkages are essential for ensuring that value-added products reach consumers at competitive prices while maximizing returns to producers. Strengthening linkages through contract farming, direct marketing, retail partnerships, institutional procurement, e-commerce platforms, export promotion, and digital agricultural markets reduces dependence on intermediaries and improves price realization. Consumer-oriented production, branding, and quality assurance further enhance market competitiveness and support the development of integrated agricultural value chains.

Policy and Institutional Support

The Government of India is very actively creating a platform for supportive policies and institutional frameworks for developing post-harvest infrastructure, processing enterprises, producer organisations, digital systems and market linkages. There are various initiatives of the Government such as Agriculture Infrastructure Fund (AIF), Pradhan Mantri Kisan Sampada Yojana (PMKSY), KCC Card Scheme, Digital Agriculture, Pulse and Oilseeds Mission, Mission for Integrated Development of Horticulture (MIDH), and schemes for promoting Farmer Producer Organizations provide financial assistance, infrastructure support, and capacity-building support to different value chain actors. These schemes are leading to effective value-chain development. Farmers and FPOs may face difficulties in understanding eligibility conditions, preparing project reports, completing documentation, arranging matching finance and managing sanctioned infrastructure. Extension organisations are providing institutional handholding by creating awareness, supporting proposal preparation, facilitating convergence among departments and connecting beneficiaries with technical and financial agencies.

Public to Public-Private Partnership (PPP)

Public private partnership is an arrangement between public institutions and private sector organisations, generally established to combine their respective expertise, resources and capacities for delivering services or infrastructure (Hodge and Greve, 2007). In agriculture value chains, public–private partnerships have great potential for their ability to connect farmers with input companies, processors, exporters, retailers, warehousing agencies, logistics providers, financial institutions and digital agricultural start-ups. Public extension agencies can provide technical guidance, mobilisation and institutional support, while private organisations may contribute specialised technologies, processing

facilities, market information and procurement arrangements. Extension personnel have an important role in ensuring that such partnerships remain transparent, farmer-oriented and beneficial to small and marginal producers. Public-private partnerships, access to affordable credit, investment incentives, and regulatory reforms further encourage private sector participation and accelerate value chain modernization.

Conclusion

Agricultural extension has an important role in empowering farmers and other players to realise full potential of farming. Considering the need for reorienting extension services from production-centric to value chain-centric approaches, the focus is shifting beyond production to encompass the entire agricultural value chain, covering input supply, quality assurance, post-harvest management, value addition, processing, branding, transportation, storage and market linkage. Towards this, the Government is now developing Farmer Producer Organizations (FPOs) into value chain facilitators for their ability to achieve scale, reduce transaction cost, establish infrastructure to support processing and storage, negotiate with buyers and integrate quality production with organised domestic and internal market. Agriculture has become multi-dimensional and technology is going to be an effective support. In order to support farmers and other players all along the supply chain, the extension system is now encouraging adoption of digital technology such as Artificial Intelligence (AI), the Internet of Things (IoT) and blockchain leading to various digital agricultural initiatives like Bharat Vistaar, AgriStack and Farmer IDs, eNAM and various mobile Apps. One of the most important focus area is building capacity of the extension professionals on different components of agriculture value chain to improve their ability to support farmers on aspects like access to inputs, production-technology, post-harvest infrastructure, government schemes, credit and public–private partnerships to support sustainable value chain development. Agriculture is changing, the environment in which it is practiced is changing, which calls for refocusing and redefining the concept of agricultural extension to go beyond the farmer and production, to include different actors and the components/activities supported by them all along the agricultural value chain (Ahmad & Slathia, 2011).

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Evaluating Farmers' Participation Dynamics and Satisfaction Levels: A Case Study of Kisan Melas in Punjab

Guranshpreet Singh Sethi[1], Manisha Bhatia[2], Hardeep Singh Sabhikhi[3]

ABSTRACT

Kisan melas serve as an effective platform for dissemination of agricultural technologies and strengthening farmer–scientist interactions. The primary goal of such farmers' fairs is to educate the farmers about new technologies developed by the researchers, mostly from State Agricultural Universities (SAUs), agricultural and allied research centers and the government sector. Considering its importance, an exploratory study was conducted with the aim to assess farmers' participation and satisfaction towards kisan melas. The data was collected during the kisan melas organized in Punjab during March and September 2025. A total of 120 farmers were selected using random sampling technique and data were collected through a structured interview schedule. Frequencies and percentages were calculated. Satisfaction was measured using 3-point scale. Mean scores were calculated and ranked accordingly. The findings revealed that a majority of farmers (54 per cent) attended both melas, indicating sustained interest among farmers. Extension workers (38 per cent) emerged as the major source of information, followed by digital media such as WhatsApp and internet (22 per cent). The primary purpose of attending the mela was to gain technical knowledge (67.5 per cent), followed by obtaining updated agricultural information (61.67 per cent) and seed purchase (59 per cent). Farmers reported gaining maximum information on improved crop production practices (81 per cent), farm machinery (76 per cent) and government schemes (73 per cent).

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Although 30.83 per cent of farmers reported no constraints; issues such as high prices of commodities, lack of proper sanitation and drinking water facilities were highlighted by rest of the farmers. Among the various aspects, behaviour of staff was ranked highest on satisfaction score (mean = 2.48), whereas quality of products was ranked the lowest (mean = 2.23). The study concludes that kisan melas are effective in technology dissemination but there is a scope of improvement in infrastructure and input quality to enhance farmer satisfaction.

Key words: Agriculture, Kisan mela, Perception, Constraints, Satisfaction

Introduction

Agricultural extension plays a crucial role in enhancing farmers' knowledge, skills and adoption of improved technologies. It plays a crucial role in bridging the gap between research institutions and farmers by ensuring recommended technologies, improved varieties, management practices and advisory services reach farming communities in a practical and understandable form. Traditional extension methods such as demonstrations, training programmes, farmer meetings, exhibitions and fairs continue to be important extension activities, especially in regions where face-to-face interaction remains a trusted mode of communication (Swanson & Rajalahti, 2010).

Among the traditional extension methods, kisan melas serve as important opportunity for communication between farmers, researchers and other stakeholders, promoting improved dairy and agricultural technology, knowledge sharing and innovation demonstration (Badhala et al., 2026). It is an effective way to raise awareness of various technologies among farmers, scientists, officers from agriculture and related departments, non-governmental organizations, private agencies, who come together at a common place where various technologies related to agriculture and related sectors are displayed for the public with the aim of education, entertainment and sales. (Jambagi, 2020).

Earlier studies have shown that farmers generally perceive kisan melas as useful for obtaining technical information, observing improved technologies and interacting with experts. Ansari and Paswan (2018) reported that a majority of farmers considered kisan melas organised by universities as useful, especially for obtaining information related to agricultural machinery, integrated farming systems, dairy and allied sectors. Similarly, Kumari et al. (2023) observed that most of the farmers attending a university kisan mela were satisfied with the venue, timing, stall orientation and behaviour of organizing personnel, although some constraints such as drinking water, input pricing and seed availability were also reported. More recently, Swati and Singh (2024) also emphasized that

farmers perceive kisan melas as an effective platform for knowledge exchange and extension outreach.

Despite the widespread organization of kisan mela across agricultural institutions, there is still a need to systematically evaluate them from the perspective of farmers who actually attend them. Understanding their purpose of participation, constraints faced by them while attending kisan mela and level of satisfaction is necessary for effectiveness of future melas. The study becomes more relevant in light of the fact that kisan melas are organized for farmers by a number of organizations in addition to agricultural universities. As a result, the current study is more pertinent to examine the efficacy of kisan melas hosted by agricultural universities to keep it at par with kisan melas organised by other organizations. Keeping this in view, the present study was undertaken with the objectives:

- To study the participation pattern of the farmers in the kisan melas;
- To highlight the constraints faced by the farmers while attending kisan melas;
- To assess the satisfaction of farmers attending kisan melas.

Material and Methods

The present study was conducted at two kisan melas organized by Punjab Agricultural University, Ludhiana, Punjab, one held in March 2025 and the other in September 2025. A total of 120 male farmers attending the mela were selected randomly during the two events. The farmers were personally interviewed at the mela venue. A structured interview schedule was developed and used for data collection. The interview schedule included sections on socio-economic profile, participation pattern, constraints faced by the farmers and statements to assess the satisfaction level regarding various aspects of the mela. Participation pattern was studied by including questions on the source of information of mela, purpose of attending, information gained during the kisan mela. The data were tabulated and analysed using appropriate statistical tools. Satisfaction was measured on 3-point scale. A mean satisfaction score was calculated on a 3-point scale (1 = Not satisfied, 2 = Satisfied, 3 = Most satisfied).Mean scores for each item were calculated and ranked accordingly.

Results and Discussion

Socio-economic profile of farmers

The results regarding socio-economic profile of the farmers including age, education, caste, operation landholding, livestock possession are presented in table 1. The results indicate that a higher proportion of farmers belonged to the

middle age group i.e. between 30 to 50 years (37.00%) followed closely by young farmers below 30 years (34.00%).

Table 1: Distribution of farmers according to their socio-economic profile (n = 120)

Variables	Category	Frequency	Percentage
Age	Below 30 years	41	34.17
	30–50 years	45	37.50
	Above 50 years	34	28.33
Education	Middle	6	5.00
	High school	27	22.50
	Senior Secondary	52	43.33
	Graduate	35	29.17
Caste	SC	7	5.83
	BC	7	5.83
	General	106	88.33
Operational landholding	Landless	8	6.67
	Marginal	17	14.17
	Small	42	35.00
	Medium	36	30.00
	Large	17	14.17
Livestock possession	No animal	11	9.17
	Small (1–5)	44	36.67
	Medium (6–10)	35	29.17
	Large (>10)	30	25.00

In the present study, most of farmers had attained education upto senior secondary (43.00%) and graduation (29.00%), indicating a relatively high literacy level among participating farmers. A greater majority of farmers belonged to General category while only 10 per cent of them belonged to SC and BC category. This might be due to the fact that In Punjab, SC households have relatively lower representation in agricultural landholding compared with other social groups as indicated in NSS 77th Round report (2019). Similar observations regarding socio-economic profile of farmers were aslo reported by Ansari and

Paswan (2018) and a further study conducted by both these authors (2020) who found that a large proportion of kisan mela participants had formal schooling and was receptive to technical information shared during such events.

The economic status of the farmer is important to study as this may have an impact on their capacity to adopt and sustain agricultural and allied enterprises. To have an insight into the economic status of the farmers, data on their land and livestock possession were gathered. The data revealed that the majority (35.00%) of the farmers were small landholders while a similar proportion of them were medium farmers (30.00%). Marginal and large farmers constituted an equal proportion of 14.17 per cent each, whereas only 6.67 per cent of the farmers were landless. The findings on the another economic indicator with respect to animal holding showed that the highest proportion of farmers (36.67.00%) possessed a small herd size (1–5 animals), followed by 29.17 per cent having medium herd size (6–10 animals). While one-fourth of the farmers had large herds (>10 animals) and only 9.17 per cent of them did not own any animals. The results points to the fact that the farmers in the present study were below 50 years of age, belonged to general category, educated and had limited to moderate land and animal resources. These findings are in line with the findings of Swati and Singh (2024), who also observed that majority of the farmers who attended kisan mela were actively engaged in farming and had sufficient educational background to benefit from extension events.

Participation pattern and source of information

Kisan melas are organised by Punjab Agricultural University twice in a year i.e. during March and September. Participation pattern was seen as the attendance of farmers in the kisan melas organised by the University.

The results in table 2 revealed that more than half of the farmers (54.00%) attended both kisan melas organized in March and September, indicating sustained interest and perceived usefulness of these events. These results are consistent with research by Sharma et al. (2023), who also reported that most farmers frequently attended kisan melas twice in a year at Punjab Agricultural University in Ludhiana. Repeated participation signifies that farmers consider kisan melas as reliable and valuable platforms for continuous learning and exposure to the new technologies.

Table 2: Distribution of farmers according to their participation pattern and sources of information (n = 120)

Indicator	Category	Frequency	Percentage
Kisan mela attended	March only	21	18
	September only	34	28
	Both March and September	65	54
Source of information	KVK/Extension workers	46	38
	Newspaper	17	14
	Internet/WhatsApp	26	22
	Friends/relatives	12	10
	Changi Kheti/Progressive Farming/Kheti Sandesh	14	12
	Others	5	4

Among the source of information about the conduct of kisan mela, extension personnel and Krishi Vigyan Kendras (KVKs) emerged as the primary source (38.00%), followed by internet and WhatsApp (22.00%). The relatively lower reliance on newspapers (14.00%) and friends/relatives (10.00%) suggests a shift towards more credible and real-time information sources. This is in slight deviance with the findings of the study conducted by Yadav and Kumar (2018), where the most popular sources of information for kisan mela were friends, relatives and fellow farmers followed by KVKs/University, private organization, state agriculture department, newspaper, farm magazine, radio, SMS/internet/new media, and television. The growing role of digital media is also consistent with the observations of Sandeep et al. (2022), who highlighted that social media platforms are becoming increasingly effective in agricultural information dissemination among farmers. Thus, in the present study traditional communication channels i.e. KVK and extension personnel emerged as the most important source of information. On the other hand, modern communication channels such as internet/WhatsApp are also evolving as important source of information. With rapid proliferation of smartphone –enabled extension networks rural agrarian communities are being restructured (Mittal and Meher, 2016)

Purpose of attending the kisan mela

The results regarding the purpose of attending the kisan mela revealed that the

technical information gained by the farmers through exhibitions was the main purpose of attending kisan mela as shared by 67 per cent of the farmers (Table 3). Almost a similar proportion of farmers (61.67%) visited kisan mela to acquire latest information related to agriculture. The data further indicated that about three-fifths of the farmers visited kisan mela to purchase seed. Information related to animal husbandry was next to follow. Relatively lower per cent of farmers (15.00%) reported entertainment as the primary purpose to attend melas. This indicates that farmers perceive kisan melas as both educational and commercial platforms.

Table 3: Distribution of farmers according to theirpurpose of attending the kisan mela (n = 120)

Purpose of attending kisan mela	Frequency	Percentage*
Technical information through exhibitions	81	67.5
Latest information related to agriculture	74	61.67
Seed purchase	71	59.17
Information related to animal husbandry	67	55.83
Entertainment	18	15
Purchase of machinery	17	14.17

*Multiple response

The findings of the present study are in line with the study conducted by Ansari and Paswan (2018), who reported that farmers considered kisan mela useful particularly for information on agricultural implements, dairy, allied enterprises and integrated farming systems. Similar findings were reported by Gangil et al. (2019) in which the primary goal of farmers' visits to kisan mela was to learn about new techniques before making purchases of supplies linked to agriculture, horticulture, crops and fodder.

Thus the study revealed that farmers attended kisan mela with a professional and knowledge-oriented mind-set rather than recreational purposes.

Information gained from the mela

The results on the information gained from the mela revealed that the majority of the farmers (81.67%) gained information on improved crop production practices followed by farm machinery and implements (Table 4). More than seven of every ten farmers viewed that they gathered information on government schemes and subsidies. Almost same proportion of the farmers agreed to have gained information on pest and disease management.

Table 4: Distribution of farmers according to their type of information gained from kisan mela (n = 120)

Information gained	Frequency	Percentage*
Improved crop production practices	98	81.67
Farm machinery and implements	92	76.67
Government schemes and subsidies	88	73.33
Pest and disease management	84	70.00
Fertilizer and nutrient management	76	63.33
Marketing and agribusiness opportunities	53	44.17
Allied enterprises	44	36.67

*Multiple response

However, information related to nutrient management (63 per cent), marketing and agri-business opportunities (44 per cent) and allied enterprises (36 per cent) were gathered by relatively lesser number of farmers. This points towards the effectiveness of the kisan mela in disseminating core agricultural technologies and policy related information. Similar results were presented by Goswami et al. (2024) as their study found that majority of farmers participating in kisan mela gained useful information regarding agricultural tools and machinery, seed processing and storage, high yielding seed varieties, fertilizers, mushroom cultivation, dairy and animal husbandry, irrigation techniques and organic farming.

Constraints faced by farmers during the Kisan mela

The constraints perceived by the farmers are important to focus on the potential areas of improvement for conducting kisan melas in future. So the results on this aspect in the present study revealed that three out of every ten farmers did not perceive any constraint (Table 5). The most frequently reported constraint included higher prices of the products and seeds. Other areas which require improvement including sanitation related issues and poor drinking water facility.

Table 5: Distribution of farmers according to the constraints perceived while participating in kisan melas (n = 120)

Constraints	Frequency	Percentage*
No constraints	37	30.83
High price of product/seed etc.	35	29.17
Sanitation facility	26	21.67
Lack of drinking water facility	23	19.17
Non-availability of desired quality seeds	18	15.00
Duration of Kisan Mela	8	6.67
Routine agricultural work gets disturbed	7	5.83
Any other	6	5.00

*Multiple response

The results of the present study are in line with the results of studies conducted by Pratap et al. (2019), who found that while most farmers had no constraints, some mentioned financial costs, difficulty getting to the kisan mela ground, lack of food arrangements, and non-availability of desired grade seeds. Similarly results of the study by Kumari et al. (2023), also indicated that at a university kisan mela farmers face obstacles such the unavailability of desired grade seeds, the high cost of goods and seeds and the lack of drinking water facilities. On the similar lines study conducted by Sattari et al. (2021) reported lack of interaction of farmers with scientists and experts, lack of drinking water, misbehaviour by other farmers, a lack of transportation as major constraints.

The findings of the present study therefore indicate that alongwith information about the technologies and accessibility and availability of seeds and planting material, efficient basic facilities like sanitation and drinking water facility are important to improve the efficiency of kisan melas.

Satisfaction of farmers regarding different aspects of the Kisan Mela

Satisfaction of the farmers regarding different aspects of the kisan mela was studied on the basis of satisfaction score calculated on 3 point scale. A minimum score of 7 and maximum score of 21 was obtained. Based on the scores farmers were classified into three categories- low satisfaction, medium satisfaction and high satisfaction. Majority of the farmers were moderately satisfied with the different aspects of the kisan mela.

Table 6: Distribution of farmers according to their satisfaction about kisan mela (n=120)

Category	Frequency	Percentage
Low Satisfaction (≤ 14)	15	12.5
Medium Satisfaction (15 – 18)	91	75.83
High Satisfaction (≥ 19)	14	11.67

More than three-fourths of the farmers (75.83%) exhibited a medium level of satisfaction regarding the kisan mela, indicating that the event largely met the expectations of the visitors in terms of information dissemination, organization and usefulness. Nearly 12 per cent of the farmers reported a high level of satisfaction, reflecting the effectiveness of the mela in providing relevant agricultural knowledge and exposure to improved technologies. Similar proportion of the farmers fell under the low satisfaction category, suggesting that a relatively small proportion of visitors perceived shortcomings in the event. The findings indicate predominance of medium to high satisfaction levels which points to the fact that kisan mela are effective agricultural extension platform and plays an important role in enhancing farmers' knowledge and improved farming practices. Therefore, it can be sad that kisan melas served as an effective extension platform for the majority of the participants, although further improvements in specific aspects identified by farmers may enhance overall satisfaction levels. A similar study by Badhala et al. (2026) indicated that kisan mela are an effective extension intervention and favourably influence farmers' knowledge, attitude and adoption behaviour.

Item wise satisfaction score as shown in Table 7 indicated that behaviour of faculty and staff was ranked at number one position with mean score of 2.48. It was closely followed by orientation of different stalls (mean score = 2.47) and location of venue (mean = 2.40). This is indicative of the organisational management and communication skills of the faculty and staff contributing positively to the overall experience of the farmers.

Table 7: Satisfaction of farmers regarding different aspects of kisan mela (n = 120)

Sr. No.	Item	Mean Score	SD	Rank
1	Location of venue	2.40	0.56	III
2	Timings of mela	2.38	0.57	IV
3	Orientation of different stalls	2.47	0.55	II

4	Information provided in kisan mela	2.33	0.61	V
5	Behaviour of faculty/staff	2.48	0.59	I
6	Information regarding new variety of crop	2.30	0.63	VI
7	Quality of available products	2.23	0.75	VII

However, in the present study relatively lower satisfaction scores were observed regarding the quality of available products (mean = 2.23) and information regarding new crop varieties (Mean = 2.30). This suggests that alongwith the effective organization, there is also a need to improve the quality and relevance of information and inputs provided during melas. Study by Sharma et al. 2023 also indicated that the farmers were satisfied about the technical information provided during kisan mela organised by Punjab Agricultural University, Ludhiana, while less satisfaction was expressed with the arrangements regarding eatables and entertainment.

Conclusion

This study underscores that kisan melas organized by state agricultural universities serve as a resilient and trusted institutional bridge for technology dissemination and expert-farmer engagement in Punjab The high rate of repeat attendance (54 per cent) demonstrates that these melas remain highly relevant in the modern agricultural extension landscape. While information on crop production and farm machinery successfully trickles down to small and medium landholders, there is a clear deficit in information seeking related to market-driven agribusiness opportunities and allied agricultural enterprises.

Furthermore, while the interpersonal communication skills of extension staff received high satisfaction scores, the physical infrastructure—specifically basic sanitation, drinking water availability, and product pricing models—represents a critical bottleneck. The present study was limited to a sample of 120 male farmers across two seasonal events in a single year Future research should expand to multi-year longitudinal assessments and deliberately incorporate the perspectives of women farmers and youth to capture a more inclusive demographic shift in agricultural extension adoption.

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Farmer-led innovations in Commercial Dairy Farms of Punjab and Haryana

S. Ashok kumar[1] and K. Ponnusamy[2]

ABSTRACT

Dairying plays a vital role in the economic development of low-income countries such as India. The present study was conducted to explore the important features of selected dairy-based grass root innovations developed by the commercial dairy farmers. Case study method was adopted to carry out the research. Six farmers were identified to conduct the study. The result reveals that, innovations developed by the farmers are locally adoptive in nature, involve less cost, are developed using locally available resources and have a high level of compatibility. However, not all the farmers commercialized the technologies due to their inability to demonstrate their advantages and market the innovations. Hence, it is important to validate the innovative technologies of farmers by the agricultural institutions.

Key words: Features, Innovations, Farmers, Case studies, Dairy

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Introduction

Dairying plays a significant role in the process of economic development of low-income countries like India. Along with agriculture, livestock is primarily practised as a complementary enterprise along with crop farming by vast majority of Indian farmers (Ponnusamy and Pachaiyappan, 2018). Around 80 million rural households in the country are engaged in milk production. Besides, the country is home to about 535.78 million livestock population, wherein bovine population accounts for 302.79 million (GoI, 2019). The value of output from dairying is higher than the value of output of wheat and paddy together. However, dairy farming is facing many challenges such as reduction in fodder grown area, non-interest of youngsters towards dairy, non-availability of suitable technologies, penetration of adulterated milk in the market, high dependence on external labour force, climate change, non-availability of land and manpower, low prices, incidence of disease and import of low-cost milk and milk products (Singh et al., 2021; Chugh and Kaur, 2022). One of the factors that determine the sustainability of dairy farming is providing appropriate technologies to the farmers at relatively low cost, with more adoptability and easy accessibility (Balaine et al., 2020).

In India, research work in agriculture and allied activities are mainly carried out by ICAR (Indian Council for Agricultural Research) with the help of large number of agencies that fall under this organization. According to Ponnusamy and Padaria (2021), investment of India on agricultural research is of 0.3 per cent of agriculture GDP, which is much lower than the spending of China (0.62 per cent). Although, agriculture investment supported the country in achieving higher production through effective implementation of innovative technologies and methods of agricultural institutions. Adoption of technologies depends upon the characteristics of innovation (Shanmugam and Shanmugam, 2021). To increase the rate of adoption, the approach followed in development of innovations is gradually changing from formal agricultural research to participatory development (Ponnusamy and Padaria, 2021). On the other hand, farmers themselves developed new innovations by means of experimentation of traditional knowledge and new ideas originated from a variety of sources (Ponnusamy et al., 2021). Generally, farmer's innovations are cost effective, suitable to local condition and easily accessible in nature, hence, farmer-led innovations were rapidly accepted by the other farmers (Datt et al., 2013; Gowda et al., 2019). Certainly, modern technologies help in augmenting the productivity of crops or livestock especially in the short run. However, in long run, the technologies that are developed by farmers have high level of sustainability. Farmer innovations remain unrecognized by communities themselves. Numerous agencies and organisations, including the Indian

Council of Agricultural Research (ICAR), the National Innovation Foundation, and the National Bank for Agriculture and Rural Development (NABARD), are working to document, validate, and commercialise farmer-led innovations in India (Sharma et al., 2018). Identifying and characterization of farmer-led innovation would give better insights that help in framing policies. With this view, the present study focused on studying the features of farmer-led dairy-based innovations.

Materials and Methods

In view of nature and significance of the study, case study method was adopted for the present investigation. The samples were selected purposefully based on the data given by the Progressive Dairy Farmers Association (PDFA) of Punjab, KVKs, NGOs and personal interaction with the experts of ICAR-NDRI, Karnal, GADVASU, Ludhiana and PAU, Ludhiana. As per World Bank (2011) report, two types of progress were observed in dairy production system across the country viz., i) leading: livestock activity is more commercialized and market-driven enterprise which includes states of Punjab, Haryana, Gujarat and Tamil Nadu; ii) lagging : includes the state of Odisha where livestock activity is mainly of subsistence nature and act as a livelihood security to the farmer's. However, Kale et al. (2016) classified the dairy production system of India into three categories viz., high, medium and low, wherein, Punjab and Haryana come under the high dairy progressive category, primarily due to the inclination of farmers towards high profit oriented dairy enterprise. Considering the progressiveness and commercialization of dairy enterprises, the present study was restricted to the state of Punjab and Haryana. Finally, six innovations namely sprinkler system using PVC pipe (developed by Mr. Ranjeet Singh), self-designed shed with movable sides (developed by Mr. Hemraj), individual water bowl (developed by Mr. Jatinder Singh), own feed preparation (developed by Mr. Pawan Kumar), silage pit cum storehouse (developed by Mr. Kumar Gautham Chauhan) and membership card for customers (developed by Mr. Rohit) that are relevant to the dairy farming were selected for this study. By seeing the utility of the farmer innovations and their potential for further upscaling, six innovations that are different from each other and could provide different insights as motivation for other farmers in dairy farming were selected. Apart from the personal interview method, observation method was also used in the collection of data.

Innovation is crucial for successful continuance of any enterprises. Farmers did not adopt the new technology as such, and they tend to modify the technology or create an alternative route or model according to their need and skill. An attempt was made to identify the characteristics of innovations which resulted in better performance of dairy farms of Punjab and Haryana.

Dairying plays a vital role in the economic development of low-income countries such as India. The present study was conducted to explore the important features of selected dairy-based grass root innovations developed by the commercial dairy farmers. Case study method was adopted to carry out the research. Six farmers were identified to conduct the study. The result reveals that, innovations developed by the farmers are locally adoptive in nature, involve less cost, are developed using locally available resources and have a high level of compatibility. However, not all the farmers commercialized the technologies due to their inability to demonstrate their advantages and market the innovations. Hence, it is important to validate the innovative technologies of farmers by the agricultural institutions.

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Fig. 1: Sprinkler system using PVC pipe

Besides, the country is home to about 535.78 million livestock population, wherein bovine population accounts for 302.79 million (GoI, 2019). The value of output from dairying is higher than the value of output of wheat and paddy together. However, dairy farming is facing many challenges such as reduction in fodder grown area, non-interest of youngsters towards dairy, non-availability of suitable technologies, penetration of adulterated milk in the market, high dependence on external labour force, climate change, non-availability of land

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Fig. 4: Silage pit cum storehouse

Innovation 5: Membership card for the customers

Customer loyalty is one of the business strategies in any venture. Retaining the customer base would substantially boost the income of the farmers. An innovation in customer retention will play a crucial role in commercial dairy farming. Mr. Rohit, a young farmer residing in Gurugram and owned a dairy farm in Delhi, has introduced a membership card for the customers. Anyone can avail the membership card from his dairy by paying Rs. 100, which is refundable in nature. The farmer used to provide a discount for card holders on litre basis, for instance, customer without membership get one litre of milk at Rs.70, while the cardholders get a discount of Rs. 3 per litre (Rs.67/lit). The discount rate varies according to the season; for example, during winter time, the rate of discount was high and it was lower during festival season. By adopting this method, the farmer has attracted around 180 membership customers to his farm. Among those, about 150 customers are regularly purchasing milk from their farm.

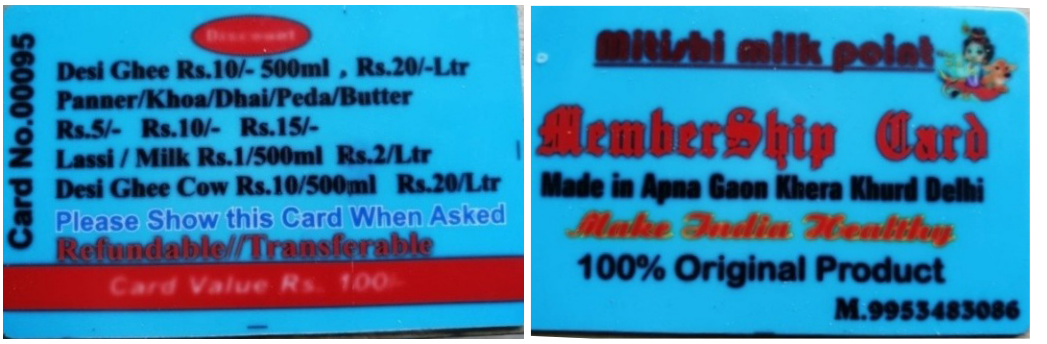

Fig.5: Membership card for customers

Table 1: Specific attributes of selected dairy-based farmer-led innovation

Farmer-led innovations					
Attributes	**Sprinkler system using PVC pipe**	**Self-designed shed with movable sides**	**Individual water bowl**	**Silage pit cum storehouse**	**Membership card for the customers**
Utility	Used to cool the dairy animals during summer	Most important factor which influences m ilk production is temperature. It protects the animals from both freezing and hot temperature and mosquitos.	No labour is required. Continuous supply of water to animals.	Generally, farmers use the silage pits for a period of 6 months especially during summer. This structure acts as both silage pit (during summer) and store house (during winter).	In the competitive dairy industry, attracting and retaining customer is a difficult task. Maintains a consumer base for the commercial farm.
Cost	The farmer recycled the available resources by using the broken PVC irrigation pipes.	Cost is much higher; however, it has longevity	To cover twenty animals, farmers need to spend approximately six thousand rupees.	Average cost for the construction of shed is about Rs. 1 lakh	Cost of membership card is around Rs. 2500 for 100 cards.
Benefits	It helps to protect the animals from heat stress that in turn increases the reproduction rate and milk yield.	It helps to reduce the mortality rate of young calf which are more vulnerable to freezing temperature.	It is a better alternative to the water trough which is much costlier than individual water bowl.	Quality feed is available for dairy round the year. No need of any additional structures to keep dairy implements.	Beneficial to farmers as well as consumers. As a result, it draws more customer and builds a customer base for the dairy farm, increasing the farmer's profit.

Suitability	Since the water usage is more, it is very much suitable for the farmers practicing both crop and dairy farming.	The structure requires small investment. Hence, it is suitable for medium to large dairy farmers.	This technology is much needed in commercial dairy farms which faces the problem of non-availability of labours. Suitable for all type of dairy farms.	Preparation of silage is an important practice among all type of dairy farms. So, its suitable for all the farms.	It is very much suitable for commercial farms and also farmers having 10-20 animals.
Sustainability	It paves a way to re-use of PVC pipes which affect environment negatively. This system also allows effective utilization of waste water.	This structure is eco-friendly.	This technology is made with bowl and simple concrete structure to improve the dairy animals' health.	This structure is made with the help of local wisdom and modifications of traditional structure.	Similar cards were issued in a variety of businesses, including the clothing, electronics, and medical industries. Strong consumer base encourages farmers to diversify their product lines.

Innovation 6: Own feed preparation (developed by Mr. Pawan Kumar)

Farm made feed is always helpful to the farmers to reduce the cost of milk production drastically. A progressive dairy farmer from the Karnal district of Haryana has prepared their own concentrate feed for their dairy animals. He used to prepare 5 quintals of nutritious concentrate for 100 dairy animals per month with a feed cost of Rs. 24/Kg. Earlier, he used to buy the feed from local market at cost range of Rs. 30-35/kg depending on the quality of feed. Preparation of one's own feed helped to save around Rs. 5000 per month. The ingredients were grinded and mixed well in the feed mill located at a nearby place. It has helped the farmer to improve milk quality as well as the productivity of animals by about 5-7%. The ingredients used were as follows:

Own feed formulations (5q/month):

- Wheat - 1 quintal
- Bengal gram - 1 quintal
- Cotton - 1 quintal
- Mustard - 2 quintal
- Mineral Mixture - 20 Kg
- Calcium - 5 litre

Fig.6: Own feed formulation

Conclusion

Innovation is crucial for developing the sustainable dairying. Six different innovations emanated from this study indicated that, most of farmers have developed the innovation which has the features of lesser cost, local adaptability, more convenient and comparative advantage over the existing technology available with them. However, the innovations developed by the farmers are neither commercialized nor reached many other farmers residing nearby places. Presently, government is encouraging the development of innovation through farmer's participation. In addition, extension agents should take vigorous efforts to focus more on validation of the farmer's innovations and its adoptability over other places. After the validation, the innovations need to be commercialized or diffused to other dairy farmers especially small and medium commercial dairy farms which helps to increase their income and animal health.

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Direct and Indirect Effects of Farmers' Characteristics and their Knowledge about Environmental Degradation

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ABSTRACT

The present investigation was carried out in the Anand district of Gujarat. 160 farmers from four talukas were selected randomly for the study. A total of sixteen variables were studied in path analysis. The study revealed that the input utilization pattern had exerted a maximum direct positive effect and a substantial effect on farmers' knowledge of environmental degradation, and social media exposure had the maximum total indirect effect on farmers' knowledge of environmental degradation.

Keywords: Environmental degradation, Farmers, knowledge, direct-indirect effect

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Introduction

Environmental degradation in agricultural systems manifests through accelerated soil erosion, nutrient depletion, chemical contamination, and biodiversity loss, all of which undermine ecosystem resilience and long-term productivity. Synthetic fertilizer inputs, which in India exceeded 55 Mt in 2021–22, contribute to significant nitrous oxide emissions and nitrate leaching, triggering eutrophication of freshwater bodies and hypoxic "dead zones" (Ramachandra et al., 2025). Addressing these interconnected challenges requires a suite of integrated strategies such as no-till conservation, precision nutrient management, crop diversification, and residue recycling to restore soil health, reduce emissions, and improve farm-level sustainability (Verma et al., 2024). Most farmers possess awareness about bio stimulants, eco-friendly agricultural inputs that can reduce chemical use and enhance crop yields (Desai et al., 2025).

Objective

To study the direct and indirect effects of farmers' characteristics and their knowledge of environmental degradation

Methodology

The study was carried out in the Anand district, located in central Gujarat. In Anand, 160 farmers are chosen using a step-by-step random process. First, four talukas were picked randomly, then selected four villages from each taluka, and finally picked ten farmers from each village. Data was gathered using a structured interview schedule, with interviews conducted either at the farmers' homes or farms. Microsoft Excel (MS 365) and SPSS (version 16.0) statistical tools were applied for data analysis. The research utilized an ex-post facto (Kerlinger, 1976) research design. The collected data were examined to identify the relationship between each independent variable and the dependent variable. A variable was deemed to have a significant association if the computed value met or exceeded the critical value in statistical tests. Furthermore, the study aimed to assess both the direct and indirect effects of key independent variables on farmers' knowledge regarding the environmental degradation, along with the nature of that influence.

The path coefficient technique, which measures the proportion of the total effect's standard deviation caused by a specific factor, was applied by solving simultaneous equations derived from the below given method.

Estimation of Direct and Indirect Effects

The direct effect of each independent variable on the dependent variable is

obtained through **standardized regression coefficients (β).**

$$P_{iy}=\beta_{iy}$$

Where

- P_{iy}= Direct effect (path coefficient) of X_i on Y

  Regression equation:

$$Y=b_1 X_1+b_2 X_2+b_3 X_3+...+b_n X_n+e$$

Where

- b_1, b_2, b_3= regression coefficients
- e= residual effect

Indirect effect occurs when an independent variable affects the dependent variable **through another variable.**

Indirect effect formula:

$$\text{“Indirect effect of “ } X_i \text{ “ through “ } X_j = r_{ij} \times P_{jy}$$

Where

- r_{ij}= correlation between X_i and X_j
- P_{jy}= direct effect of X_j on Y

Total indirect effect is obtained by summing all indirect paths.

In this study, total 16 variables were considered as the independent variable affecting the dependent variable Y, which stands for environmental degradation.

Results and Discussion

Path analysis was employed across all sixteen variables to explore their causal interrelationships. This technique enabled us to separate and measure the direct impact of each variable, as well as its indirect influence mediated through other variables. The findings suggest that the relationships observed between the variables were partly direct and partly indirect. The indirect, or partial, relationships reflect the combined influence of other variables.

Therefore, it is important to examine how one variable affects another both directly and indirectly, through the impact of other variables involved in the scenario. The results of the path analysis are shown in Table 1.

Direct effect

The data in Table 1 revealed that input utilization pattern had exerted a maximum

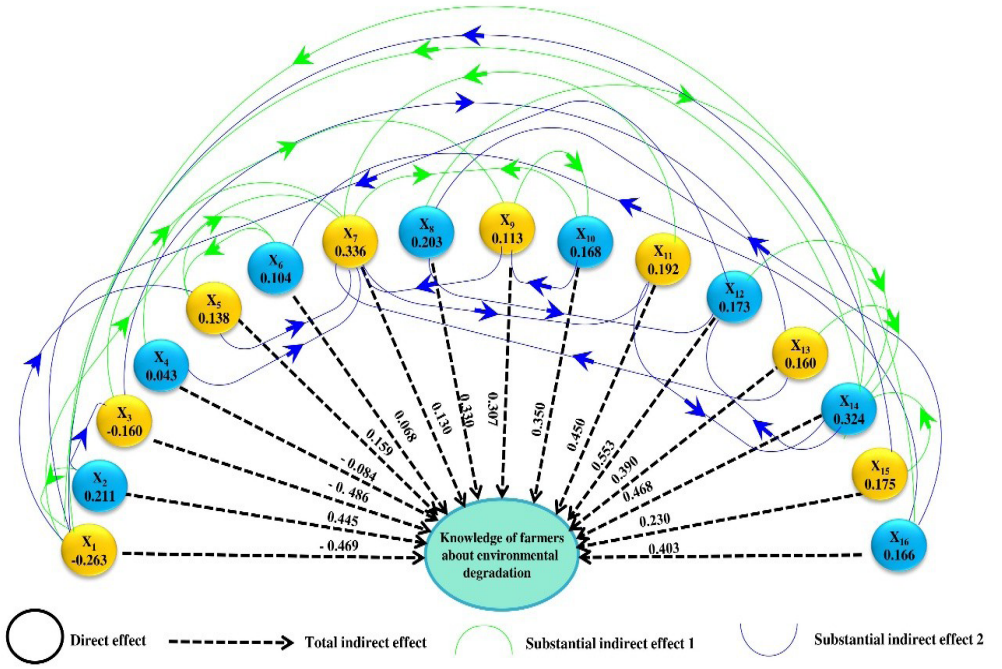
direct positive effect on farmers' knowledge of environmental degradation (0.336), followed closely by scientific orientation (0.324), education (0.211), social participation (0.203), extension participation (0.192), risk orientation (0.175), social media exposure (0.173), annual income (0.168), innovation proneness (0.166), training received (0.160), cropping pattern (0.138), landholding (0.113), cropping intensity (0.104) and family size (0.043).

Table 1: Direct and indirect effect of farmers' characteristics and their knowledge of environmental degradation (n=160)

Sr. No.	Variables	Direct effect	Total indirect effect	Substantial indirect effect through	
				1	2
X_1	Age	-0.263	-0.469	0.018(X_7)	0.016(X_5)
X_2	Education	0.211	0.445	0.124(X_1)	0.079(X_3)
X_3	Farming experience	-0.160	-0.486	0.019(X_7)	0.015(X_{13})
X_4	Family size	0.043	-0.084	0.022(X_9)	0.022(X_7)
X_5	Cropping pattern	0.138	0.159	0.073(X_6)	0.039(X_7)
X_6	Cropping intensity	0.104	0.068	0.096(X_5)	0.024(X_{16})
X_7	Input utilization pattern	0.336	0.130	0.048(X_{10})	0.044(X_{11})
X_8	Social participation	0.203	0.330	0.067(X_{14})	0.054(X_{12})
X_9	Landholding	0.113	0.307	0.077(X_{10})	0.069(X_7)
X_{10}	Annual income	0.168	0.350	0.097(X_7)	0.052(X_9)
X_{11}	Extension participation	0.192	0.450	0.077(X_7)	0.067(X_{14})
X_{12}	Social media exposure	0.173	0.553	0.128(X_{14})	0.096(X_1)
X_{13}	Training received	0.160	0.390	0.069(X_{14})	0.069(X_7)
X_{14}	Scientific orientation	0.324	0.468	0.095(X_1)	0.069(X_{12})
X_{15}	Risk orientation	0.175	0.230	0.082(X_{14})	0.040(X_1)
X_{16}	Innovation proneness	0.166	0.403	0.049(X_1)	0.047(X_8)

Conversely, variables with negative direct effects include age (-0.263) exerted the maximum negative effect on farmers' knowledge of environmental degradation and farming experience (-0.160), indicating that as farmers grow older or gain more experience, their direct impact on the dependent variable decreases. Understanding these ongoing influences is essential for designing extension and training programs targeted effectively to different farmer demographics.

It can be inferred that the input utilization pattern had exerted the maximum positive direct effect on knowledge of environmental degradation followed by scientific orientation, education, social participation, extension participation, risk orientation, social media exposure, annual income, innovation proneness and training received, deferred gratification cropping pattern, landholding, cropping intensity and family size.



X_1 : Age	X_5 : Cropping pattern	X_9 : Landholding	X_{13}: Training received
X_2 : Education	X_6 : Cropping intensity	X_{10} : Annual income	X_{14}: Scientific orientation
X_3 : Farming experience	X_7 : Input utilization pattern	X_{11}: Extension participation	X_{15} :Risk orientation
X_4 : Family size	X_8 : Social participation	X_{12}: Social media exposure	X_{16}: Innovative proneness

Fig.: Direct and indirect effect of farmers' characteristics and their knowledge of environmental degradation

Total indirect effect

So far, the total indirect effect is concerned; fourteen variables had a positive total indirect effect on knowledge of environmental degradation. Further, it can be observed that social media exposure had the maximum total indirect effect (0.553), followed by scientific orientation (0.468), extension participation (0.450), education (0.445), innovation proneness (0.403), training received (0.390), annual income (0.350), social participation (0.330), landholding (0.307), risk orientation(0.230), cropping pattern (0.159), input utilization pattern (0.130), cropping intensity (0.068), whereas the highest negative indirect effect was exerted by family size (–0.084), age (–0.469), and farming experience (–0.486).

Substantial indirect effect

Data further revealed that out of 32 substantial indirect effects, eight each routed through input utilization pattern, five each routed through scientific orientation and age, two each routed through cropping pattern, landholding, annual income and social media exposure, one through farming experience, cropping intensity, social participation, extension participation, training received innovation proneness and deferred gratification.

Concluding the findings, it can be said that the input utilization pattern exerted the highest direct effect and substantial effect and social media exposure exerted the maximum total indirect effect on the farmers' knowledge of environmental degradation.

Conclusion

The path analysis showed that the input utilization pattern had the highest direct positive effect on farmers' knowledge of environmental degradation (0.336), while scientific orientation (0.324 direct, 0.468 indirect) and education (0.211 direct, 0.445 indirect) significantly influenced knowledge. Age (–0.263 direct, –0.469 indirect) and farming experience (–0.160 direct, –0.486 indirect) exhibited negative effects. While social media exposure had the maximum total indirect effect (0.553). These results emphasize the key roles of input utilization and social media exposure in enhancing environmental knowledge among farmers, suggesting that focusing on these factors could effectively improve awareness and promote sustainable practices.

Conflict of Interest

The authors declare no conflicts of interest related to the research presented in this article.

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Sustainable Cashew Cultivation through Water Footprint Assessment and Conservation in Rayagada and Gajapati Districts, Odisha (India)

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ABSTRACT

Cashew cultivation, initially introduced for soil erosion control, has developed into an important contributor to global trade and a major livelihood source for small and marginal farmers, who represent over 70% of growers in India. In Odisha, with nearly 2.23 lakh hectares under cashew, large-scale plantations were initiated during 1954–55 under the Soil Conservation Department. This study focuses on Gajapati and Rayagada districts, where tribal communities rely on cashew cultivation but face constraints such as soil erosion due to hilly terrain, post-monsoon water scarcity, and climate variability.

Targeted soil and water conservation (SWC) interventions were implemented in selected villages of Gunupur and Gumma blocks to address these challenges. The study estimates the water footprint of cashew, assesses the impact of SWC measures on soil erosion, and identifies strategies to improve productivity. Results indicate that the average water footprint is about 15 m³/kg for raw nuts and 50 m³/kg for shelled nuts, with water deficits of 223 mm (948 m³/ha) in Gajapati and 224 mm (971 m³/ha) in Rayagada.

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The implementation of SWC measures – such as contour trenches, bench terraces, water absorption trenches, coconut husk burial, mulching, and modified bunds – can reduce soil erosion, alleviate water deficits, and improve soil health, thereby supporting sustainable yields across plantation stages. In the absence of irrigation infrastructure, improved SWC practices are essential for enhancing cashew productivity, addressing climate change impacts, and sustaining livelihoods in these regions.

Keywords: Cashew Cultivation, Water Footprint, Soil and Water Conservation, Water Deficit, Soil Erosion

Introduction

Cashew (Anacardium occidentale L.), native to Brazil (Mangalassery et al., 2024; Nair, 2020; Malik and Bhadauria, 2020; Jusna Mariya, 2009), was introduced to India by Portuguese explorers in the 16th century (Achaya, 2017) and has since become well adapted to diverse agro-climatic conditions (Mog et al., 2026; Poduval, 2022; Warren, 2015). In India, it is predominantly grown along coastal regions of Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, and West Bengal (Hegde, 2022), often on sloping, degraded, and marginal lands as a rainfed crop (Mangalassery et al., 2024; Adjei and Alormu, 2020; Rupa et al., 2013), mainly for soil conservation and wasteland development (Prabhakaran and Nedumaran, 2022). At present, cashew plays a significant role in global trade and foreign exchange earnings (Tola and Mazengia, 2019), with India producing nearly 9.98 lakh metric tons from about 10.30 lakh hectares (Nayak and Paled, 2018). This labour-intensive sector sustains the livelihoods of small and marginal farmers (Hegde, 2022), though productivity levels remain lower compared to other producing countries (Kamble, 2023).

Odisha accounts for about 2,23,450 hectares under cashew, with an annual production potential of 1,21,280 metric tons (DCCD, 2023). Large-scale plantation activities were initiated during 1954–55 under the Soil Conservation Department to control soil erosion. Cashew cultivation provides employment and income to numerous rural and tribal households, many of whom depend heavily on it. However, farmers in Gajapati and Rayagada districts face multiple constraints, including post-monsoon water scarcity due to insufficient water-holding structures, soil erosion on undulating terrain, and adverse impacts of climate change that reduce productivity.

Water resources in these regions are increasingly under pressure due to declining per capita availability, competing sectoral demands, pollution, low water-use efficiency in agriculture, and shifting monsoon patterns that influence runoff

and groundwater recharge (Kaur and Gauttam, 2022). Although irrigation has the potential to improve yields (Gondim et al., 2024; Saroj and Rupa, 2014), access to reliable water sources remains limited for small and marginal farmers (Saha et al., 2023). Water scarcity intensifies soil moisture stress, increases dependence on groundwater, and ultimately reduces crop yields (Nigatu et al., 2022). Climate change further compounds these issues through rising temperatures, increased evapotranspiration, altered rainfall regimes, and prolonged dry spells, affecting both water availability and quality (Nair et al., 2024).

Irregular rainfall during January to May aggravates moisture stress, negatively affecting flowering and fruit set (Mog et al., 2022). This is particularly evident in Gajapati and Rayagada districts, where it leads to premature nut drop and reduced yields (Dayal et al., 2022). In this context, in-situ soil and water conservation (SWC) measures play a crucial role in capturing rainwater and ensuring its availability during critical crop growth stages (Borah et al., 2024), thereby improving yields (Mahajan et al., 2021), reducing soil erosion, and conserving both pre- and post-monsoon runoff.

To address these challenges, the Watershed Organisation Trust (WOTR), with support from ANDHERI HILFE (AH) and the German Federal Ministry for Economic Cooperation and Development (BMZ), implemented SWC interventions in selected villages of Gunupur and Gumma blocks in Rayagada and Gajapati districts. These interventions aim to enhance productivity, reduce the gap between actual and potential yields (Gawankar et al., 2020), improve farmers' incomes, and strengthen India's competitiveness in the global cashew sector (Ramteke et al., 2024). The present study highlights the economic significance of cashew in Odisha and aims to assess its water footprint, evaluate the effectiveness of SWC interventions in controlling soil erosion, and propose practical strategies to improve sustainability and productivity.

Study Area

The study was conducted in Gajapati and Rayagada districts of Odisha, situated in the Eastern Ghats and characterized by hilly, forested terrain. These regions are prone to severe soil erosion and experience acute water scarcity during the non-monsoon period (Srivastava, A., & Chinnasamy, 2024; Manivannan et al., 2017; Swamy, 2018). For this study, four villages—Tada, Gade, Guleijung, and Kudinguda-Sanamunisingi—were randomly selected from 39 villages across Gunupur and Gumma blocks where soil and water conservation (SWC) interventions had been implemented by the Watershed Organisation Trust (WOTR) with financial support from ANDHERI HILFE (AH) and the German Federal Ministry for Economic Cooperation and Development (BMZ).

Information on water availability, changes in cashew yield, and plantation health was collected from five representative farmers in each village, resulting in a total sample of 20 farmers. The geographic details of the selected villages are presented in Table 1.

Table 1: Location details of selected study villages

District	Block	Study Village	Longitude (°E)	Latitude (°N)	Area (ha)
Rayagada	Gunupur	Tada	83.950	19.009	498.7
Rayagada	Gunupur	Gade	83.921	19.033	295.2
Gajapati	Gumma	Guleijung	83.989	18.984	110.1
Gajapati	Gumma	Kudingu-da-Sanamu-nisingi	83.924	19.010	156.9

Data Collection

Field data were collected using focus group discussions (FGDs), field observations, and structured questionnaires. In addition, long-term gridded weather data—comprising rainfall and maximum and minimum temperatures for 44 years (1980–2023)—were obtained from the Indian Meteorological Department (IMD) (Soni and Tripathi, 2024; Kumar et al., 2024; Pai et al., 2014; Srivastava et al., 2009).

Methodology

This section describes the methods applied to estimate the water footprint and assess the hydrological effects of soil and water conservation (SWC) interventions, particularly in relation to soil erosion.

Water Footprint (WF)

The water footprint quantifies the volume of freshwater used, both directly and indirectly, in the production of goods, particularly crops, relative to output. It comprises green, blue, and grey water components and is commonly expressed in m^3/ton or liters/kg. This indicator evaluates production efficiency by accounting for water consumption as well as the volume required for pollutant assimilation, thereby providing insights into sustainable water use.

In this study, blue and grey water footprints of cashew cultivation were assessed through village-level focused group discussions (FGDs) with cashew growers, along with detailed information on irrigation practices and nutrient

application across plantations of different ages. Field visits to two cashew processing units—Shri Krishna Cashew Industry in Padmapur, Gajapati, and Shri Narayana Cashew Industry in S. P. Guda, Gunupur, Rayagada—were also conducted to understand water use during primary processing of shelled cashews. The assessment followed standard procedures outlined in the Water Footprint Assessment (WFA) Manual (Aldaya et al., 2012) to ensure a systematic and comprehensive evaluation of water use across all components.

Green Water Footprint (WFgreen)

The green water footprint is defined as the ratio of green water use—i.e., soil moisture or rainfall stored in the root zone (excluding runoff) and lost through evapotranspiration during the crop growth period—to the economic yield (t/ha). Green crop water use (CWUgreen) was estimated as the lesser of crop evapotranspiration (ETc) and effective rainfall (ER) over the crop period. Effective rainfall was assumed as 70% of average seasonal rainfall, following Dastane (1974).

Daily ETc was calculated using reference evapotranspiration derived from the Hargreaves–Samani (HS) method (Allen et al., 1998) along with stage-specific crop coefficients (Kc) obtained from the Regional Fruit Research Station, Vengurla, Maharashtra. As the cashew varieties Bhubaneshwar-1, Balabhadra (BH-85), and Jagannatha (BH-6), commonly cultivated in Odisha, are related to Vengurla types (with Bhubaneshwar-1 being a progeny of Vengurla 36/3; Eradasappa et al., 2022), their stage-wise Kc values were converted into daily coefficients to estimate ETc for plantations of different ages.

Blue Water Footprint (WFblue)

The blue water footprint is expressed as the ratio of blue water consumption (m^3/ha) over the crop growth period to the economic yield (t/ha). Blue crop water use (CWUblue) refers to the volume of irrigation water applied in addition to effective rainfall (ER), and total CWUblue was estimated as the cumulative irrigation supplied during the crop cycle.

Grey Water Footprint (WFgrey)

The grey water footprint represents the volume of freshwater required to dilute pollutants to acceptable water quality standards and serves as an indicator of environmental impact. Under organic farming systems, this component can be negligible or even approach zero, emphasizing its role in reducing pollution. In the present study, focus group discussions (FGDs) with farmers in Gunupur and Gumma blocks indicated that cashew cultivation is entirely under cultivation without chemical fertilizers all across plantations of different ages.

Farmers depend solely on rainfall and organic inputs, resulting in negligible contributions from both blue and grey water footprints at the field level.

However, at the processing stage, water use becomes relevant, as approximately 3 liters of water are required to process one kilogram of shelled cashew from raw nuts. The analysis in this study is confined to on-farm water footprints and excludes additional components such as transport, marketing, input production, and supply chain processes. Since only about 20–30% of raw cashew weight is recovered as shelled kernels, the water footprint of shelled cashews is estimated to be 3–4 times higher than that of raw cashews.

Soil Erosion Estimation

The Unit Stream Power Erosion and Deposition (USPED) model (Oliveira et al., 2022; Warren et al., 2005), an extension of USLE and RUSLE, was used to evaluate soil erosion before and after soil and water conservation (SWC) interventions. Soil loss was estimated within the USLE framework incorporating USPED modifications, with all parameters processed in a GIS environment. Rainfall erosivity (R) for India was derived following Tiwari et al. (2016) using CHIRPS daily rainfall data (2020–2023) at 5 km resolution (Funk et al., 2015). Soil erodibility (K) was computed using standard equations, while slope length (L) and slope steepness (S) factors were generated from 30 m SRTM DEM data.

The cover management factor (C) was estimated annually using NDVI, and the support practice factor (P) was assigned based on land use/land cover classes. A QGIS-based modelling framework was developed to integrate all parameters with watershed boundaries, enabling estimation of soil erosion and deposition at the watershed scale and subsequent downscaling to the village level. Field verification further supported the effectiveness of SWC interventions in reducing soil loss and improving water conservation in cashew plantations.

Results and Discussion:

This section examines the water footprint of cashew cultivation in Rayagada and Gajapati districts of Odisha, along with the role of soil and water conservation (SWC) measures in controlling soil erosion. Table 2 summarizes the average yields of raw and shelled cashew nuts across plantations of different age groups. Nut yield increases with tree maturity, leading to a reduction in water footprint per unit, but tends to decline beyond 15–20 years. The results indicate that Rayagada exhibits a marginally higher water footprint than Gajapati, primarily due to a greater dependence on green water derived from effective rainfall. Figure 1 presents the water footprint (m^3/kg) of raw and shelled cashews across plantations of varying ages in both districts.

Table 2: Average cashew production across plantation age groups (25 plantations covered)

Districts	Age of Plantation (years)	Raw Cashew Yield (kg/ha)	Shelled Cashew Yield (kg/ha)
Gajapati and Rayagada	1–4	375	112.50
	5–10	875	262.50
	>10	1125	337.50

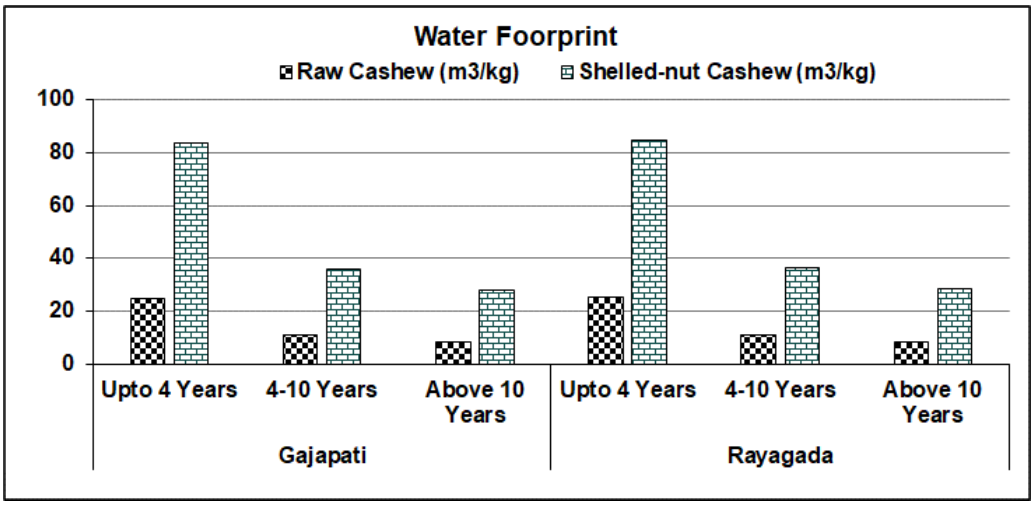

Figure 1: Water footprints of raw and shelled nut cashews of different-aged plantations in Gajapati and Rayagada

Water Deficit in Cashew Plantation

A water deficit arises when crop evapotranspiration (ETc) exceeds precipitation, causing physiological stress that negatively impacts plant growth, yield, and quality (Wang and Frei, 2011; Thitisaksakul et al., 2012). In cashew plantations, the magnitude of water deficit varies with tree age and location, as ETc changes while effective rainfall remains relatively stable. Estimating per-hectare water deficits across different age groups is essential for planning suitable in-situ soil and water conservation (SWC) measures. Recommended interventions include Continuous Contour Trenches (CCT), Graded Trenches (GT), Staggered Contour Trenches (SCT), Semi-Elliptical Trenches (SET), Crescent-Shaped Trenches (CST), Water Absorption Trenches (WAT), Continuous Bench Terraces (CBT), Reverse Terraces (RT), Modified Crescent Bunds (MCB), Tree Base Terraces (TBT), Coconut Husk Burial (CHB), larger pits, and mulching (Borah et al., 2024;

Mangalassery et al., 2024; Mahajan et al., 2021; Mangalassery et al., 2019; Rejani and Yadukumar, 2010). These measures help ensure adequate water availability during different crop growth stages. Figure 2 presents ETc, water deficit (mm), and water deficit (m^3/ha) for cashew plantations of varying ages in Gajapati and Rayagada districts, emphasizing the need for location- and age-specific SWC strategies (Rejani and Yadukumar, 2010; Saroj and Rupa, 2014).

The findings indicate that water deficit increases with plantation age due to rising evapotranspiration relative to effective rainfall. In Gajapati, deficits increase from 143 mm in 1–4-year-old plantations to 293 mm in plantations older than 10 years, while in Rayagada they rise from 153 mm to 306 mm across the same age classes. These patterns highlight the intensifying water stress in mature plantations and underscore the importance of targeted SWC interventions—such as trenching, mulching, and terracing—to reduce water deficit, enhance resilience, and maintain productivity under variable climatic conditions.

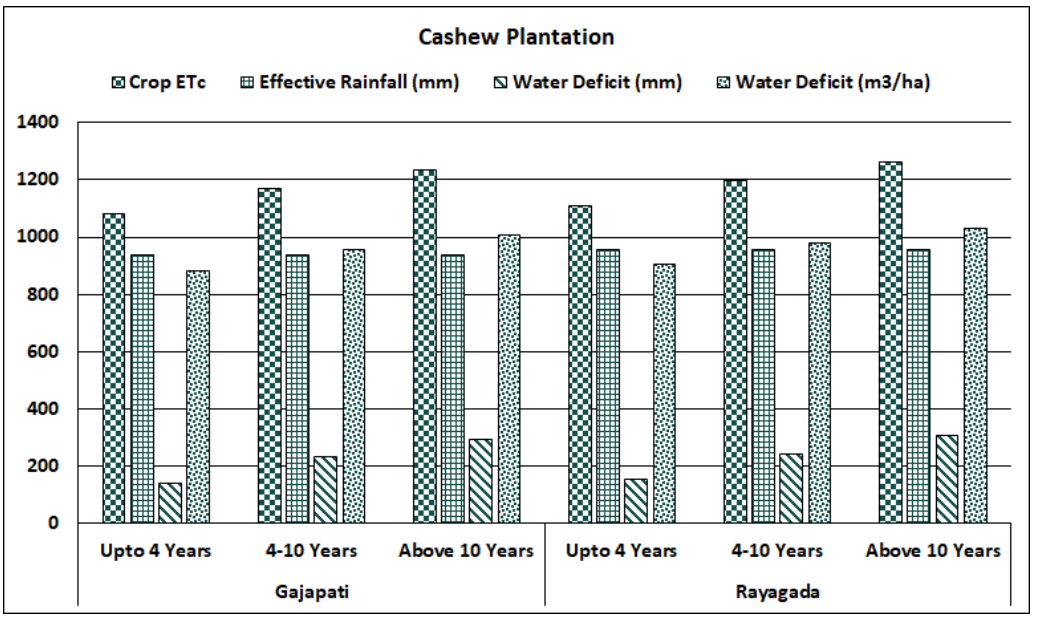

Figure 2: Average annual crop evapotranspiration, water deficit (mm), and water deficit (m3/ha) in different-aged cashew plantations of Gajapati and Rayagada districts

Impact of Soil and Water Conservation Interventions on Soil Erosion

Figure 3 shows the effect of soil and water conservation (SWC) interventions on soil erosion in cashew plantations across the study villages. Analysis of erosion rates in the four villages indicates a substantial decline in annual soil loss following the implementation of geotagged SWC measures. The watershed-

level assessment compared erosion conditions before and after the interventions. Gade village recorded a reduction of approximately 21 tons/ha/year between 2020 and 2023, while Guleijung showed a decrease of about 11 tons/ha/year, where measures such as Continuous Contour Trenches (CCT), farm bunds, stone bunds, and Water Absorption Trenches (WAT) were implemented. Sanamunisingi exhibited a moderate reduction of around 9 tons/ha/year, whereas Tada village achieved a notable decline of about 15 tons/ha/year during the same period. These reductions, summarized in Figure 3, contribute to improved soil moisture retention and are likely to enhance productivity in cashew plantations (Mensah et al., 2025; Mangalassery et al., 2024; Prabhakaran and Nedumaran, 2022; Mahajan et al., 2021; Nair and Nair, 2021; Jena and Panda, 2020; Rupa et al., 2013; Saroj and Rupa, 2014).

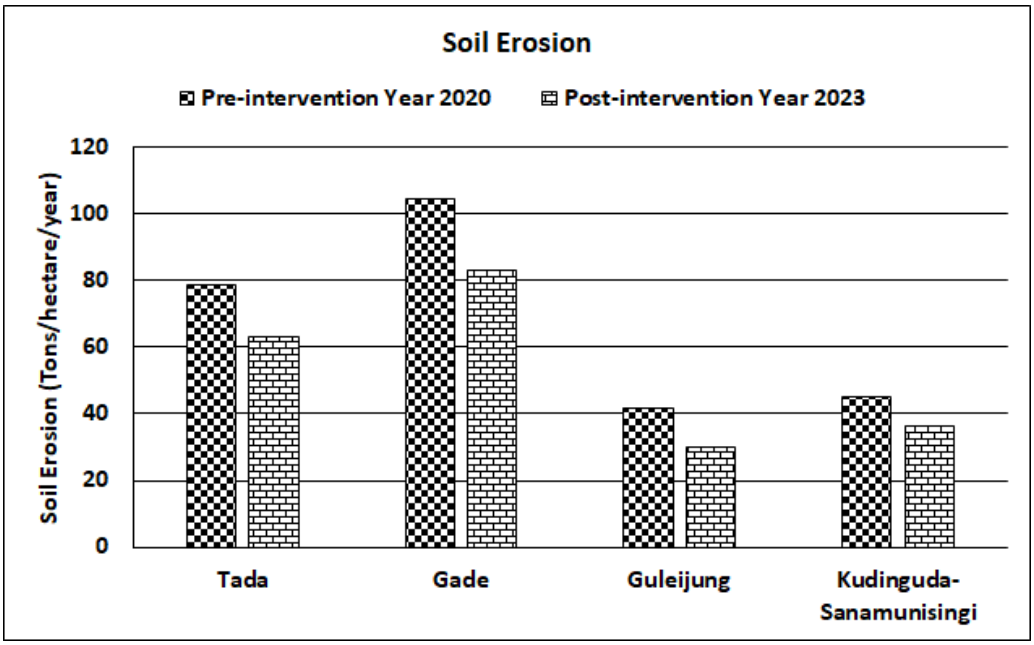

Figure 3: Village-wise soil erosion rate (tons/ha/yr) for the years 2020 and 2023

Study Findings

The study highlights the multiple benefits of cashew cultivation in the Gumma and Gunupur blocks, particularly its role in water management and soil conservation through soil and water conservation (SWC) practices. In Gajapati and Rayagada districts, the average water footprint of cashew is estimated at 15 m^3/kg for raw nuts and 50 m^3/kg for shelled nuts, while plantations face water deficits of 223 mm (948 m^3/ha) and 224 mm (971 m^3/ha), respectively, indicating the need for improved SWC interventions. The adoption of these

measures has led to a significant reduction in soil erosion across the project villages, enhancing soil quality and strengthening hydrological processes such as runoff regulation, soil moisture retention, and groundwater recharge.

Upscaling Field-Tested Water Conservation Measures for Enhanced Cashew Productivity

The effective implementation of soil and water conservation (SWC) interventions in cashew plantations of Rayagada and Gajapati districts indicates strong potential for scaling up across similar rainfed and hilly regions of Odisha and eastern India. The findings demonstrate that simple and cost-effective measures—such as Continuous Contour Trenches (CCTs), Water Absorption Trenches (WATs), farm bunds, mulching, and small water harvesting structures—can substantially reduce soil erosion, improve soil moisture retention, and alleviate water deficits in rainfed cashew systems. These interventions contribute to improved yield stability, better plantation health, and enhanced resilience to climate variability, while also supporting natural resource conservation.

For wider adoption, convergence with government schemes such as MGNREGA, RKVY, and IWMP, along with integration into existing horticulture and watershed programs, is critical. Capacity building of extension personnel and farmer field schools on these practices can promote dissemination through demonstrations and farmer-to-farmer learning. In addition, strengthening linkages with local cashew processing units can enhance economic incentives for farmers. Overall, scaling up these SWC interventions provides a practical and evidence-based approach for climate-resilient cashew production, improved water-use efficiency, and sustainable livelihoods in fragile rain-fed regions.

Conclusions

The study provides key insights into cashew cultivation and its role in supporting local economies. Water footprint analysis indicates that cashew plantations require considerable water, highlighting the importance of modern soil and water conservation (SWC) practices for reducing water deficits, minimizing soil erosion, and improving soil quality. In the absence of irrigation facilities, the adoption of such measures becomes critical for addressing climate variability, sustaining yields, and enhancing plantation resilience.

In addition, policy support through the promotion of improved cashew varieties, farmer training on advanced cultivation practices, and financial assistance for plantation development and processing infrastructure can further enhance productivity and farmer incomes. Such efforts will strengthen market competitiveness while promoting sustainable agriculture and regional economic growth.

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Disclaimer

The views expressed in this study are solely those of the authors and do not necessarily reflect the official positions of their affiliated organizations.

Financial Interests

The authors declare no financial conflicts of interest.

Credit Author Statement

Arun Bhagat: Conceptualization, methodology, investigation, data curation, formal analysis, original draft writing, review, and editing.

Aparna Yadav: Methodology and formal analysis for soil erosion.

Faraz Rupani: Review and editing.

Gyana Ranjan Baral: Data collection and field support.

Marcella D'Souza: Conceptualization and supervision.

Nikhil Nikam: Formatting and data analysis support

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A Study on the Perception of UG and PG Students Towards E-learning Platforms at SKN College of Agriculture (SKNAU), Jobner, Rajasthan

Rajni Choudhary[1], B.S.Badhala[2] and Ramswaroop Simar[3]

ABSTRACT

The rapid integration of e-learning in higher education has transformed the teaching–learning process by enhancing accessibility, flexibility, and learner engagement. The present study was undertaken to assess the perception of undergraduate (UG) and postgraduate (PG) students towards e-learning platforms at Sri Karan Narendra College of Agriculture (SKNCOA), Jobner. A total sample of 120 respondents, comprising 60 UG and 60 PG students, was selected through random sampling. Perception towards e-learning was measured using a structured interview schedule based on the Technology Acceptance Model, focusing on perceived ease of use and perceived usefulness. Data were analyzed using descriptive statistics such as mean, standard deviation, percentages, rank correlation, and the Z-test.

The findings revealed that the majority of both UG (65.00%) and PG (71.67%) students belonged to the medium level of perception category. PG students consistently exhibited a higher level of perception compared to UG students for most statements related to accessibility, usefulness, time efficiency, and academic support. A strong positive rank correlation was observed between UG and PG students, indicating similar perception trends. Statistically significant differences were found between UG and PG students for several perception statements. Overall, the study concludes that students possess a positive perception towards e-learning platforms, with PG students showing greater acceptance and adaptability. The findings suggest the need for strengthening digital infrastructure and targeted training to further enhance the effectiveness of e-learning in agricultural education.

Keywords

E-learning Platforms, Student Perception, Technology Acceptance Model

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(TAM), Perceived Ease of Use, Perceived Usefulness, Agricultural Education, Higher Education, Undergraduate and Postgraduate Students

Introduction

The rapid expansion of information and communication technologies (ICTs) has significantly transformed the higher education system in India. E-learning has emerged as an important instructional approach that enhances flexibility, accessibility, and learner engagement. With the increasing use of digital platforms, learning management systems, and online resources, e-learning has become an integral component of mainstream higher education rather than being confined to distance education alone. In India, national initiatives such as SWAYAM, e-PG Pathshala, NPTEL, and various digital learning platforms promoted by the Government of India have substantially accelerated the adoption of e-learning in universities and colleges (MHRD, 2020; UGC, 2020; GoI, 2021).

In the context of agricultural education, e-learning plays a vital role in facilitating timely access to updated scientific information, enhancing skill development, and supporting learner-centered and self-directed learning. Agricultural universities increasingly rely on e-learning platforms to supplement classroom teaching, disseminate extension-related knowledge, and bridge the gap between theory and practical application (ICAR, 2019; Raut et al., 2021). Studies conducted in Indian agricultural institutions have reported that e-learning enhances learning efficiency, academic performance, and independent learning among students (Patil & Chavan, 2018; Meena et al., 2020).

However, the effectiveness and successful adoption of e-learning largely depend on students' perception of its ease of use and usefulness. According to the Technology Acceptance Model (TAM), perceived ease of use and perceived usefulness are the primary determinants influencing users' acceptance and continued use of technology (Davis, 1989). Indian studies have consistently highlighted that students' perception, attitude, and readiness towards e-learning significantly affect learning outcomes and adoption behavior in higher education institutions (Kumar & Sharma, 2016; Bansal & Pandey, 2017; Mishra et al., 2020; Gupta & Singh, 2021).

Understanding the perception of undergraduate (UG) and postgraduate (PG) students towards e-learning is therefore essential for improving online teaching strategies and policy formulation in agricultural universities. In this context, the present study was undertaken to assess and compare the perception of UG and PG students of SKNCOA, Jobner, regarding e-learning platforms, with special emphasis on perceived ease of use and perceived usefulness, so as to generate

insights for strengthening and optimizing e-learning practices in agricultural higher education.

Material and Methods

The present study was conducted at Sri Karan Narendra College of Agriculture (SKNCOA), Jobner, Rajasthan. The population of the study comprised undergraduate (UG) and postgraduate (PG) students enrolled during the academic year 2024–25. A list of registered students was obtained from the Dean's office. Using random sampling technique, 60 UG and 60 PG students were selected, making a total sample size of 120 respondents.

The perception of students towards e-learning was considered as the dependent variable and was operationalized in terms of perceived ease of use and perceived usefulness, based on the Technology Acceptance Model (Davis, 1989). Data were collected using a structured interview schedule developed specifically for the study. Perception was measured using a five-point Likert scale ranging from "strongly agree" to "strongly disagree."

The collected data were analyzed using descriptive statistics such as mean, standard deviation; mean percent score, rank order correlation, and Z-test to compare the perception levels of UG and PG students.

Result and Discussion

1. Perception levels of UG and PG students regarding e-learning platforms

The perception levels of undergraduate (UG) and postgraduate (PG) students of SKNCOA regarding the e-learning platform were classified into three categories, namely low, medium, and high, based on the mean and standard deviation of their perception scores. The analysis included both UG and PG students.

The results presented in Table 1 and fig 1 revealed that a majority of UG students, 39 (65.00%), belonged to the medium perception category, followed by 12 (20.00%) students with a high level of perception and 9 (15.00%) students with a low level of perception towards the e-learning platform.

Table 1. Distribution of UG and PG students of SKNCOA according to their perception levels regarding e-learning platforms

n=120

S. No.	Perception level	UG (n_1=60)		Perception level	PG (n_2=60)	
		f	%		f	%
1	Low (less than 94.43)	9	15.00	Low (less than 109.30)	7	11.67
2	Medium (between 94.43 - 117.87)	39	65.00	Medium (between 109.30 - 123.04)	43	71.67
3	High (more than 117.87)	12	20.00	High (more than 123.04)	10	16.66
Total		60	100	Total	60	100
Mean= 106.15 SD= 11.72				Mean= 116.17 SD= 6.87		

Table 1 and fig 1 result indicated that the majority of postgraduate (PG) students, 43 (71.67%), exhibited a medium level of perception towards the e-learning platform, followed by 10 (16.66%) students with a high level of perception and only 7 (11.67%) students with a low level of perception. These findings are in agreement with the results reported by Ncube (2015).

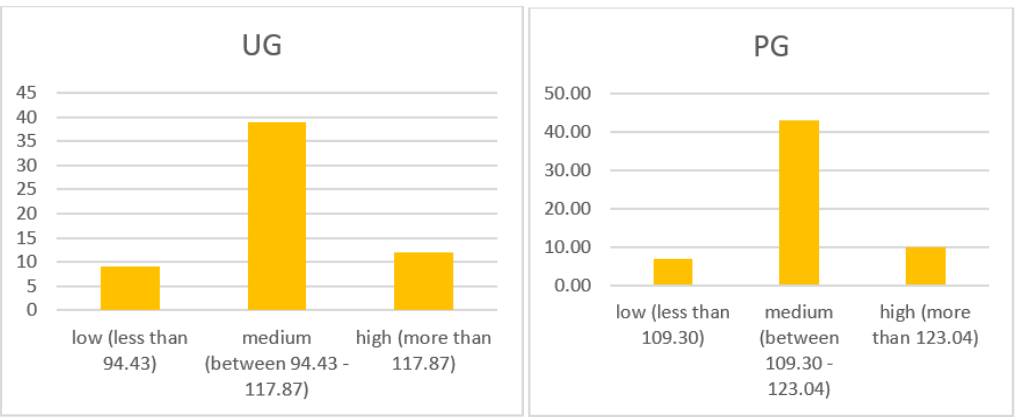

Fig 1. Distribution of UG and PG students of SKNCOA according to their perception levels regarding e-learning platforms

2. Perception level of UG and PG students of SKNCOA regarding the Ease of Use of the e-learning platform

As presented in Table 2 and fig 2, among the UG students, the overall Mean Percent Score (MPS) was found to be 75.56, indicating a moderately favourable perception towards e-learning. The highest-ranked statement was "Access to e-learning tools is possible at any time, from any location" (MPS = 85.00), followed by "e-learning platforms are user-friendly" (84.00) and "e-learning tools help with assignments and presentations" (83.67). This suggests that accessibility, ease of use, and academic support are the major advantages perceived by UG students. On the other hand, the statement "Learning from websites is difficult" received the lowest MPS (31.33), indicating that most UG students do not strongly perceive difficulty in online learning.

Table 2. Perception of UG and PG Students Regarding the Ease of Use of E-learning Platforms n=120

S.N.	Statements	UG (n_1=60)		PG (n_2=60)	
		MPS	Rank	MPS	Rank
1	E-learning platforms are user-friendly.	84.00	2	92.67	2
2	E-learning systems are clear and easy to understand.	80.00	6	88.33	5
3	The dissemination of information through e-learning systems is fast.	83.00	4	92.33	3
4	E-learning is an effective way of learning.	81.00	5	87.33	7
5	I can easily find the required information on e-learning platforms.	76.00	10	84.67	10
6	E-learning tools are free from physical effort.	71.67	12	79.33	12
7	E-learning systems enhance the learner's interest in learning.	72.33	11	81.00	11
8	It is convenient and flexible platform.	77.00	9	86.67	9
9	E-learning tools help with assignments and presentations.	83.67	3	93.33	1
10	It is a time-saving platform.	79.00	7	87.67	6
11	It is cost-effective.	78.33	8	87.00	8
12	Access to e-learning tools is possible at any time, from any location.	85.00	1	92.00	4

13	Learning from websites is difficult.	31.33	13	20.67	13
		75.56		82.54	

rs= Rank correlation rs = 0.95**

** Significant at 1% level of significance t =14.45

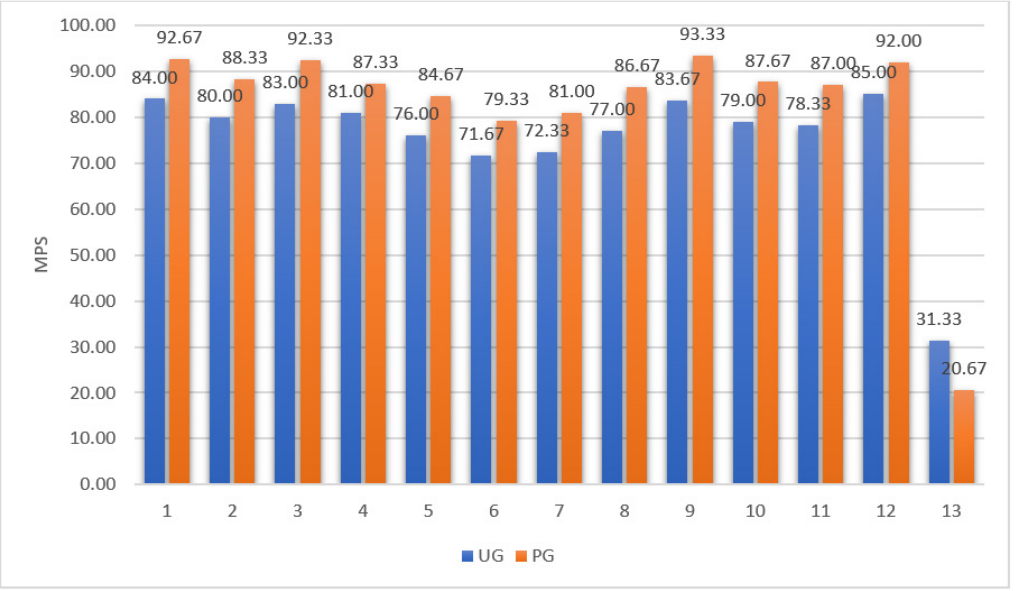

Fig 2. Perception level of UG and PG students of SKNCOA regarding the Ease of use of the e-learning platform

Similarly, among PG students, the overall MPS was higher (82.54), reflecting a more positive perception towards e-learning as compared to UG students. The top-ranked statement was "E-learning tools help with assignments and presentations" (MPS = 93.33), followed by "E-learning platforms are user-friendly" (92.67) and "The dissemination of information through e-learning systems is fast" (92.33). This indicates that PG students highly value efficiency, usability, and academic assistance provided by e-learning platforms. Similar to UG students, the statement "Learning from websites is difficult" was ranked lowest (MPS = 20.67), showing minimal difficulty experienced by PG students.

A comparison between UG and PG students clearly shows that PG students have a more favorable perception of e-learning, as evidenced by their higher MPS across most statements. Furthermore, the rank correlation (rs = 0.95**) indicates a very high degree of agreement between UG and PG students in ranking the statements, and it is statistically significant at the 1% level.

3. Comparison of perception level of UG and PG students of SKNCOA regarding Ease of Use of the e-learning platforms

The comparison of perception towards e-learning between UG and PG students reveals clear differences across multiple aspects. PG students show a more favourable perception towards e-learning than UG students. Significant differences were observed in most statements based on Z-values at both 5% and 1% levels of significance. PG students found e-learning platforms more user-friendly and easier to understand (significant at 5%). They also believed that information dissemination through e-learning is faster (significant at 1%) and more effective (significant at 5%).

Additionally, PG students reported greater ease in finding required information and felt that e-learning increases their interest in learning (both significant at 5%). They rated e-learning as more flexible (5%) and highly useful for completing assignments and presentations (1%). PG students also perceived it as time-saving (5%) and cost-effective (5%). Accessibility of e-learning anytime and anywhere was also significant at the 5% level.

However, no significant difference was found regarding physical effort involved in using e-learning tools. UG students perceived learning from websites as more difficult, and this difference was highly significant at the 1% level. Overall, PG students appear more comfortable and adaptable to e-learning, possibly due to their higher academic exposure and familiarity with digital learning environments.

Table 3. Comparison of perception level of UG and PG students of SKNCOA regarding Ease of Use of the e-learning platforms **n=120**

S.N.	Statements	UG (n_1=60)		PG (n_2=60)		Z value
		Mean	SD	Mean	SD	
1	E-learning platforms are user-friendly.	4.20	1.10	4.63	0.55	2.72**
2	E-learning systems are clear and easy to understand.	4.00	0.92	4.42	0.81	2.63**
3	The dissemination of information through e-learning systems is fast.	4.15	0.97	4.62	0.64	3.11**
4	E-learning is an effective way of learning.	4.05	0.96	4.37	0.55	2.21*
5	I can easily find the required information on e-learning platforms.	3.80	1.23	4.23	0.83	2.26*

6	E-learning tools are free from physical effort.	3.58	1.24	3.97	0.90	1.94^{NS}
7	E-learning systems enhance the learner's interest in learning.	3.62	1.24	4.05	0.79	2.29*
8	It is convenient and flexible platform.	3.85	1.01	4.33	1.00	2.64**
9	E-learning tools help with assignments and presentations.	4.18	1.02	4.67	0.54	3.25**
10	It is a time-saving platform.	3.95	1.16	4.38	0.90	2.29*
11	It is cost-effective.	3.92	1.18	4.35	0.78	2.37*
12	Access to e-learning tools is possible at any time, from any location.	4.25	0.91	4.60	0.56	2.53*
13	Learning from websites is difficult.	1.57	1.09	1.03	0.64	3.26**

* Significant at 5% level of significance, NS= non-significant

** Significant at 1% level of significance

Based on the findings presented in Tables 1, 2, and 3, it can be concluded that the majority of both undergraduate (UG) and postgraduate (PG) students belonged to the medium perception category, with a higher proportion of PG students (71.67%) compared to UG students (65.00%). PG students exhibited the highest perception towards the statement "e-learning tools help with assignments and presentations", whereas UG students showed the highest perception for "access to e-learning tools at any time and from any location". Both UG and PG students reported the lowest perception for the statement "learning from websites is difficult".

A strong positive rank order correlation was observed between UG and PG students, indicating a similar pattern of relative perception across various e-learning statements. However, statistically significant differences were observed between UG and PG students both at the statement-wise and overall levels, with PG students consistently demonstrating higher perception levels. This higher perception among PG students may be attributed to their greater academic maturity and frequent use of e-learning platforms, which they perceived as more effective, accessible, creative, time-saving, and supportive for academic tasks. Overall, the findings indicate a more favorable perception of e-learning platforms among PG students compared to UG students.

4. Perception level of UG and PG students of SKNCOA regarding the perceived usefulness of the e-learning platform

As presented in Table 4 and fig 3, undergraduate (UG) students reported the

highest perception for the statement "e-learning improves performance" with a Mean Percent Score (MPS) of 85.00, ranking first, followed by "e-learning helps in better time management" (84.00 MPS). Other highly perceived statements included access to additional study materials for personal development, efficient management of time and space, flexibility in learning, learner independence, increased efficiency in daily tasks, and motivation to learn, with MPS values ranging from 83.67 to 76.00, ranking up to the eighth position. Moderate levels of perception were observed for statements related to interactivity, conceptual clarity, productivity, self-confidence, self-paced learning, and enjoyment in learning, with MPS values ranging from 75.67 to 74.00. The lowest perception among UG students was recorded for the statement "e-learning results in deterioration of health" (47.33 MPS).

In the case of postgraduate (PG) students, the highest perception was observed for the statement "students can access additional study materials from e-learning for personal development" (92.33 MPS), followed by "e-learning improves performance" (91.00 MPS). Other highly ranked statements included efficient management of time and space, increased efficiency in daily tasks, better time management, flexible learning opportunities, improved conceptual understanding, and learner independence, with MPS values ranging from 90.67 to 85.00. Moderate perception levels were noted for statements related to self-confidence, motivation, interactivity, productivity, self-paced learning, and enjoyment, with MPS values ranging from 84.67 to 82.67. Similar to UG students, the lowest perception among PG students was observed for "e-learning results in deterioration of health" (34.67 MPS).

Table 4. Perception level of UG and PG students of SKNCOA regarding the perceived usefulness of the e-learning platform n=120

S.N.	Statements	UG (n_1=60)		PG (n_2=60)	
		MPS	Rank	MPS	Rank
1	E-learning improves performance.	85.00	1	91.00	2
2	E-learning provides motivation to learn.	76.00	8	84.33	10
3	E-learning increases productivity.	75.00	11	83.67	12
4	E-learning helps to manage time and space efficiently.	82.67	4	90.67	3
5	E-learning increases the efficiency of performing daily tasks.	76.67	7	90.33	4

6	E-learning helps to be more independent in learning.	77.00	6	85.00	8
7	E-learning is an active and Interactive way of learning.	75.67	9	84.00	11
8	E-learning makes learning more enjoyable.	74.00	14	82.67	14
9	E-learning tools help to understand the concepts more clearly.	75.33	10	86.00	7
10	E-learning is self-paced and give students a chance to speed up/slow down if necessary.	74.33	13	83.00	13
11	Students can access additional study materials from e-learning for personal development.	83.67	3	92.33	1
12	E-learning helps to improve self confidence in expressing ideas and opinions.	74.67	12	84.67	9
13	E-learning provides highly flexible learning opportunities	79.33	5	88.33	6
14	E-learning helps in better time management.	84.00	2	89.67	5
15	E-learning results in deterioration of health.	47.33	15	34.67	15
	Overall	78.11		85.56	

rs= Rank correlation rs = 0.90**

** Significant at 1% level of significance t =7.44

An attempt was made to examine the rank order correlation between the perception levels of undergraduate (UG) and postgraduate (PG) students with respect to the perceived usefulness of the e-learning platform. The rank correlation coefficient (rs) was found to be 0.90, indicating a strong positive correlation between UG and PG students. The significance of the correlation was tested using the t-test, and the calculated t value (7.44) exceeded the corresponding table value, confirming that the correlation was statistically significant. This indicates a similar pattern in the ranking of perception among UG and PG students regarding the e-learning platform. These findings agree with those reported by Ncube (2015).

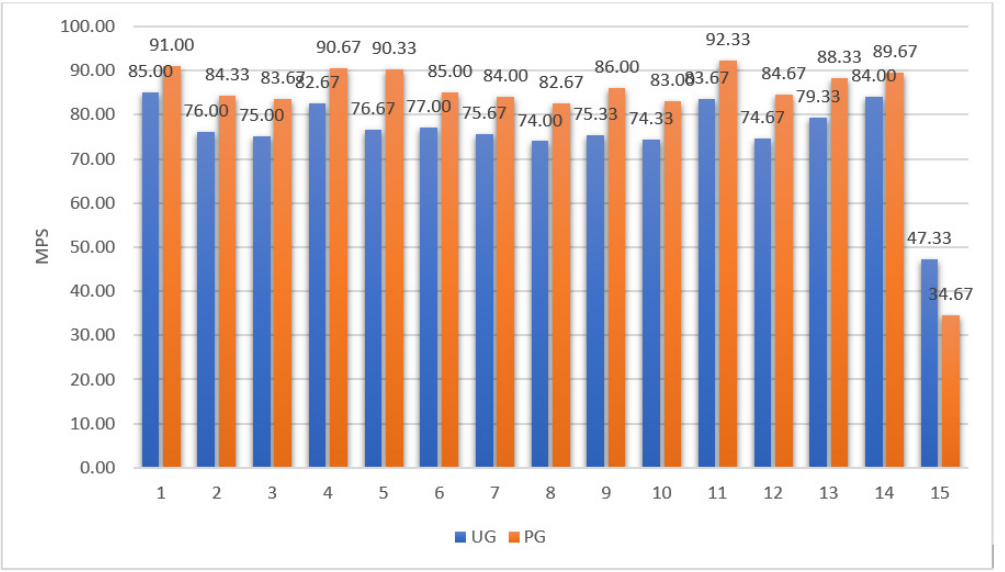

Fig 3. Perception level of UG and PG students of SKNCOA regarding the Perceived usefulness of the e-learning platform

5. Comparison of perception level of UG and PG students of SKNCOA regarding perceived usefulness of the e-learning platforms

The data presented in Table 5 indicate that statistically significant differences existed between undergraduate (UG) and postgraduate (PG) students regarding perceived usefulness of the e-learning platform. The calculated Z values were significant at the 1 per cent level for statements related to efficient management of time and space, improved efficiency in daily tasks, learner independence, better conceptual understanding, access to additional study materials for personal development, and flexibility of learning. Further, significant differences at the 5 per cent level were observed for statements related to performance improvement, learner motivation, productivity, interactivity, enjoyment of learning, self-paced learning, self-confidence, time management, and perceived health impact.

Table 5. Comparison of perception level of UG and PG students of SKNCOA regarding perceived usefulness of the e-learning platforms n=120

S.N.	Statements	UG (n_1=60)		PG (n_2=60)		Z value
		Mean	SD	Mean	SD	
1	e-learning improves performance	4.25	0.82	4.55	0.59	2.30*
2	e-learning provides motivation to learn	3.80	1.16	4.22	0.85	2.25*

3	e-learning increases productivity	3.75	1.23	4.18	0.95	2.16*
4	e-learning helps to manage time and space efficiently	4.13	0.98	4.53	0.68	2.60**
5	e-learning increases the efficiency of performing daily tasks	3.83	1.17	4.52	0.72	3.85**
6	e-learning helps to be more independent in learning	3.85	0.86	4.25	0.82	2.61**
7	e-learning is an active and Interactive way of learning	3.78	1.14	4.20	0.80	2.32*
8	e-learning makes learning more enjoyable	3.70	1.18	4.13	1.16	2.03*
9	e-learning tools help to understand the concepts more clearly	3.77	1.05	4.30	0.72	3.25**
10	e-learning is self-paced and give students a chance to speed up/ slow down if necessary	3.72	1.25	4.15	0.88	2.20*
11	Students can access additional study materials from e-learning for personal development	4.18	0.85	4.62	0.58	3.24**
12	e-learning helps to improve self confidence in expressing ideas and opinions	3.73	1.22	4.23	0.91	2.55*
13	e-learning provides highly flexible learning opportunities	3.97	0.92	4.42	0.81	2.85**
14	e-learning helps in better time management	4.20	0.68	4.48	0.60	2.42*
15	e-learning results in deterioration of health	2.37	1.55	1.73	1.36	2.38*
	health					

* Significant at 5% level of significance

** Significant at 1% level of significance

Based on the findings presented in Tables 4 and 5, it can be concluded that postgraduate (PG) students exhibited the highest perception for the statement "students can access additional study materials from e-learning for personal development", whereas undergraduate (UG) students showed the highest perception for "e-learning improves performance". Both UG and PG students reported the lowest perception for the statement "e-learning results in deterioration of health".

A strong positive rank order correlation was observed between UG and PG students, indicating a similar pattern in the relative ranking of perceptions across various e-learning statements. However, statistically significant differences were observed between UG and PG students at both the statement-wise and overall levels, with PG students consistently demonstrating higher perception levels. The higher perception among PG students may be attributed to their more favorable views of e-learning in terms of academic performance, motivation, productivity, and effective time management, along with stronger disagreement toward negative perceptions related to health impacts.

Conclusion

1. The findings of the study indicate that both undergraduate (UG) and postgraduate (PG) students exhibited an overall positive perception towards e-learning platforms in terms of perceived ease of use as well as perceived usefulness.

2. With respect to perceived ease of use, UG students reported the highest perception for the statement "access to e-learning tools is possible at any time and from any location" (MPS = 85.00), whereas PG students showed the highest perception for "e-learning tools help with assignments and presentations" (MPS = 93.33).

3. Regarding perceived usefulness, the highest perception among UG students was observed for "e-learning improves performance" (MPS = 85.00), while PG students reported the highest perception for "students can access additional study materials from e-learning for personal development" (MPS = 92.33).

4. A significant positive rank order correlation was observed between UG and PG students, indicating similar trends in the relative ranking of perception across various e-learning statements.

5. Statistically significant differences were found between UG and PG students both at the statement-wise and overall levels, with PG students consistently demonstrating higher perception levels compared to UG students.

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Role of Village Level Entrepreneurs in promoting Agricultural Services to Farmers in Common Service Centers

Gujji Bhaskar

ABSTRACT

Village Level Entrepreneurs (VLEs) play a critical role in facilitating agricultural services through Common Service Centers (CSCs) in rural India. These digital access points bridge the gap between farmers and essential government schemes, agricultural advisory services and financial services. This study examines the role of VLEs in delivering agricultural services, their impact on farmers' decision-making, and the challenges they face. Using data from Siddipet and Suryapet districts in Telangana, the paper highlights the effectiveness of VLEs in improving digital literacy, providing timely information, and enhancing market access. However, gaps in training, infrastructure, and service awareness persist. The recommendations include strengthening VLE training, expanding service offerings, and improving CSC infrastructure to maximize their impact on rural agricultural communities.

Keywords: Village Level Entrepreneurs (VLE), Common Service Centers (CSC), Agricultural Services, Digital Agriculture, Village Knowledge Centers (VKCs)

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1. Introduction

Agriculture remains a dominant sector in India, employing a significant portion of the rural workforce. However, challenges such as limited access to agricultural advisory services, fluctuating market prices, and financial constraints hinder productivity and growth. To address these issues, the Government of India has established Common Service Centers (CSCs) under the National e-Governance Plan (NeGP). CSCs serve as digital access hubs that provide essential citizen services, including agricultural advisory support, e-governance, and financial inclusion programs. It is reported that over 5,96,247 CSCs are functional across India as on January 2024 and 4,73,3700 CSCs were established at gram panchayat level in rural villages. The CSCs offering web-enabled e-governance services in rural areas, including application forms, certificates, and utility payments such as electricity, telephone and water bills, rural banking, health service, education and training, DTP, printing and Internet browsing.

In addition to above citizen services, the CSC guidelines also envisage that a wide variety of content and services will be offered in the area of Agriculture and allied sectors. The products and services offered by CSCs in Agriculture and allied sectors are CSC e-Agri, Agri Tele-Consultation & E –Pashu Chikitsa, Nursery and Seed Production, Kisan E- Mart, Soil Testing, Protected Cultivation, Organic Farming and Drone Pilot Training Facility.

At the core of CSC operations are Village Level Entrepreneurs (VLEs), who act as facilitators and service providers at the grassroots level. VLEs enable farmers to access real-time government schemes, market prices, weather updates and thereby empowering them with the necessary information to make informed agricultural decisions. Despite their crucial role, VLEs face several challenges, such as inadequate training, lack of digital literacy among farmers, and infrastructure constraints.

2. Background

The Common Service Centers were established as part of the Digital India initiative to deliver digital services to rural areas. The CSCs operationalised almost at each village gram panchayat across the country to serve as multipurpose centers, offering services in education, healthcare, financial inclusion, and agriculture. To enhance the reach of citizen services to farmers at village level, VLEs are appointed to manage these centers and ensure the effective delivery of services to farmers.

VLEs are local entrepreneurs trained to facilitate digital transactions, agricultural consultations, and access to government schemes. By acting as intermediaries between farmers and technology-driven solutions, VLEs have significantly

contributed to the adoption of digital tools in agriculture. However, their success depends on their level of training of agricultural knowledge, the accessibility of services, and the overall infrastructure of CSCs.

3. Research Methodology

3.1. Objectives of the study

1. To study the satisfaction level of farmers on agricultural services available through CSCs.
2. To study the effectiveness of I.T. enabled Agricultural and allied Services (ITeAS) that delivered through CSC to cater the needs of farmers at village level.
3. To study the training needs of Village Level Entrepreneur (VLE) to operate the agricultural services through CSCs.

3.2. Methodology

This study was conducted in the districts of Siddipet and Suryapet of Telangana state, where CSCs have been actively providing agricultural services. For the purpose of sample selection, two mandals selected viz. Bejjanki, Chinakoduru from Siddipet district and two mandals from Suryapet district viz. Nadigudem and Munagala were selected. All the CSCs of these mandals were considered as sample i.e. 38 VLEs were selected for the study. Data was collected through structured questionnaires, interviews, and focus group discussions with VLEs.

Table 1: Details of the Sample size selected from Telangana districts

S.No	District/Block	No. of VLEs selected	Sample size
1	Suryapet/Nadgudem	10	10
2	Suryapet /Munagala	12	12
3	Siddipet/Bejjanki	03	03
4	Siddipet/Chinnakodur	13	13
	Total	38	38

Secondary data sources such as government reports, CSC publications, and prior research studies were also analysed to provide context and validate the findings.

4. Findings of the study

4.1 Demographic data analysis of CSC operators

The demographic data of CSC operators on Gender, Age group, Level of education, Annual income is analysed and presented in the following table.

Table 2: Socio-Economic profile of CSC Operators (VLEs)

N = 38

	Category	No. of Farmers	Percentage
Gender	Male	34	89.5
	Female	4	10.5
Age (in Years)	18-25	3	7.9
	26-45	33	86.8
	46-60	2	5.3
	Above 60	0	0
Level of Education	Illiterate	0	0
	Primary Education (up to 7th)	0	0
	Secondary Education (8-10th)	2	5.3
	Intermediate/diploma	8	21.1
	Degree and above	28	73.7
Annual Income from CSCs	< 3 lakhs	36	94.7
	3-5 lakhs	1	2.6
	5-8 lakhs	0	0
	8-10 lakhs	0	0
	Above 10 lakhs	1	2.6

The results of the demographic data on gender distribution revealed that the majority of the respondents (89.5%) were male, while a smaller portion (10.5%) were female. The data on age distribution shows that most of the respondents (86.8%) belonged to the age group of 26-45 years, followed by 7.9 per cent of operators in the 18-25 years category. A smaller percentage (5.3%) were aged

between 46-60 years. In terms of education, the majority of the respondents (73.7%) were highly educated, possessing a degree or higher qualification. A smaller proportion (21.1%) had an intermediate or diploma-level education, while only 5.3 per cent had secondary-level education. The income data shows that a vast majority (94.7%) of respondents reported an annual income of less than ₹3 lakhs from CSCs, with only 2.6 per cent earning between ₹3-5 lakhs and another 2.6 per cent earning above ₹10 lakhs. There were no respondents with annual incomes between ₹5-10 lakhs, indicating a generally low-income range for most participants.

The above data indicates that a clear male domination in operationalising CSCs at village level and the age group of 26-45 years. The CSC operators are highly educated possessing a degree or higher qualification, which will ensure the good performance of CSC operations. However, the income data shows that the CSCs operators getting annual income less than ₹3 lakhs.

4.2 Ranking of agricultural services based on Ease of implementation, Acceptability and Ease of Use as perceived by the farmers and offered by the VLEs

The satisfaction of agricultural service-wise in terms of ease of implementation, acceptability and use by farmers ranking by VLEs on scale 1-5 was asked to know the classification of satisfaction level by VLEs on agricultural service-wise. The responses are presented in the following table.

Table 3: Agricultural service-wise Ease of Implementation, Acceptability and Usefulness as perceived by the farmers provided by CSCs

Type of Service	Ease of Implementation			Acceptability			Ease of Use		
	Score	Mean	Rank	Score	Mean	Rank	Score	Mean	Rank
Agricultural Tele Consultation and e-Pashu Chikista	100	2.63	8	95	2.50	10	103	2.71	8
Soil Testing Center/ Soil Health Card	101	2.66	7	100	2.63	6	102	2.68	9
CSC e-AGRI	101	2.66	7	96	2.53	9	104	2.74	7
Kisan e-Mart	104	2.74	5	94	2.47	12	106	2.79	5
Information on Nursery and Seed Production	100	2.63	8	100	2.63	6	101	2.66	10
Farm Machinery on Rent (MOVR)	103	2.71	6	97	2.55	8	112	2.95	3

Protected Cultivation & Organic Farming	103	2.71	6	98	2.58	7	105	2.76	6
Kisan Credit Card (KCC)	109	2.87	4	108	2.84	3	109	2.87	4
Pradhan Mantri Fasal Bima Yojana (PMFBY)	114	3.00	2	116	3.05	1	118	3.11	1
Pradhan Mantri Kisan Maandhan Yojana (PMKMY)	111	2.92	3	111	2.92	2	116	3.05	2
Pradhan Mantri Kisan Samman Nidhi (PM-KISAN)	115	3.03	1	103	2.71	5	116	3.05	2
Banking Services	114	3.00	2	107	2.82	4	118	3.11	1
Market price information	109	2.87	4	100	2.63		112	2.95	3
Weather forecast	108	2.84	5	108	2.84	3	108	2.84	5

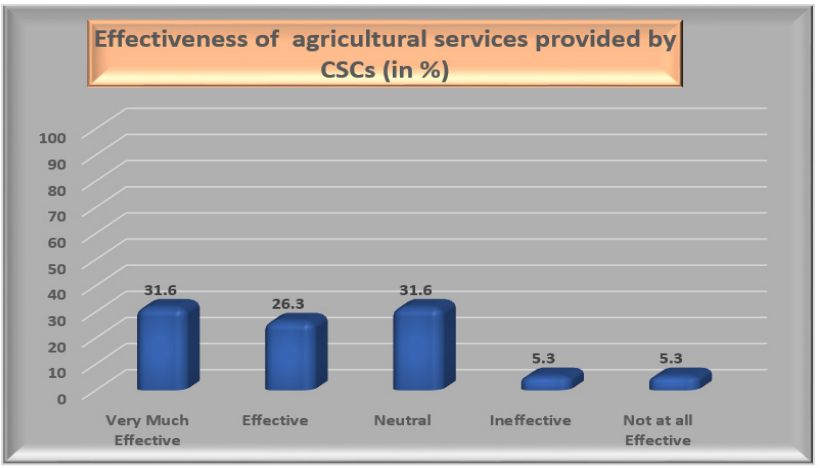
The data in above table presents the ease of implementation, acceptability, and ease of use of various agricultural services provided by Common Service Centers (CSCs), as perceived by farmers. 'Pradhan Mantri Kisan Samman Nidhi (PM-KISAN)' ranks highest in ease of implementation with a mean score of 3.03, followed closely by 'Pradhan Mantri Fasal Bima Yojana (PMFBY)' (3.00) and 'Banking Services' (3.00). In terms of 'acceptability', 'Pradhan Mantri Fasal Bima Yojana (PMFBY)' leads with a score of 3.05, followed by 'Pradhan Mantri Kisan Maandhan Yojana (PMKMY)' (2.92) and 'Kisan Credit Card (KCC)' (2.84).

For 'ease of use', 'Pradhan Mantri Fasal Bima Yojana (PMFBY)' and 'Banking Services' both scored the highest at 3.11, indicating they are considered most user-friendly by farmers. 'Farm Machinery on Rent (MOVR)' follows closely with a score of 2.95. Other services, such as 'CSC e-AGRI', 'Soil Testing Center/Soil Health Card', and 'Agricultural Tele Consultation and e-Pashu Chikista', show moderate performance across all three categories, while 'Weather Forecast' and 'Market Price Information' score moderately in ease of use and acceptability but slightly lower in ease of implementation.

The above table results shows that the ease of implementation, acceptability and ease of use of agricultural services at CSCs are PM-KISAN, PMFY, PMKMY, PMFBY and Banking Services. It indicates the services related to various Government schemes and banking services are utilising by farmers very well. And, the other farm related agricultural services are not much utilised and needs to be improved.

4.3 Effectiveness of agricultural services provided through CSCs

The effectiveness of agricultural services provided by CSCs to farmers was asked to know the classification of effectiveness of farmers on agricultural services. The responses are presented in the following graph.



The results show that the highest percentage of respondents, 31.6 per cent, rated the agricultural services provided by CSCs as both "Very Much Effective" and "Neutral". Following this, 26.3 per cent found the services "Effective". A smaller percentage (5.3 per cent) rated the services as both "Ineffective" and "Not at all effective".

This study results indicates that the majority of farmers expressed that the services provided at CSCs are very much effective and helpful in their day-to-day agricultural operations.

4.4 Training received by CSC Operators (VLEs)

Village Level Entrepreneurs (VLEs) serve as the backbone of CSC operations, ensuring that agricultural services reach rural farmers effectively. They provide critical support by assisting farmers in applying for government schemes, accessing financial services, and obtaining agricultural advisory inputs. VLEs also facilitate digital literacy among farmers, enabling them to utilize online platforms for weather updates, market information, and best farming practices. Their role extends to bridging the gap between technology and traditional farming methods, thus promoting the adoption of digital tools in agriculture. Additionally, VLEs assist farmers in obtaining essential documents, such as land records and soil health cards, which are necessary for availing agricultural subsidies. However, despite their pivotal role, many VLEs face obstacles such as limited technical training, inadequate internet connectivity, and insufficient awareness among farmers about CSC services.

Table 4: Training received by CSCs operators (VLEs) on agricultural services

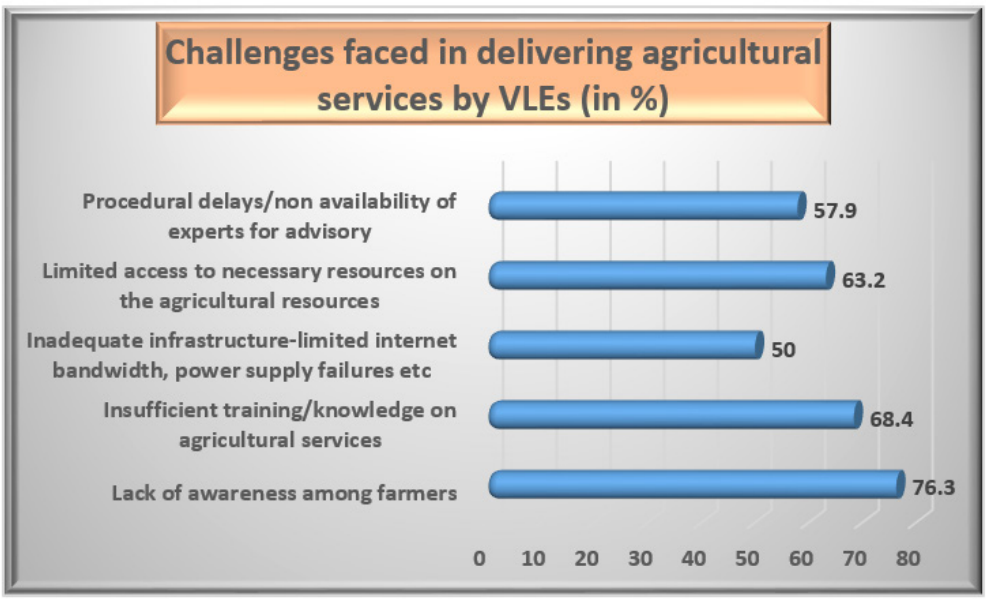
	Yes	No	Total
Training received by CSCs operators on agricultural services	14	24	38
Total percentage	36.8	63.2	100

The training received by VLEs shown in the above table reveals that only 36.8 per cent of CSC operators (VLEs) have received training on agricultural services, while majority (63.2 per cent) of them have not received any such training. This indicates a considerable gap in the provision of training, which could affect the operators' ability to effectively deliver agricultural services to farmers. The VLEs expressed that they need for intensive training on agricultural services for 1-2 weeks at the district level.

Strengthening VLE capacity through structured training programs, financial incentives, and improved infrastructure can significantly enhance their efficiency in delivering agricultural services. By addressing these training needs, VLEs can become powerful enablers of rural development and ensure that farmers fully benefit from digital interventions in agriculture.

4.5 Challenges Faced by VLEs

The various challenges faced in delivering agricultural services by VLEs at CSCs presented in the following graph.



The data highlights the challenges faced by Village Level Entrepreneurs (VLEs) in delivering agricultural services. The most frequently cited challenge is the lack of awareness among farmers, reported by 76.3 per cent of respondents. Insufficient training or knowledge on agricultural services is another significant issue, affecting 68.4 per cent of VLEs. Inadequate infrastructure, such as limited internet bandwidth and power supply failures, was mentioned by 50.0 per cent of respondents. Additionally, limited access to necessary agricultural resources was a challenge for 63.2 per cent of VLEs, while procedural delays or unavailability of experts for advisory impacted 57.9 per cent. These challenges reflect various barriers that hinder the effective delivery of agricultural services.

The results shows that the major challenges faced by VLEs was knowledge upgradation on agricultural services, availability of experts for supporting advisory services, limited bandwidth and power breakdowns effecting the services at CSCs. It is also observed that many farmers do not aware of the availability of agricultural services at CSCs. These deficiencies can be addressed by the capacity building of VLEs on agricultural services, linking VLEs with experts of KVKs and conducting village level campaigns of agricultural services of CSCs.

5. Conclusion and Recommendations

VLEs offer a variety of services, with high engagement in government programs such as PM-KISAN and PMFBY. However, there is notably less involvement in operational services like advisory services, farm machinery rentals, indicating possible gaps in addressing farmers' specific needs. This variation in service delivery suggests that although VLEs are willing to provide assistance, they may lack the necessary resources or specialized knowledge to effectively deliver certain types of services. The preference expressed by VLEs for short, focused training sessions indicates a practical approach to improve their service delivery capabilities. Regular, accessible training sessions could help bridge existing knowledge gaps and equip VLEs to better serve the farming communities. VLEs often lack specific agricultural expertise, affecting service quality. Only few VLEs reported receiving agricultural training, which indicates a considerable gap in the knowledge needed to effectively assist farmers. Regular, practical training for VLEs, focusing on agriculture-specific topics and digital tools, could significantly enhance their ability to meet farmer's needs.

Sector-specific analysis reveals that VLEs recognize the importance of CSCs evolving into Village Knowledge Centers (VKCs) to address diverse agricultural needs. There is strong demand for expanded advisory services, high-quality inputs, accessible machinery, and support in areas such as insurance and credit access. Services for horticulture and animal husbandry also emerge as priorities,

with particular emphasis on veterinary support, animal feed provision, and access to horticultural information. These insights demonstrate that VLEs are aware of the varied and complex needs of farmers and understand the potential impact of a more comprehensive suite of services.

To enhance the effectiveness of VLEs, the following recommendations are proposed based on the information collected from VLEs:

1. Enhanced Training Programs: Conducting regular, specialized training programs for VLEs focusing on agricultural best practices, digital literacy, and financial management.
2. Strengthen Partnerships with Agricultural Institutions: Collaborate with State Agricultural Universities (SAUs), Krishi Vigyan Kendras (KVKs), and departmental officials to offer expert advice and specialized knowledge through CSCs, enhancing their role as knowledge centers for rural communities.
3. Diversify Agricultural Services: Expand CSC services to cover a broader range of agricultural needs, including support for horticulture, livestock management, and fisheries to address the diverse needs of rural farmers.
4. Align CSCs to FPOs: The CSCs should be made aligned with FPOs, so that the services needed by the farmers in that FPOs will be effectively met. It is a win-win situation for CSCs, FPOs, and Farmers as this kind of networking facilitates effective knowledge sharing.
5. Improved Infrastructure: Strengthening digital connectivity and ensuring CSCs are equipped with modern tools for better service delivery.
6. Awareness Campaigns: Conducting farmer awareness programs to promote the benefits of CSC agricultural services and encourage digital adoption.

By addressing these gaps, CSCs can evolve into fully functional Village Knowledge Centers (VKCs), empowering farmers and promoting sustainable agricultural development in rural India.

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Factors Affecting the Farmer-To-Farmer Spread of Selected Climate Resilient Technologies

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ABSTRACT

Climate change has significantly altered the priorities of the agriculture research, experiencing the impacts of climate change, the focus of agriculture research has shifted from yield intensification to climate adaptation and mitigation through climate resilient agriculture. Effective adaptation to climate change requires efficient technology dissemination system. Understanding technology spread pathways, factors influencing spread of the technologies is very important for the efficient spread of climate resilient technologies. The present study was conducted to find out the factors affecting the farmer-to-farmer spread of climate resilient technologies in the state of Telangana. Ex-post facto research design was used. Khammam district was selected purposively. Enkoor mandal was selected purposively as the spread of climate resilient technologies is observed in the mandal. Two NICRA villages and two NON-NICRA villages were selected from the mandal randomly. 30 farmers were selected at random from each village to create a sample of 120 respondents. The relationship analysis between factors affecting farmer to farmer spread of climate resilient technologies regarding NICRA farmers out of 18 variables 9 variables namely farm size, annual income, irrigation, information seeking behaviour, extension contact, participation in extension activities and relative advantage, trialability and access to technology showed significant correlation at 1% and 5% level of probability with technology spread. Where as in Non-NICRA respondents out of 18 variables 2 variables namely irrigation, access to technology were positively correlated at 0.05 level of significance.

Keywords: NICRA, technology spread. Climate resilience, Access to technology

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1. Introduction

Crops are vulnerable to extreme temperature events, changes in historical average temperatures, increased seasonal variability of precipitation, declining soil quality, and increasing pest and disease occurrences. Climatic uncertainties can significantly affect water availability and, consequently, agricultural productivity (Dhungana et al. 2020 and Xu et al. 2019)) and Rainfall and temperature are the most critical climate variables for agricultural production (Fahad et al. 2019 and Fahad et al. 2018). Loss of crop yields increases food prices, and also can have an absurd effect on agriculture welfare globally. Increasing crop resilience (ability to withstand these stressors) will be fundamentally important as it will reduce the farmers' vulnerability to crop loss and a country's ability to sustain its food security. "A rise in the average seasonal temperature can shorten the growing season for many crops, lowering their final yield. Warming will have an immediate impact on yields in locations where temperatures are already close to the physiological maximum for crops" (IPCC, 2007). The goal of climate resilient agriculture (CRA) is to increase long term farm incomes and productivity by sustainably utilizing the natural resources already available through crop and livestock production systems. Climate resilience can be enhanced by implementing short and long-term climate mitigation and adaptation strategies, as well as ensuring transparent and inclusive participation of multiple actors and stakeholders in decision-making and management processes. Practices like the use of improved seeds, rainwater harvesting, crop/livestock insurances, and ICT based agro advisories etc. can also help farmers to minimize the effect of climate change and variability (Mittal, 2012).

In order to minimize the detrimental effects of climate change on Indian Agriculture, Climate Resilient Agricultural (CRA) technologies were introduced and being promoted through ICAR- NICRA in the selected vulnerable districts across the country started on 2nd February 2011(Pabba et al. 2021). The NICRA project has substantially improved the income and employment levels of participating farmers compared to non-NICRA areas, highlighting its role in livelihood enhancement (Lenka et al. 2022). NICRA project in Telangana, empowered the rainfed farmers to adopt integrated farming systems, improved water management practices and drought-tolerant crops, for better adaptation to climatic risks (Naik et al. 2024). Adoption of climate resilient technologies under NICRA such as improved crop varieties, water management, and livestock practices has led to notable increases in crop yields and productivity (Choudhary et al. 2025). Education, annual income, land holding, individual and mass media exposure, economic motivation, risk taking ability, and innovative proneness showed positive and significant relation with the overall

adoption of CRA technologies at a 5 per cent level of significance in Khammam and Suryapet districts of Telangana (Naik et al. 2023). Although numerous studies conducted under NICRA have evaluated technology adoption, crop productivity, livelihood improvement, resilience enhancement and climate adaptation, very limited attention has been devoted to understanding the pathways through which climate-resilient technologies spread among farming communities. Existing studies primarily assess programme impacts, whereas evidence on farmer-to-farmer dissemination mechanisms, institutional interactions, communication pathways, technology attributes governing diffusion and comparative roles of public and private extension systems remains scarce. The present investigation addresses this knowledge gap by delineating determinants influencing technology spread and analysing farmer-to-farmer diffusion networks. Therefore, it is crucial to understand the factors influencing the adoption of these climate-resilient technologies to ensure their wider spread and long-term sustainability among farming communities.

2. Objective of the study

To study the factors affecting the farmer-to-farmer spread of climate resilient technologies

3. Methodology

The study was conducted in the state of Telangana. Study, employed an ex-post facto research design. As described by Kerlinger (1973), Ex post facto research refers to a systematic empirical investigation wherein the researcher lacks direct control over the independent variables, as they have already occurred or are intrinsically non-manipulable in nature.

Khammam district was purposively selected because it is one of the NICRA intervention districts in Telangana where climate-resilient technologies have been implemented continuously through ICAR since 2011. The district represents a climate-vulnerable region frequently affected by drought and rainfall variability, making it suitable for studying climate-resilient technology dissemination. Enkoor Mandal was selected because it exhibited objective selection criteria (e.g., documented horizontal diffusion, comparable agro-ecology, and spillover of technologies). In addition, the presence of both NICRA-adopted and neighbouring non-NICRA villages with comparable agro-ecological and farming conditions provided a suitable framework for examining and comparing the factors influencing farmer-to-farmer dissemination of climate-resilient technologies. Two NICRA villages (Nacharam and Colony Nacharam) and two neighbouring non-NICRA villages (Rangapuram and Nemalipuram) were purposively selected as they possess comparable agro-

climatic conditions, cropping systems, soil characteristics, rainfall pattern and socio-economic characteristics, enabling meaningful comparison between NICRA and Non-NICRA villages while differing mainly in exposure to climate-resilient interventions.

Thirty farmers were randomly selected from each village; thus, 60 respondents were drawn from NICRA-adopted villages and 60 from non-NICRA villages, yielding a total sample of 120 respondents. As two technologies were considered in the study, the factors influencing their adoption were examined separately for each technology. Data collected through interview schedule was coded tabulated and analysed. Pearson's correlation coefficient was employed to examine the relationship between independent variables and technology spread separately for NICRA and Non-NICRA farmers.

The conceptual framework of the study grouped the determinants influencing technology dissemination into four major dimensions, namely socio-economic, technological, institutional and extension-related factors. These determinants were identified through an extensive review of literature and validated during the field investigation. Their influence on farmer-to-farmer dissemination was examined separately for WGL-44 saline-tolerant rice variety and CRT-Farm Pond technology.

Dimension	**Variables**
Socio-economic	Age, education, farm size, annual income, farming experience, irrigation
Extension	Information seeking behaviour, extension contact, participation in KVK activities
Technology attributes	Relative advantage, trialability, compatibility, complexity, affordability, need, access
Institutional	Availability of infrastructure, NICRA support, demonstrations, KVK interventions

4. Results and Discussion

Relationship between factors affecting farmer to farmer spread of climate resilient technologies.

WGL-44 saline-tolerant rice variety and CRT-Farm Pond were selected because these were the most widely disseminated climate-resilient technologies under NICRA in the study area, exhibiting substantial farmer-to-farmer diffusion compared with other interventions. In order to study the nature of relationship between the factors affecting farmer to farmer spread of climate resilient technologies, correlation co-efficient (r) were computed and the values were

presented in Table 1.

Table 1 Correlation analysis of factors affecting farmer to farmer spread of climate resilient technology – Wgl-44 saline tolerant variety.

S. No	Variables	NICRA Farmers (n=30)	NON-NICRA Farmers (n=30)
		Correlation coefficient	Correlation coefficient
1	Age	0.0343	0.025
2	Education	0.046	0.037
3	Family type	0.155	0.116
4	Farm size	0.355*	0.119
5	Farming experience	0.412	0.040
6	Irrigation	0.254**	0.129*
7	Annual income	0.412*	0.028
8	Information seeking Behaviour	0.233*	0.034
9	Extension contacts	0.211**	0.046
10	Participation in KVK Activities	0.346**	0.064
11	Affordability	0.131	0.092
12	Relative advantage	0.152*	0.017
13	Trail ability	0.249*	0.067*
14	Compatibility	0.219	0.022
15	Need for technology	0.004	0.020
16	Complexity	0.377	0.110
17	Availability of Infrastructure	0.236	0.226
18	Access to technology	0.165*	0.115*

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

From the table 1, regarding NICRA farmers out of 18 variables 9 variables namely farm size, annual income, irrigation, information seeking behaviour, extension contact, participation in extension activities and relative advantage, trialability and access to technology showed significant correlation at 1% and 5% level of probability with technology spread. And 8 out of 18 variables namely education, family type, farming experience, compatibility, complexity, availability of infrastructure, affordability and need for technology are positively correlated with technology spread but not significant. The variable age is negatively related to technology spread.

As a result, it can be inferred that farm size (r=0.355*) had positive and significant effect on technology spread among the farming communities, as it will enable the farmer to trial and observe the result of climate resilient technologies in a part of the farm. Farmers with higher incomes (r= 0.412*) can practice climate resilient technologies such as farm pond construction, micro irrigation techniques, intercropping, and diversifying activities for a longer period of time, resulting in long-term profits with visible impact. This result is consistent with the findings of Pise et al. (2018) and Neelima et al. (2024).

It was perceived from the above table that irrigation (r=0254**) had positive and highly significant relationship with the technology spread. From this it can be comprehend that the farmers with available water resources are willing to experiment and spread the climate resilient technologies. Information seeking behaviour (r= 0.233*) was positive and significantly correlated to Technology spread. It was also observed the extension contact (r= 0. 211**) of the farmers has direct and positively significant effect on technology spread.

It was perceived from the above table that there was positive and highly significant relationship between the farmers' participation in KVK activities (r= 0.346**) and technology spread. Technology factors have direct and positive significant influence on the spread of technology. The technology factors like relative advantage (r= 0.152*), trialability (r=0.249*) had positive and significant effect on technology spread as these factors help the farmers to analyse and realize the importance and need of climate resilient technologies. Access to technology (r= 0.165*) positive and significant relation with the technology spread.

CRT-Farm Pond

Table 2: Correlation analysis of factors affecting farmer to farmer spread of climate resilient technology – farm pond

S. No	Variables	NICRA Farmers (30)	NON-NICRA Farmers (30)
		Correlation coefficient	Correlation coefficient
1	Age	0.0223	0.015
2	Education	0.035	0.026
3	Family type	0.135	0.122
4	Farm size	0.277*	0.119
5	Farming experience	0.376	0.101
6	Irrigation	0.233**	0.110*
7	Annual income	0.312	0.024
8	Information seeking Behaviour	0.243*	0.036
9	Extension contacts	0.219**	0.023
10	Participation in KVK activities	0.325**	0.055
11	Affordability	0.122	0.082
12	Relative advantage	0.111*	0.011
13	Trail ability	0.121	0.054
14	Compatibility	0.118	0.023
15	Need for technology	0.023	0.018
16	Complexity	0.383	0.131
17	Availability of infrastructure	0.244	0.221
18	Access to technology	0.122*	0.115

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

From the table 2, regarding NICRA farmers out of 18 variables 7 variables namely farm size, irrigation, information seeking behaviour, extension contact, participation in extension activities and relative advantage and access to technology showed significant correlation at 1% and 5% level of probability with technology spread. And 11 out of 18 variables namely age, education, family type, farming experience, compatibility, complexity, availability of infrastructure, affordability and need for technology are positively correlated with technology spread but not significant.

Farm size (r=0.277*) had positive and significant relation with the technology spread. As a result, it can be inferred that greater the farm size greater will be the technology spread among the farming communities. Large farms provide opportunities for experimentation, visibility and observation by neighbouring farmers, thereby facilitating horizontal diffusion.

There was a positive and highly significant correlation between irrigation (r=0.233**) and technology spread. Extension contacts (r= 0.219**) and participation in KVK activities (0.325**) had positive and highly significant correlation with the technology spread. Training and demonstrations improve observability and trialability. Seeking technical advices regarding climate resilient technologies from various sources, such as KVK scientists, mass media, and fellow farmers, and make decisions accordingly. Similar findings were reported by Dhanalakshmi et al. (2025) and Neelima et al. (2024). Relative advantage (r=0.111*) of the technology and Access to technology (r=0.122*) had positive and significant relation with the technology spread. Farmers spread technologies only after observing visible economic benefits.

Although the magnitude of correlation varied across the two climate-resilient technologies, the findings consistently demonstrated that farm size, irrigation, extension contact, participation in extension activities, information-seeking behaviour, relative advantage and access to technology emerged as the most influential determinants of farmer-to-farmer dissemination among NICRA farmers. These determinants collectively indicate that technology diffusion depends not only on farmers' socio-economic capacity but also on the strength of extension support and perceived technological benefits.

Conclusion

The present study revealed that the farmer-to-farmer spread of climate-resilient technologies is influenced by the combined effects of socio-economic, technological and institutional factors. Among NICRA farmers, farm size, annual income, irrigation access, information-seeking behaviour, extension contact, participation in Krishi Vigyan Kendra (KVK) activities, access to technology,

and the perceived relative advantage of the technologies exhibited significant positive relationships with technology dissemination. In contrast, comparatively weaker associations observed among non-NICRA farmers indicate disparities in access to extension services, institutional support and technology dissemination opportunities.

The findings demonstrate that successful farmer-to-farmer dissemination depends not only on the availability of climate-resilient technologies but also on enabling conditions that promote awareness, experimentation, confidence and knowledge sharing among farmers. Socio-economic resources such as farm size and irrigation facilitate experimentation, while extension interventions through KVKs and regular extension contacts strengthen farmers' capacity to adopt and disseminate technologies. Furthermore, technologies possessing greater relative advantage and easier accessibility are more readily accepted and diffused within farming communities. Therefore, strengthening extension systems, improving farmers' access to climate-resilient technologies, and promoting participatory learning approaches are essential for accelerating the horizontal spread and wider adoption of climate-resilient technologies.

Policy Implications

Policy efforts should strengthen the ecosystem in which the farmers operate by scaling up the field demonstration and capacity building programmes through KVKs and ICAR institutes, given the strong influence of extension contacts and participation in KVK activities. Participatory approaches like farmers groups, innovative farmers networks and peer learning can accelerate technology diffusion and adoption. Investments in resource infrastructure are essential for farmers experimentation of new practices. Additionally, policymakers should design targeted outreach for non-NICRA areas to bridge dissemination gaps and ensure inclusive scaling of climate-resilient agriculture.

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Effectiveness of Government Policy for Cereal Crop Seed Marketing in Syangja District, Nepal

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ABSTRACT

The study investigates the implementation of government policies on marketing of cereal crop seed in Syangja district of Nepal. The public interventions aimed at increasing the availability of inputs for seed production are insufficient. Although they seek to improve the system, they do not adequately address the underlying structural problems in the input market. The data were descriptively analyzed by using descriptive statistics, Pearson correlation and Chi-square test using a randomized sample of 223 seed producing farmers calculated via Yamane's formula. The study highlighted an absolute institutional dependence of 100% such that respondents used only publicly funded source seeds and technical extension services. The source seed production is almost fully subsidized (99.10%), but the satisfaction with agricultural policies remains moderate, being 2.15 out of 3.0. Institutional testing services and seed support ranked the highest on satisfaction, while DESES and formal seed price mechanisms fared poorly. Major market vulnerabilities include crop damage by wild animals (index value = 0.97) and poor market prices (reported by 85.2% of farmers). These problems are made worse by the very low crop insurance enrollment rate of only 0.90%. The study recommends strengthening policy implementation by expanding support beyond production subsidies to include post-harvest processing, improving the functionality and crop-specific applicability of the Digitally Enabled Seed Subsidy Management System (DESES), and promoting accessible crop insurance schemes to enhance market resilience and reduce farmers' exposure to wildlife and climate-related risks.

Keywords: Cereal Crop, Government policy, Marketing tools, Seed Holding Capacity, DESES

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1. Introduction

Quality seeds are the basic input necessary for enhancing productivity and thus acts as a critical precursor to not only generate higher yields but also integrate food security. Empirical literature shows that use of quality certified seed can independently increase crop yields 10–15%, with advanced institutional management claiming yield increases of 15% to 20% (Madan et al., 2020). In a developing agrarian economy, seed systems are split between formal sectors (vertically integrated production and certification with government quality control) and informal sectors (farmer-saved seeds, bartering to obtain crops planted for next season, and local grain markets). In less developed countries, informal systems often provide around 90% of staple crop seeds because structural constraints limit delivery through formal markets(Almekinders & Louwaars, 2023).Cereal crops provide 26.64% share of the agricultural gross domestic product (AGDP) and hence are considered as a backbone of AGDP sector, Nepal(MoALD, 2024). Of the total arable land area in Syangja district, cereals is grown on 52,000 hectares and amounts to a total production of 154,000 metric tons(MoALD, 2024). In order to harness this production capacity, the Government of Nepal has provided macro-level frameworks with initiatives like National Seed Vision (2013–2025), Agriculture Development Strategy (ADS 2015-2035) and Seed Policy, 2022. They explicitly promote improved local seed security, public–private interactions and varietal competition. At the heart of this contemporary policy framework is the Digitally Enabled Seed Subsidy Management System (DESES), which has been developed by SQCC to collate real time tracking data for breeder, foundation and certified seeds. (SQCC, 2025).

However, for the most part, improved seeds are far from being widely adopted in practice due to policies which not yet applied. Improved maize varieties capture an insignificant 10% of the market share, while smallholders resort to informal sources. The policy-formulation-to-grass-roots-market-execution is not practical. However, the varied geography and changing cropping practices that are seen in Syangja necessitate a systematic assessment of which government policy and instruments: production subsidies, regulatory licenses and digital marketing platforms have real impacts on commercial outcomes for farmers.

2. Objectives of the Study

To resolve the analytical gaps in current policy evaluations, this study operates with a clear, specific focus on measuring the field-level execution of public seed policies. The research is guided by the following objectives:

- To analyze socio-economic characteristics of cereal seed producers and also cropping system practices in the Syangja district.

- To quantify institutional delivery of government support mechanisms, source seed subsidies, technical training, and digital marketing platforms (DESES).
- To analyze the level of farmer satisfaction regarding state-administered pricing, licensing, and seed testing services.
- To identify and rank the primary biophysical and economic constraints that hinder seed marketing.

3. Research framework

For this study, the following theoretical framework has been formulated after reviewing the literature. The proposed conceptual framework presented in the figure depicts the relationship of independent variables (Seed Distribution Mechanism, Quality Control Regulations, and Training Programs, Institutional Support, Subsidy Policy) with dependent variable for seed marketing also supported by (Pereira etal, 2024)

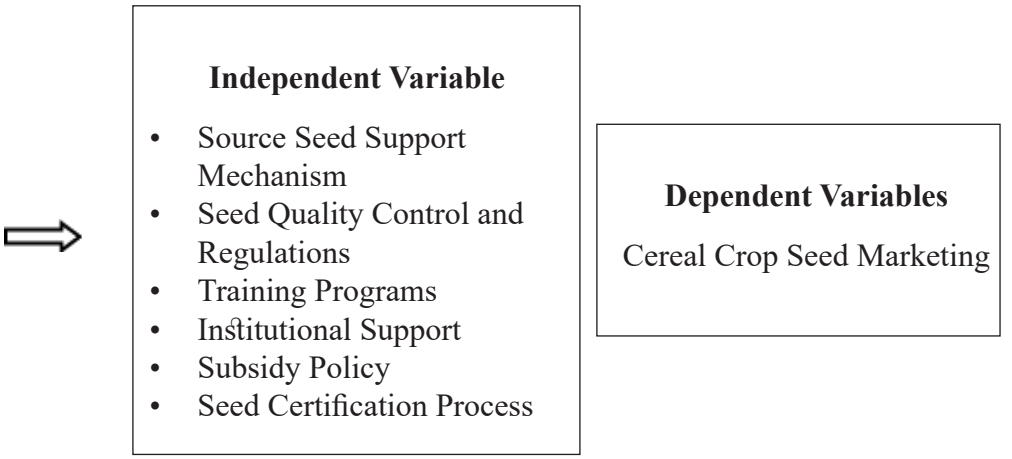


Figure 1. Research Framework of policy support on cereal crop seed marketing

4. Research Methodology

4.1 Research Design and Sampling Framework

Using a mixed-methods research design of quantitative surveys and qualitative validation tools (FGDs and KIIs), this study assesses the relationship between policy inputs and marketing success. This population constituted around N = 800 cereal seed producers registered at four different local levels, i.e., Chapakot, Galyang, Biruwa and Phedikhola of Syangja district.

To guarantee statistical representativeness, the minimum sample size (n) was calculated using Yamane's formula for finite populations n = N / (1 + N (e) 2)

Where N is the total population of seed producers (800) and e is the margin of error (0.05 at a 95% confidence level). Applying the parameters yielded an initial requirement of approximately 267. Due to fieldwork accessibility constraints and data verification adjustments during field compilation, a finalized sample of 223 farmers was randomly selected and surveyed across the designated local administrative blocks. Primary data were gathered through structured household questionnaires using 5-point Likert scales, complemented by Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) with government extension staff and cooperative leaders.

4.2 Operationalization of Statistical Tools

Quantitative data were processed and analyzed using Microsoft Excel and SPSS. The analytical tools were selected to match the specific properties of the data variables:

- Descriptive Statistics (Mean, Standard Deviation, Indexing): Used to summarize demographic profiles, experience levels, and institutional coverage. Priority rankings for field challenges were structured using an index calculated from weighted rankings.
- Pearson Correlation Analysis (r): Applied to continuous numerical and interval scale satisfaction variables to determine the direction and strength of linear relationships among service attributes (e.g., age, experience, licensing satisfaction, and pricing satisfaction).
- Chi-Square Test of Independence (χ^2): Used for categorical variables to evaluate whether demographic traits or crop categories significantly influence policy access, training benefits, or digital technology usage. The threshold for statistical significance was set at $\alpha = 0.05$.

5. Results and Discussion

This section presents and interprets findings from a field survey of 223 cereal seed producers in Syangja District, Nepal, with the objective of assessing the effectiveness of government policies and programs in cereal crop seed marketing. The analysis integrates descriptive statistics, satisfaction assessments, market evaluations, and inferential statistical tests to provide a comprehensive understanding of policy performance, institutional support, and farmer outcomes.

5.1 Demographic and Socioeconomic Characteristics of Seed Producers

The gender composition in seed production is fairly balanced, with males at 56.5% and females at 43.5%, indicating significant female involvement. However, ethnic representation is skewed, dominated by Brahmin/Chhetri groups (72.6%), potentially impacting socio-economic findings. The respondents' ages averaged 49.6 years, highlighting an experienced but aging farming population, raising concerns about generational continuity. Educationally, most farmers have secondary education (52.9%), suggesting adequate literacy for adopting new technologies, though ongoing investment in training and extension services is crucial for enhancing technical capacity.

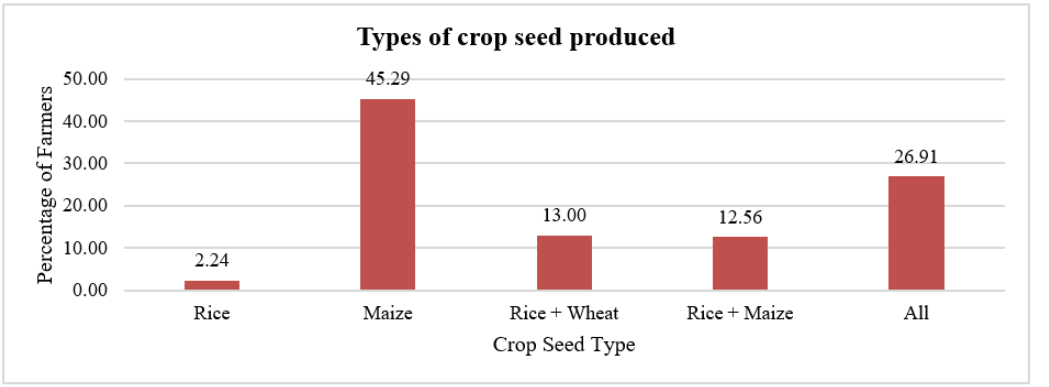
5.2. Seed Production Experience and Crop Specialization

Respondents reported an average of 10.35 years of experience in seed production, indicating a balanced mix of seasoned producers and relatively newer entrants as presented in table. This combination can foster knowledge exchange, innovation diffusion, and gradual modernization of seed production practices.

Table 1: Years of experience in seed production

Mean	Minimum	Maximum
10.35	3	20

Source: Field Survey, 2025



Source: Field Survey, 2025

Figure 2: Type of crop seed production

Crop-wise analysis indicates that maize seed production is predominant, with 45.29% of farmers engaged in its cultivation, driven by market demand, adaptability, and profitability. Meanwhile, 26.91% of farmers produce multiple cereal seeds like rice, maize, and wheat, showcasing diversification for income stability. Exclusive rice seed production remains low at 2.24%, likely due to

labor intensity, production risks, or lower returns. These findings suggest that maize remains the primary seed crop, promoting diversification could enhance resilience, reduce dependency on a single commodity, and strengthen overall seed system stability.

5.3. Government Dominance in Seed Supply and Technical Support

A striking result of the study is the complete reliance on government institutions for seed procurement and technical support. All surveyed farmers (100 percent) reported sourcing seed exclusively from government agencies, with no engagement from private companies, NGOs, or informal local sources as displayed in table below. This demonstrates strong government penetration in the seed input market but also highlights a lack of private sector participation and market competition.

Table: 2 Source of seed purchase

Source of seed purchase	Frequency	Percentage
Government	223	100

Source: Field Survey, 2025

Similarly, all respondents reported receiving technical support solely from government institutions. While this reflects the effectiveness of public extension outreach, it also signals institutional dependency and limited diversification of service providers. Strengthening partnerships with private seed companies, cooperatives, NGOs, and lead farmers could enhance service coverage, innovation, and long-term sustainability as shown in table below.

Table 3: Source of technical support in seed production

Institution	Frequency	Percentage
Government	223	100

Source: Field Survey, 2025

5.4. Training Coverage and Capacity Development

Capacity development programs show excellent nominal coverage, with 94.62% of seed producers receiving specialized training. Mechanistically, 48.88% completed integrated training covering seed production alongside pest management. However, a critical training gap exists regarding institutional and regulatory frameworks: only 1.35% of farmers received dedicated training on seed legislation, and only 1.79% received focused training on specialized pest control.

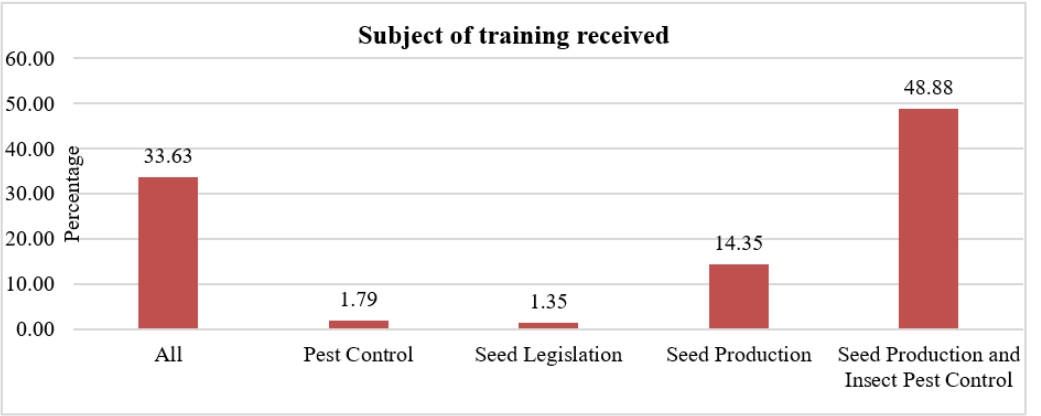
This policy delivery imbalance is also clear when examining infrastructure and

financial subsidies. While source-seed production subsidies reach 99.10% of the target group, they focus almost entirely on initial input costs. Financial support for value-addition processes—such as grading machinery, specialized cleaning tools, localized processing units, and storage infrastructure is completely absent. Consequently, 79.82% of producers must rely on low-cost, basic household storage solutions like standard seed bins or hermetic PIC bags.

Table 4: Status of training received

Particulars	Frequency	Percent
Farmers receiving training	211	94.62
Farmers not getting training	12	5.38
Total	223	100.0

Source: Field Survey, 2025



Source: Field Survey, 2025

Figure 3. Subject of training received

This integrated training approach likely contributes to improved production practices, yet the limited emphasis on seed laws and regulatory compliance may restrict farmers' ability to fully engage in formal seed markets. Expanding targeted training on legal frameworks, quality assurance, and post-harvest management could strengthen commercialization outcomes.

5.5 Subsidy Coverage and Infrastructure Support

Subsidy distribution in the study area appears extensive, with 99.10 percent of farmers reporting receipt of government subsidies for source seed production

and marketing as presented below in table. This indicates high program coverage and successful policy outreach. Most respondents received multiple forms of support, including subsidies for source seed, machinery, and combined assistance packages.

Table 5: Status of subsidy on source seed production and marketing

Particulars	Frequency	Percent
Farmers not getting subsidy	2	0.90
Farmers getting subsidy	221	99.10
Total	223	100.0

Source: Field Survey, 2025

However, subsidies related to seed processing, grading machinery, fertilizer, and pesticides were entirely absent, suggesting either limited program availability or insufficient awareness among farmers. This gap points to an opportunity for policy refinement, particularly in supporting value addition, quality enhancement, and cost-efficient production.

Regarding storage infrastructure, most farmers relied on low-cost household storage solutions such as seed bins or PIC bags (79.82 percent), while only 20.18 percent used cooperative-based RCC storage facilities.

Table 6: Seed storage structure

Particulars	**Frequency**	**Percent**
Seed bin/Pic Bag in own home	178	79.82
RCC storage of Group and Cooperative	45	20.18
Total	223	100.0

Source: Field Survey, 2025

The complete absence of private RCC storage highlights financial and infrastructural constraints, underscoring the need for investment in community-level storage facilities and post-harvest infrastructure.

5.6. Seed Availability and Challenges of seed production

Nearly all respondents (99.10 percent) reported receiving their desired quantity and variety of seed, suggesting that government-supported seed distribution systems are effective in meeting production requirements. This reflects strong

alignment between seed supply and farmer demand, a critical indicator of functional seed system performance.

Nevertheless, several production challenges persist. Wild animal attacks emerged as the most severe constraint (Index = 0.97), followed by insect and pest infestations (Index = 0.67) and low seed prices (Index = 0.64). Climatic risks, technical difficulties in machinery operation, storage capacity limitations, and source seed availability were ranked as moderate to low but remain relevant barriers.

These findings suggest that while institutional support has improved input access, external risks and market-related constraints continue to threaten seed production profitability as presented in table below.

Table 7: Ranking of the problems

Problems	Index Value	Rank
Attack of wild animals	0.97	I
Problem of insect and pest	0.67	II
Price of seed is low	0.64	III
Climatic factors like rainfall and drought	0.50	IV
Technical problem in operating seed machinery	0.46	V
Seed Holding Capacity	0.42	VI
Source Seed Availability	0.33	VII

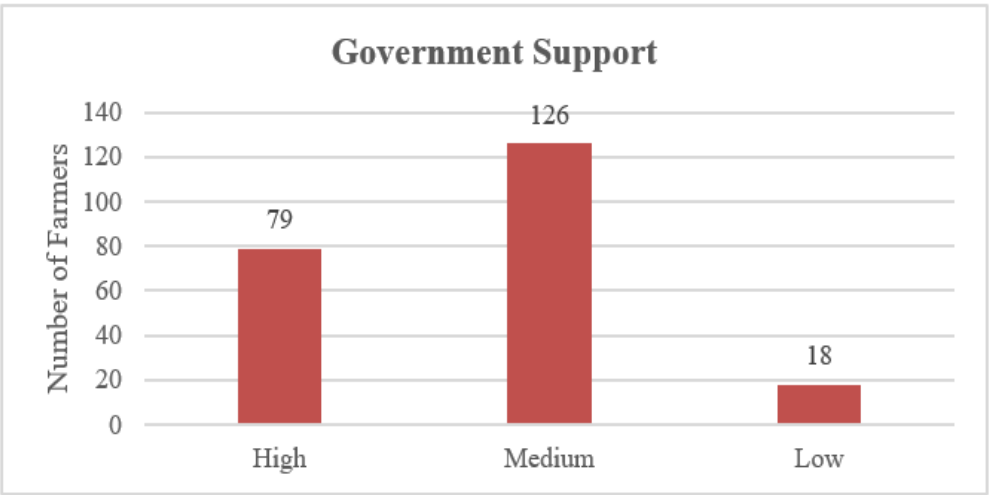
Source: Field Survey, 2025

5.7. Satisfaction with Government Services and Market Conditions

Farmers expressed moderate to high satisfaction with multiple dimensions of government services. Satisfaction with seed license approval was generally medium to high, indicating that administrative procedures are functional but could be further streamlined.

Similarly, most respondents reported moderate satisfaction with government support and subsidy programs, suggesting that assistance is beneficial but not fully adequate in addressing all farmer needs. Satisfaction with information access followed a similar pattern, with a majority rating it as medium, reflecting

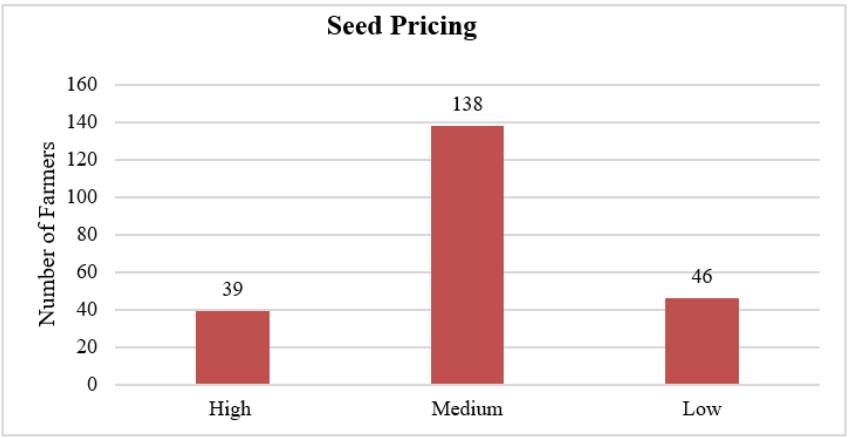
ongoing challenges related to information timeliness, accessibility, and relevance as shown below.



Source: Field Survey, 2025

Figure 4. Satisfaction on government support and subsidy in seed production and marketing

Seed pricing satisfaction emerged as a critical concern. While most farmers rated pricing satisfaction as medium, a substantial proportion expressed low satisfaction, highlighting profitability challenges and perceived inadequacy of price structures. This underscores the importance of revising pricing policies, strengthening price stabilization mechanisms, and enhancing farmers' bargaining power as reflected below.



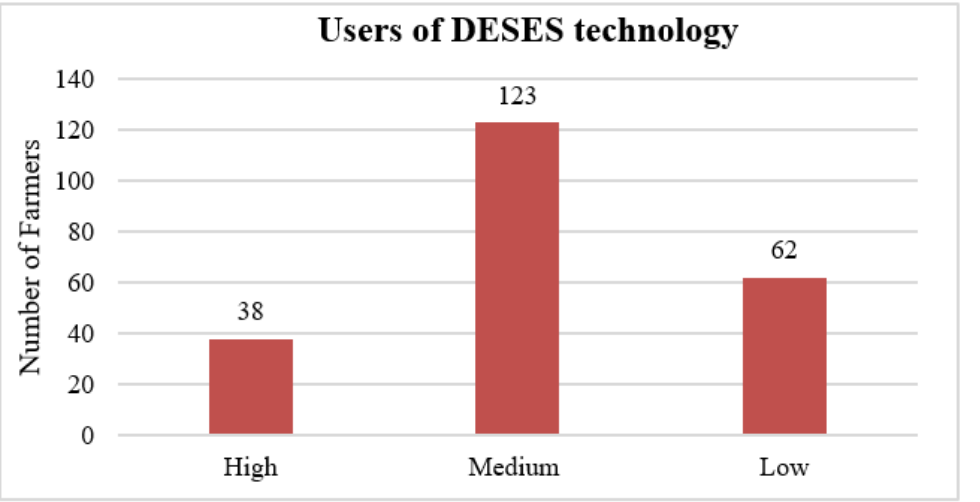
Source: Field Survey, 2025

Figure 5: Satisfaction on price of seed received

5.8. Adoption and Perception of DESES Technology

Survey results indicate moderate adoption levels. Most respondents reported medium DESES usage, while a considerable share indicated low usage due to limited awareness, technical barriers, or perceived complexity.

Finding revealed that a relatively small number of farmers i.e. 38, reported an elevated high level use of DESES; this implies that only a small number of farmers are actively utilizing DESES services to its maximum potential. On the other hand, another small number of farmers i.e. 62, reported that they use DESES services at a low level.



Source: Field Survey, 2025

Figure 6. Satisfaction on use of DESES technology

The limited use of DESES as a marketing platform suggests the need for improved training, system expansion beyond rice and wheat, and integration with market linkages to enhance adoption.

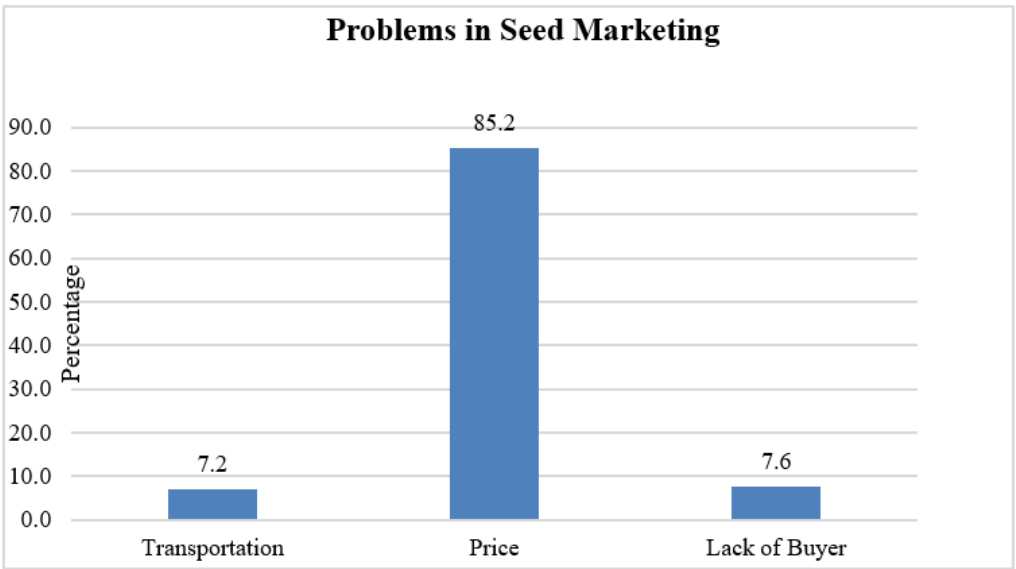
5.9. Market Channels and Seed Marketing Constraints

Government institutions serve as the dominant market outlet, with 96 percent of farmers selling their seed through government channels. Engagement with cooperatives, agro-vets, and seed companies remains minimal, highlighting limited private sector integration and market diversification.

Outside the DESES system, farmers primarily marketed seed through agro-vets (49.3 percent) and government institutions (48.8 percent), while direct engagement with seed companies remained negligible (1.9 percent). This pattern

indicates restricted competition, limited price negotiation opportunities, and dependence on institutional buyers.

Price-related challenges emerged as the most significant marketing constraint, affecting 85.2 percent of respondents. Transportation and buyer availability were relatively minor issues. These findings reinforce the central role of pricing mechanisms in determining farmer profitability and market sustainability as presented below.



Source: Field Survey, 2025

Figure 7. Major problems in seed marketing

5.10. Crop Insurance and Risk Management

Participation in crop insurance programs was exceptionally low, with 99.10 percent of farmers reporting no insurance coverage. This suggests substantial barriers related to awareness, affordability, trust, or institutional accessibility. Given the high risks associated with climate variability, pests, and wildlife damage, expanding crop insurance outreach could significantly improve risk resilience among seed producers.

5.11. Inferential Analysis: Correlation and Chi-Square Findings

Correlation analysis reveals strong interrelationships among satisfaction variables, indicating that farmers' perceptions of service quality are interconnected. Satisfaction with government support exhibited the strongest correlation with testing services and information access, suggesting that overall satisfaction is driven by service experience rather than financial incentives alone.

Table 8: Correlation analysis among the variables

Variable	Age	Education	Experience	Training	Subsidy	Sat_ License	Sat_ Testing	Sat_ Support	Sat_Info	Sat_ DESES	Sat_ Price
Age											
Education	-0.30**										
Experience	0	-0.27*									
Training	0.20*	-0.09	0.01								
Subsidy	0	0	0.05	-0.01							
Sat_License	-0.1	-0.12	0.03	0.16*	0.04						
Sat_Testing	-0.1	-0.30**	0.32**	0.08	-0.1	0.40**					
Sat_Support	-0.20**	-0.19*	0.19*	0.07	0.04	0.60**	0.63**				
Sat_Info	-0.20**	-0.19*	0.07	-0.08	0.04	0.44**	0.52**	0.63**			
Sat_DESES	-0.1	-0.35**	0.38**	-0.05	-0.02	0.18*	0.48**	0.30**	0.41**		
Sat_Price	-0.20**	-0.23*	0.05	-0.01	0	0.33**	0.40**	0.53**	0.44**	0.42**	

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level.

Farmer experience is positively correlated with seed testing satisfaction (r = 0.32) and DESES platform satisfaction (r = 0.38). Conversely, education level displays a negative correlation with DESES satisfaction (r = -0.35), indicating that more educated farmers have higher expectations for digital tools and are more critical of the platform's limitations. The strongest positive correlation is between overall government support satisfaction and official testing services (r = 0.63), as well as access to information (r = 0.63). This shows that farmer satisfaction is driven by high-quality, reliable services rather than financial handouts and financial subsidies show near-zero correlation with all satisfaction variables, proving that simply giving out inputs does not solve core market problems like poor farm-gate prices.

Table 9: Chi square test of different variables

Variable 1	Variable 2	χ^2 Statistic	p-value	df	Result (α=0.05)
Gender	Subsidy Receipt	0.8149	0.3667	1	Not Significant
Ethnicity	Training Status	4.3569	0.8236	8	Not Significant
Extension Contact	Subsidy Receipt	0.0000	1.0000	0	Not Significant
Training Status	Satisfaction Support	8.9076	0.3501	8	Not Significant
Crop Type	DESES Satisfaction	136.7045	0.0000	8	Significant

Source: Field Survey, 2025

Chi-square analysis further demonstrated that most demographic variables (gender, ethnicity, extension contact) did not significantly influence access to subsidies or training, indicating relatively equitable program coverage. However, crop type showed a strong and statistically significant association with DESES satisfaction, suggesting that digital service effectiveness varies by crop and may require crop-specific customization.

6. Conclusion

This study demonstrates that government seed policies in the Syangja district have successfully established a baseline of high input reach and extensive training coverage, they suffer from deep structural weaknesses. The complete state monopoly over seed supply and extension services creates institutional

bottlenecks and blocks private sector innovation. Furthermore, current policy mechanisms are poorly aligned with field realities: financial subsidies ignore post-harvest processing needs, the DESES digital platform lacks proper functionality for the district's dominant maize crops, and a near-total absence of crop insurance leaves smallholders highly vulnerable to severe wildlife and climate risks.

7. Policy Recommendations

- De-monopolize Extensions and Seed Channels: Create public-private-cooperative partnerships to break the state monopoly. Transition agrovets and local agricultural cooperatives from simple traders into registered, certified source-seed distributors.
- Upgrade Post-Harvest and Storage Subsidies: Shift funding focus away from simple input subsidies and toward value-addition infrastructure like community-managed RCC storage facilities and modern seed-cleaning tools.
- Adapt and Simplify the DESES System: Modify the DESES platform to include comprehensive tracking and marketing tools tailored specifically for maize varieties.
- Enforce Mandatory Insurance and Wildlife Mitigation: Address the district's top operational hazard by linking government input subsidies directly to mandatory crop insurance enrollment and introducing subsidized community fencing.
- Expand Regulatory and Legal Training: Shift extension training priorities toward seed legislation, quality control compliance, and modern marketing strategies to help smallholders transition smoothly into formal commercial markets.

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Hybrid Seed Adoption and Farmers' Perceptions of Traditional Seed Varieties in Northwestern Bangladesh

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ABSTRACT

Hybrid seeds are widely promoted to enhance agricultural productivity, yet their rapid diffusion has raised concerns about the erosion of traditional seed diversity and long-term agro-biodiversity in smallholder farming systems. This study examined hybrid seed adoption, farmer motivations, institutional support, and perceived implications for traditional seed use in northwestern Bangladesh. Primary data were collected through a structured survey of 100 farmers across five districts through a structured survey and analyzed using descriptive statistics, correlation, and regression analysis.Results indicate that 63–64% of farmers adopted hybrid seeds mainly for higher yield and increase income, rice was the most preferred hybrid crop (28.74%), followed by maize (9.58%), okra (7.78%), and potato (7.18%). Hybrid cultivation was associated with higher input intensity, as 42% of farmers applied increased levels of irrigation and fertilizers, while 59% reported severe pest and disease problems. Institutional support was limited, with 78% of respondents receiving no formal training on hybrid seed cultivation and only 8% accessing advice from agricultural extension services. In contrast, 48% of farmers considered traditional varieties more climate-resilient, compared to 27% for hybrids, reflecting their adaptability, lower input requirements, and cultural food preferences. The findings reveal a clear productivity–resilience trade-off, where hybrid seeds offer short-term yield advantages while traditional varieties contribute to agro-biodiversity conservation and climate adaptability. The results suggest the coexistence of dual seed systems shaped by economic incentives and institutional constraints. Future research should employ broader studies and evaluate biodiversity and policy interventions to better understand long term sustainability outcomes.

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1. Introduction

Seed production is fundamental to agricultural development and plays a critical role in ensuring food security, generating rural income, and promoting national economic growth. The availability and use of quality seeds are essential for achieving sustainable productivity and enhancing the resilience of farming systems (Louwaars&Manicad, 2022). Beyond their productive function, seeds serve as an important mechanism for technology transfer and constitute a vital component of agrobiodiversity conservation (Louwaars& De Boef, 2012).

Agrobiodiversity refers to the variety and variability of plants, animals, microorganisms, and genetic resources that are directly or indirectly used in agriculture and food production systems (Food and Agriculture Organization [FAO], 2019). It encompasses the diversity of crop species, varieties, farming practices, and associated ecosystems that support agricultural productivity, environmental sustainability, and resilience to biotic and abiotic stresses. The conservation of agrobiodiversity is increasingly recognized as essential for ensuring long-term food security under changing climatic and socio-economic conditions.

Traditional crop varieties represent valuable genetic resources, possessing traits such as resistance to pests and diseases, tolerance to drought and flooding, and adaptation to diverse agroecological conditions (Lazaridi et al., 2024). In Bangladesh, these varieties have been cultivated for centuries and form an integral part of the country's agricultural heritage (Hosan et al., 1970). A notable example is Rayada, a deep-water rice ecotype characterized by exceptional submergence tolerance (Bin Rahman & Zhang, 2013). These farmer-managed seed systems are typically based on seed saving, exchange, and local adaptation, enabling farming communities to maintain a diverse portfolio of crop varieties suited to varying environmental conditions and cultural preferences.

In contrast, hybrid seeds are developed by crossing genetically distinct parental lines to produce offspring with enhanced yield potential, uniformity, and other desirable agronomic traits (Chakrabarty et al., 2025). In Bangladesh, hybrid seeds have demonstrated yield advantages of approximately 15–20% over traditional varieties (Mottaleb et al., 2025). Consequently, farmers have increasingly adopted hybrid seeds, primarily driven by the pursuit of higher yields, improved market opportunities, and policy support.

The expansion of hybrid seeds has significantly transformed traditional seed systems. Historically, farmers relied on locally adapted varieties and

informal seed networks based on seed saving, exchange, and community-level management. However, hybrid seeds generally require farmers to purchase new seeds each growing season because the desirable characteristics of first-generation hybrids are not reliably maintained in subsequent generations. This shift has gradually increased farmers' dependence on formal seed systems, commercial seed suppliers, and external agricultural inputs. In Bangladesh, the adoption of hybrid rice accelerated during the 1990s, facilitated by government initiatives, technologies released by the Bangladesh Rice Research Institute (BRRI), and collaborations with the International Rice Research Institute (IRRI) (Mottaleb et al., 2015a). Between 1998 and 2010, a total of 75 hybrid rice varieties were approved for cultivation, including 60 originating from China, five from India, one from the Philippines , four developed by BRRI, and five introduced by private companies (Spielman et al., 2012a). Although initial adoption remained limited, with approximately 1% of farmers using hybrid seeds during the early stages (Azinu, 2014), hybrid rice expanded to cover around 6.8% of the total rice cultivation area in Bangladesh by 2010 (Spielman et al., 2012b).

While the expansion of hybrid seeds has contributed to increased agricultural productivity, it has also generated concerns regarding the decline of traditional seed systems and the erosion of agrobiodiversity. The widespread replacement of traditional varieties with a limited number of commercially available hybrids can reduce on-farm genetic diversity and increase the vulnerability of agricultural systems to pests, diseases, climate variability, and market disruptions (Foysal et al., 2021). Furthermore, reliance on hybrid seeds is often associated with increased dependence on external inputs, including fertilizers and pesticides, higher seed costs, and reduced farmer autonomy over seed management (Macharia et al., 2010). Similar concerns have been reported in neighboring countries, where dependence on imported hybrid seeds has raised issues related to production costs, local seed sovereignty, and genetic erosion (Bist et al., 2025).

Farmers perception is important in the choice of seed selection and conservation of traditional crop varieties(Edilegnaw Wale, 2017). Although Hybrid seeds are popular for their higher yield potential and market demand.Many farmers still prefer traditional varieties for their better taste, adaptation to local conditions, lower input needs and the possibility to save seeds for the next season. However, the replacement of traditional varieties is often driven by factors such as increasing market competition, government support and availability of commercial hybrid seed(Bist et al., 2025).These perceptions are important for explaining the seed choice behaviour of farmers and assessing for the impact of hybrid seed adoption on the conservation of agrobiodiversity.

Previous studies indicate that hybrid seed adoption is influenced by factors such as farm size, access to credit, market integration, and rural infrastructure (Mottaleb et al., 2015b). Although it is widely recognized that hybrid adoption may contribute to declining varietal diversity, much of the existing literature relies on theoretical assumptions or indirect evidence rather than localized empirical investigations. Studies such as Pautasso et al. (2013) have highlighted the biodiversity risks associated with varietal replacement; however, the direct relationship between hybrid seed adoption and measurable agrobiodiversity loss remains insufficiently explored, particularly at regional scales.

To address this research gap, the present study integrates farmer survey data, seed inventory assessments, and spatial analysis to examine the decline of traditional seed varieties and its relationship with hybrid seed adoption in northwestern Bangladesh, specifically in the districts of Joypurhat, Naogaon, Natore, Pabna, and Rajshahi. By providing empirical evidence from a major agricultural region, this study contributes to a better understanding of how seed system transformation influences agrobiodiversity and farmers' seed management practices and to analyze the correlation between farmers' socio-economic perceptions (e.g., yield preferences, market pressure) and the calculated agrobiodiversity scores (H') and know the varietal richness and diversity.

The findings of this research are expected to support the achievement of the United Nations Sustainable Development Goals (SDGs), particularly SDG 2.4 and SDG 2.5. By identifying pathways to balance productivity gains from hybrid seeds with the conservation of traditional varieties, the study contributes to SDG 2.4, which aims to ensure sustainable food production systems and promote resilient agricultural practices that maintain ecosystems and strengthen adaptation to climate change. Furthermore, by documenting the status and decline of traditional seed varieties and highlighting the importance of conserving locally adapted genetic resources, the study directly supports SDG 2.5, which focuses on maintaining the genetic diversity of seeds, cultivated plants, and farmed animals. Ultimately, the research seeks to inform evidence-based policies and interventions that foster both agricultural productivity and the long-term conservation of Bangladesh's agricultural biodiversity.

2. Methodology

2.1. Study Area

This study was conducted in the districts of Joypurhat, Naogaon, Natore, Pabna and Rajshahi in northwestern Bangladesh. The five districts were selected because they represent major agricultural production zones of northwestern

Bangladesh where both hybrid and traditional varieties coexist, allowing assessment of varietal replacement and agrobiodiversity change.

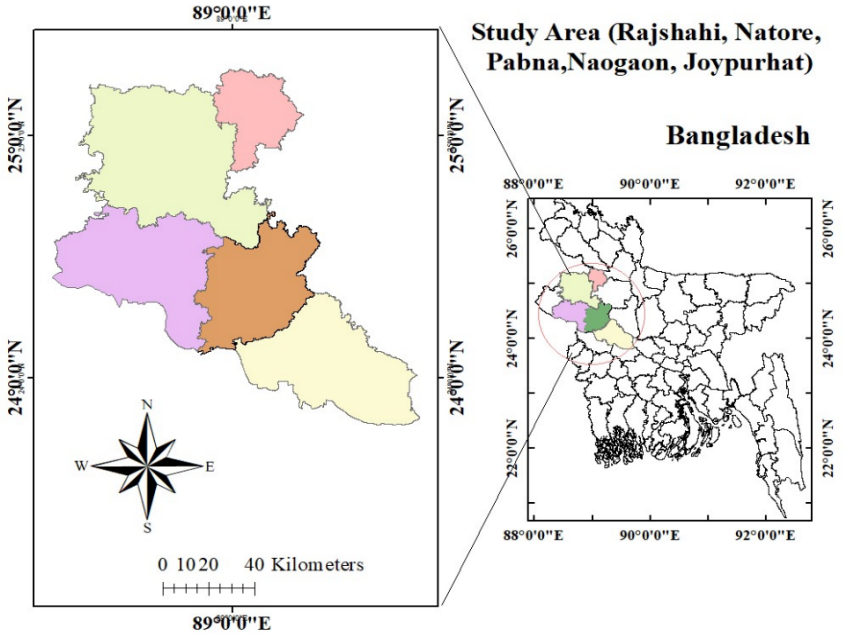

Figure 1. Map of Study Area

2.2. Research framework

This study applied a mixed-methods approach to assess the impact of hybrid seed adoption on agrobiodiversity.

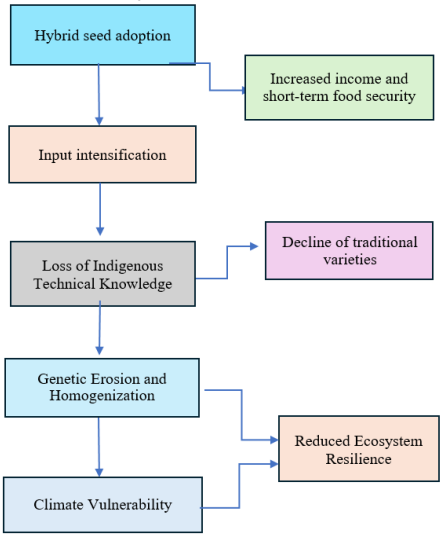

Figure 2. Social-Ecological Framework of Hybridization Risk

2.3. Sampling Procedure

A multistage sampling procedure was used in this study. Initially, five districts of northwestern Bangladesh—Rajshahi, Naogaon, Natore, Pabna, and Joypurhat—were purposively selected due to the widespread cultivation of hybrid crops and the continued existence of traditional crop varieties in these areas.

In the second stage, a total of 40 villages were selected from the study districts with the assistance of local agricultural extension personnel. The selected villages represented different levels of hybrid seed adoption and farming practices.

The respondents were chosen to capture a broad range of farming experiences and perceptions regarding hybrid seed adoption and its implications for agro-biodiversity.

2.4. Sample size

100 farmers were randomly selected from village clusters for face-to-face interviews. The sample size was considered suitable given the exploratory nature of the study and logistical limitations of time.

2.5. Data Collection and Quality Control

• Collection period:

Primary data were collected between 10 July and 10 August 2025 during the monsoon crop season.

• Questionnaire survey:

The questionnaire was reviewed by three agricultural research experts and pre-tested with 15 farmers outside the study sample. Necessary modifications were made based on respondent feedback.

• Focus Group Discussions (FGDs):

Five FGDs were conducted, one in each district, involving 10–15 participants including farmers, extension officers, and local agricultural experts. Discussions were audio-recorded, field notes were taken, and thematic summaries were prepared for analysis.

2.6. Data analysis

Data were analyzed using SPSS for statistical analysis and ArcGIS (version 10.8) for spatial mapping. Pearson correlation analysis was used to examine relationships among key variables, while the chi-square test was applied to assess associations between categorical socio-economic and institutional factors.

2.7. Potential Sources of Bias

The study considered potential sources of bias that could influence the findings. Recall bias may have occurred because respondents relied on memory when reporting past farming practices and seed-use histories. Perception bias may also have affected responses regarding the benefits and risks of hybrid seed adoption. To minimize these biases, cross-checking questions were incorporated into the survey, and survey findings were triangulated with FGD results and information obtained from local agricultural extension personnel

2.8. Ethical Consideration

Participants were clearly informed about the objectives of the study. Assurance was provided that the collected information would be used solely for research purposes and that all personal information would be kept confidential. Throughout the data collection process, participants were appreciated for their time and valuable opinions, and they were encouraged to express their views freely. Standard ethical principles for conducting research with farmers were strictly maintained to ensure trust, transparency, and fairness in the study.

3. Result and Discussion

3.1. Farmers' perceptions of yield performance in hybrid and traditional varieties

The pie chart (Figure 1) shows that most farmers preferred hybrid seeds mainly for their higher yield performance, while a smaller group favored traditional varieties for their superior taste. A few respondents expressed no specific preference. The yield advantage was the most influential factor, and taste preference ranked lowest in relative importance (R), indicating that productivity remains the key driver in farmers' seed selection decisions. Sensory attributes such as taste and grain quality tend to play a secondary role in varietal adoption when yield performance and productivity gains are prioritized by farmers (Ghimire et al., 2015). Although many farmers believe hybrids have superior appearance and aroma compared to traditional varieties, only a small proportion feel that their taste is better than that of traditional types (Spielman et al., 2021). Yield is prioritized over taste and quality by farmers, limiting the understanding of comprehensive adoption factors. The effects of hybrids on taste, quality, and farmer preferences alongside productivity should be explored in future studies.

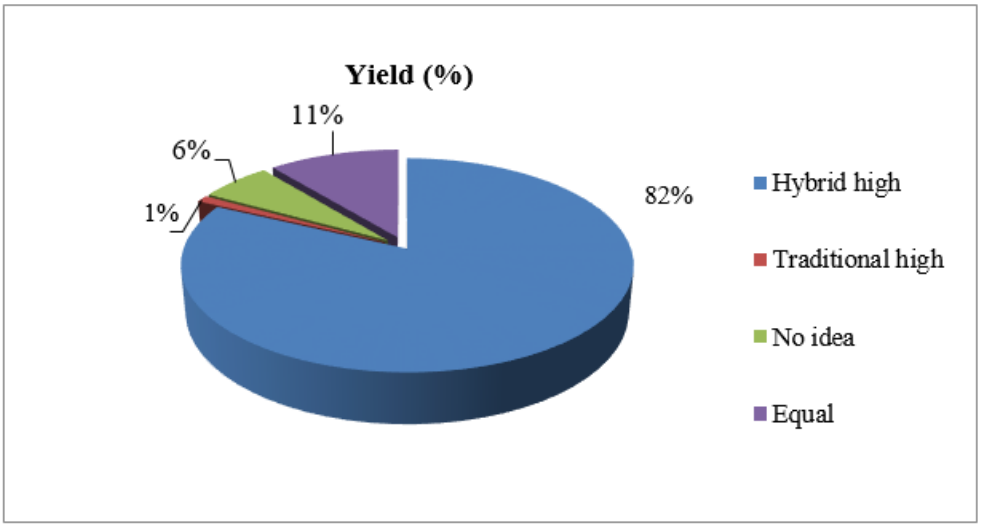

Figure 3. Yield comparison of hybrid and traditional varieties

3.2. Suitable seeds for adverse climatic condition

When selecting seeds for challenging climates, a majority of farmers (45%) favored hybrids due to their higher yield and resilience (Figure 2). Conversely, a significant 34% chose traditional seeds, valuing their minimal input requirements. This observation contrasts with other research that indicated a much larger adoption rate (exceeding 65%) of specific climate-resilient modern varieties in coastal regions (Nayak et al., 2022). This implies that local conditions play a crucial role in these decisions. Moreover, while the data reveals only 11% of farmers employing a mixed approach, numerous studies suggest that in regions with high agrobiodiversity, over 40% of farmers frequently utilize different seed varieties (Pautasso et al., 2013).A declining tendency toward varietal diversification may reduce the resilience of local seed systems and increase vulnerability to climatic and environmental shocks (Hampton et al., 2016).This indicates that the area we investigated may be drifting away from diverse agricultural practices. This study is limited because it focuses on just one area and relies on survey data, which may not include all factors affecting seed choice. The low adoption of mixed and climate-resilient varieties points to a gap in understanding how farmers make decisions. Future research should include studies from multiple locations over time. It should also consider environmental, socio-economic, and market factors to better explain seed selection patterns.

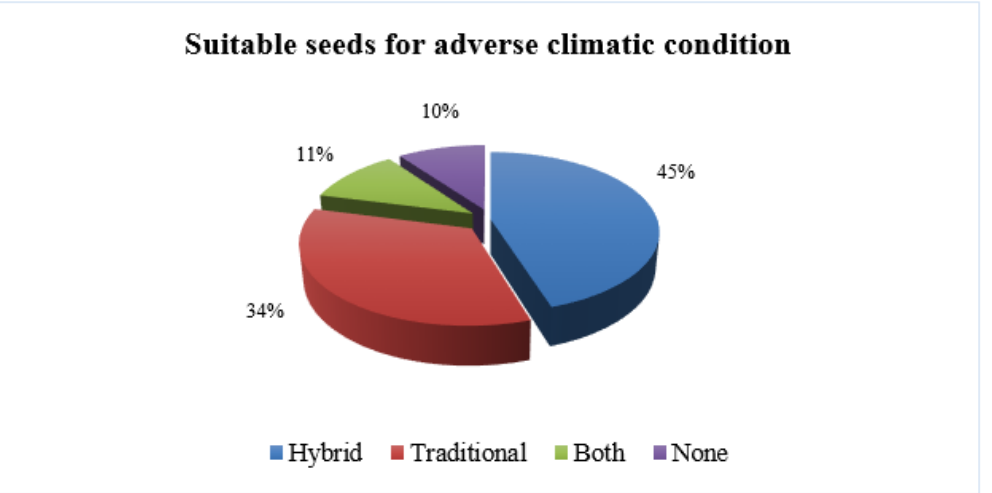

Figure 4. Suitable seeds for adverse climatic condition

3.3. Age, Educational Qualification, Experience in agriculture field

The analysis of correlation (Table 1) indicated a negative correlation between Age and Educational Qualification ($r = -0.337$). Notably, we did not find a significant correlation between Education and Agricultural Experience ($r = -0.185$, $p=0.065$). This finding differs from another study that reported a significant positive correlation ($r = 0.28$, $p < 0.01$) between education levels and the effectiveness of adopting agricultural technology in China (Wang et al., 2020).The findings reveal no such relationship in this context, implying that the local socio-economic factors may obstruct the usual positive association between education and efficient farm management, potentially due to a lack of relevant agricultural training within formal education. In many smallholder systems, agricultural experience is primarily accumulated through hands-on practice and intergenerational knowledge transfer rather than through formal education pathways (Lazaridi et al., 2024). The study relies on correlations, which don't capture the socio-economic or institutional factors that influence education and farming experience. The lack of a significant connection points to a gap in understanding why education does not enhance farm management in the area. Future research should use a mix of methods, including multivariate and qualitative approaches, to investigate barriers like limited agricultural training and socio-economic challenges.

Table 1. Age, Educational Qualification, Experience in agriculture field

Correlations				
		Age	Educational Qualification	Experience in agriculture field
Age	Pearson Correlation	1	-.337**	.568**
	Sig. (2-tailed)		.001	.000
	N	100	100	100
Educational Qualification	Pearson Correlation	-.337**	1	-.185
	Sig. (2-tailed)	.001		.065
	N	100	100	100
Experience in agriculture field	Pearson Correlation	.568**	-.185	1
	Sig. (2-tailed)	.000	.065	
	N	100	100	100

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

a. Predictors: (Constant), Experience in agriculture field, Age

b. Dependent Variable: Land size

3.4. Association of age, farming experience, and land size

A regression analysis indicated no significant correlation between the size of land and the age of farmers (B=0.011, p=0.222) or their agricultural experience (B=0.002, p=0.857), with the model accounting for merely 2.7% of the variance (R^2=0.027). This is in contrast to other research, which demonstrated that hybrid adopters had larger farms (1.22 ha compared to 0.39 ha, p<0.01) (Mottaleb et al., 2015). Additional studies have also revealed a positive association between age and farm size (β=0.15, p<0.05) (Yan et al., 2022). The findings suggest that land access in Northwestern Bangladesh is influenced more by structural factors than by the demographics of the farmers. Structural and institutional arrangements, including land tenure and inheritance systems, often play a more decisive role in determining landholding size than farmers' age or experience (Louwaars&Manicad, 2022). It misses structural and institutional factors that might better explain landholding patterns. The absence of significant relationships, which contradicts studies that show links between farm size, age, and technology adoption, highlights a gap in understanding why demographics do not affect land access in this context. Future research should include variables such as land tenure systems, inheritance practices, and socio-economic constraints. It should also use broader, multi-regional models to identify the structural drivers that shape land distribution.

Table 2. Regression analysis age, experience and land size

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.163[a]	.027	.007	.64226332

a. Predictors: (Constant), Experience in agriculture field, Age

b. Dependent Variable: Land size

Model		Sum of Squares	do	Mean Square	F	Sig.
1	Regression	1.094	2	.547	1.327	.270[b]
	Residual	40.013	97	.413		
	Total	41.107	99			

a. Dependent Variable: Land size

b. Predictors: (Constant), Experience in agriculture field, Age

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.163	.335		.486	.628
	Age	.011	.009	.150	1.230	.222
	Experience in agriculture field	.002	.010	.022	.180	.857

a. Dependent Variable: Land size

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.4398650	.8772346	.6905020	.10514039	100
Residual	-.69278079	2.50166082	.00000000	.63574271	100
Std. Predicted Value	-2.384	1.776	.000	1.000	100
Std. Residual	-1.079	3.895	.000	.990	100

a. Dependent Variable: Land size

3.5. Received training and the location

The table shows that 78% of farmers had received no formal training in hybrid seed cultivation, indicating a major gap in capacity building. Among those trained, Agricultural Extension Officers or unspecified organizations were the most common sources (8%), while BRRI (2%), BADC (2%), AIS (1%), and internet platforms (1%) were less frequent. These results highlight the limited reach of formal training and the need to strengthen extension services and knowledge dissemination, practical, hands-on knowledge transfer can often be more influential than formal training in improving farmers' adoption of hybrid seeds (Chakrabarty et al., 2025). Nonetheless, previous studies reveled that knowledge rather than formal training may be the key driver of adoption, suggesting that improving farmers' practical understanding of hybrid seed cultivation is as important as expanding formal training programs (Sarma et al., 2022). Farmers reported that the majority of them had not received any formal training on hybrid seed cultivation, revealing a substantial weakness in current capacity development efforts. The limited involvement of key institutions such as BRRI, BADC, and AIS further highlights the need for more structured and accessible training opportunities.

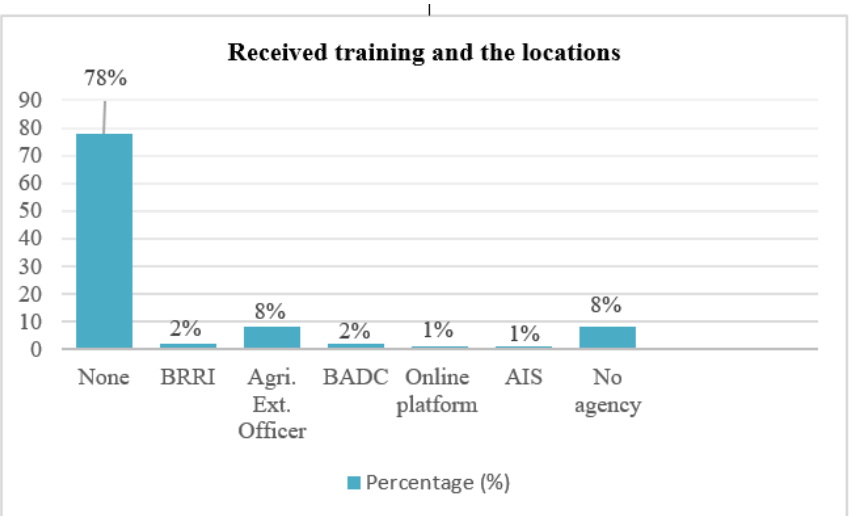

Figure 5. The location of training

3.6. Factors of hybrid seed for the conservation of agrobiodiversity

The study shows that 64% of farmers choose hybrid seeds mainly for higher yield. Food security accounts for 13.6%, while disease resistance plays a role for 11.2%. Other reasons include increased food production at 6.4%, harvesting benefits at 2.4%, food demand conservation at 1.6%, and suitable conditions at 0.8%. These findings emphasize that productivity drives adoption more than ecological or

conservation concerns. Yield is the primary motivator for hybrid seed adoption, often outweighing other factors such as ecological benefits or disease resistance (Bist et al., 2025). In contrast, various studies highlight more diverse reasons for adoption. Several studies found that only 42% of farmers in Nepal adopted hybrids primarily for yield (Ghimire et al., 2015). Disease resistance influenced 21%, nearly double the 11.2% we observed. Similarly, several studies reported that food security concerns motivated 35-40% of adopters in India and the Philippines, which is much higher than our 13.6%. This suggests that farmers in areas with greater food insecurity depend on hybrids for stability(Pandey, 2010). Environmental factors also vary significantly. These differences indicate that farmers in the study area focus on short-term yield benefits, while farmers in other regions consider broader risks, ecology, and food security. Improving extension support may help connect hybrid adoption with agro-biodiversity conservation goals. Farmers reported that they adopt hybrid seeds mainly for higher yield, placing productivity above other considerations. Their limited mention of factors such as food security, disease resistance, and environmental suitability suggests a narrow understanding of the broader agronomic and sustainability benefits of hybrid seed use.

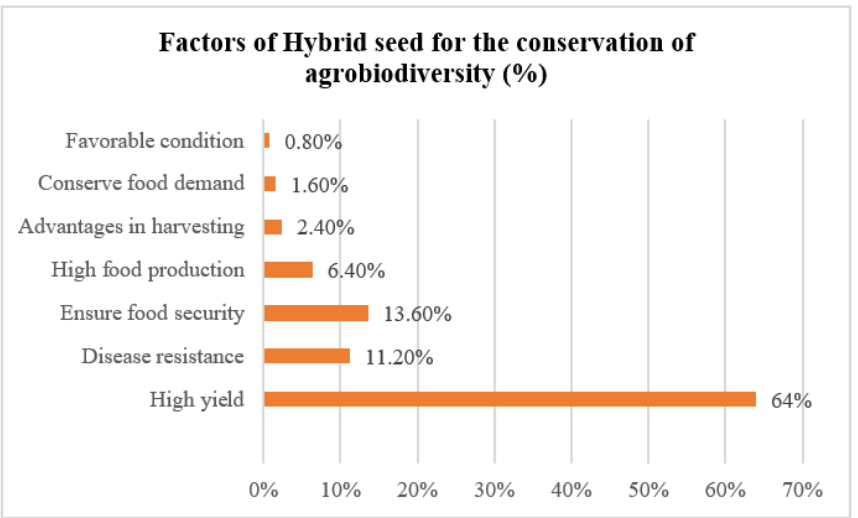

Figure 6. Factors of Hybrid seed for the conservation of agrobiodiversity

3.7. Climate-friendly varieties

The findings indicate that farmers perceive traditional varieties as significantly more climate-friendly, with 48% supporting this view, compared to only 27% for hybrids. This stands in stark contrast to studies conducted in areas with robust breeding initiatives. Few studies demonstrated that certain enhanced alfalfa hybrids retained up to 90% of their biomass yield even under extreme

water restrictions, surpassing traditional varieties(Molero et al., 2019). Hybrid varieties developed through breeding often show better drought tolerance and stable yields (Louwaars&Manicad, 2022). Furthermore, previous studies also highlighted that advancements in breeding for climate resilience have resulted in varieties that can achieve yields 20-30% higher under drought conditions compared to local cultivars in select temperate regions (Hampton et al., 2016). The predominant preference for traditional seeds observed in our study area underscores a notable limitation of hybrid varieties available in Bangladesh, which have yet to convincingly demonstrate improved climate adaptability to farmers. The statement that natural disasters rapidly harm hybrid seeds. In a similar vein, the finding that hybrids need more pesticides may differ depending on the area and farming methods, resulting in an inadequate evaluation of their environmental impact. Furthermore, a thorough understanding of the environmental effects of hybrid seed farming is limited because the study does not completely assess long term ecological effect such as soil health and fertility.

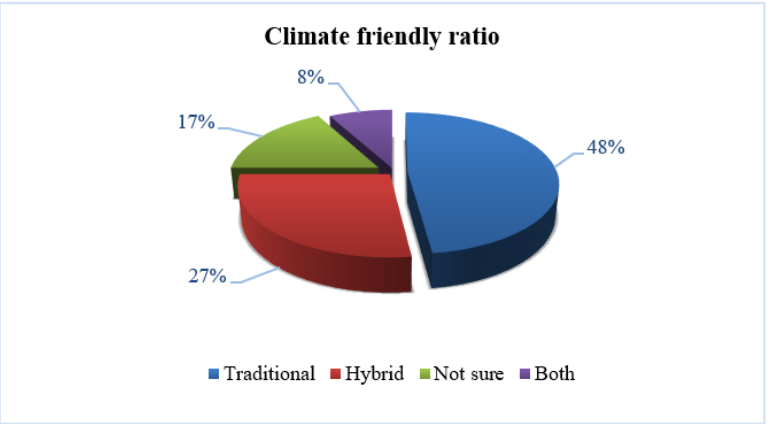

Figure 7. Climate friendly ratio between traditional and hybrid

3.8. Effect in food culture and crop diversity for hybrid seed on age

This study shows that the prevalent belief of "high yield but inferior taste" was common across all age demographics. This perspective contradicts findings suggesting a significant generational shift in preferences. For instance, A study noted that in African contexts, younger farmers frequently drove the adoption of new hybrid seeds, resulting in a 40% quicker turnover rate of varieties in communities with strong youth participation(Sperling & Mcguire, 2010). Generational differences in adoption may be influenced by access to information and exposure to new varieties (Louwaars&Manicad, 2022). Our data does not reveal a distinct generational gap. Instead, the shared acknowledgment of the taste compromise indicates that cultural and culinary values persist as a strong,

unifying concern that transcends age groups, serving as a more effective barrier to the full acceptance of hybrids than previously observed in other regions. The primary downside is that it is based on participant views rather than actual taste testing, so assertions that hybrids taste worse could be the result of cultural preference or subjective bias. For more trustworthy findings, empirical taste assessments should be used in future studies.

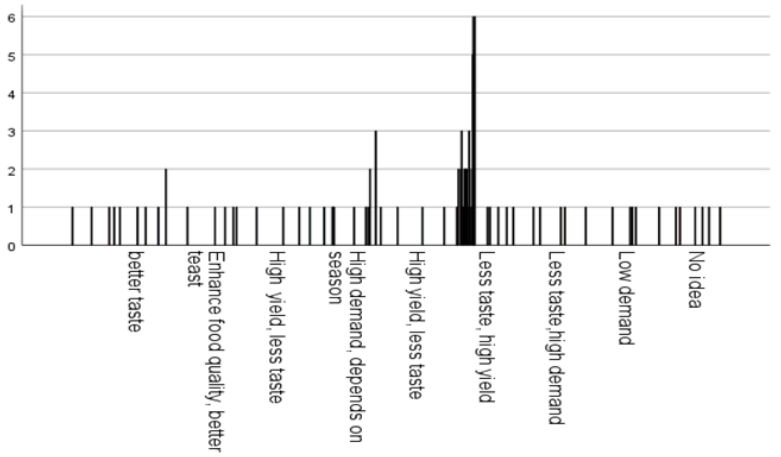

Figure 8. Effect in food culture and crop diversity for hybrid seed on age

Table 3:Case Processing Summary

Valid		Missing %		Total		
	N		Percent	N	%	
Effect in food culture and crop diversity for hybrid seed * Age	100	49.0%	104	51.0%	204	100.0%

3.9. Disease and Pest problem for hybrid seed in study area

A majority of farmers, 59%, reported encountering significant issues with pests and diseases related to hybrid seeds. The major pest of crop varieties like rice yellow stem borer, brown planthopper, rice hispa, cutworm, aphids etc are responsible for crop loss. Besides these, major diseases like rice blast, BLB, wheat blast, jute stem rot, late blight of potato, powdery mildew etc. are majorly harmful for crops which are also responsible for maximum crop loss. This elevated level of biotic stress presents a far more negative outlook than indicated in other studies. Previous study revealed that while pest pressures existed, farmers cultivating high-yielding varieties in certain regions of Bangladesh

reported that effective pesticide application reduced perceived crop losses to below 20%(Ali et al., 2020). Limited training in integrated pest management can exacerbate pest problems in hybrid cultivation (Louwaars& De Boef, 2012). The serious challenges highlighted by our farmers, with 59% experiencing high problems compared to the managed losses of under 20% reported elsewhere, emphasizes that the difficulty lies not only with hybrid technology itself but also with a combination of highly susceptible varieties available in our study area and a critical deficiency in training for integrated pest management, resulting in uncontrolled infestations. The reliance on farmer self-reports in a specific region, possible perception bias, and variations from other studies that restrict direct comparisons limit research findings on pest and disease issues in hybrid seeds. Firm judgments about causality cannot be drawn from observational data highlights the importance of conducting empirical research.

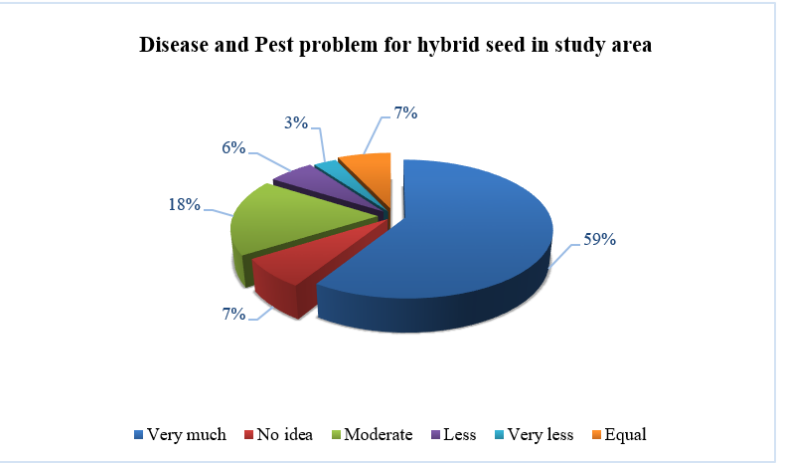

Figure 9. Disease and Pest problem for hybrid seed in study area

4. Conclusion

This study focused on the perceptions of farmers towards hybrid seeds and traditional varieties in the areas of inputs, crop preferences, training, institutional support, adoption and constraints in productivity, climate adaptability and pest or disease incidence. The majority of the farmers (63-64%) adopted hybrid seeds mainly for higher yields and income, with rice as the most preferred hybrid crop. However adoption was not uniform as 78% of the farmers did not receive training and 59% identified pest and disease susceptibility as a major hindrance and mostly are pest and disease resistant along with drought and saline tolerant varieties. Traditional seeds were more climate adaptable (48%) than hybrids (27%), which is consistent with the continued reliance on conventional varieties for resilience, lower input requirements and cultural food traditions.

Overall, the findings indicated that while hybrid seeds play an important role in improving agricultural productivity and farm income, traditional seed varieties are still crucial for climate resilience, local adaptation and the conservation of agricultural biodiversity. The sustainable and resilient agricultural future in Bangladesh requires balanced adoption of improved hybrid seeds and conservation of traditional seed varieties through increased awareness of farmers, active community participation, supportive policies and effective seed management practices.

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