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Deciphering the Constraints Perceived by Farmers in the Adaptation of Climate-Resilient Technologies in the NICRA Village of Jharsuguda District in Odisha, India: RBQ and Kendall's Coefficient of Concordance Approach

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ABSTRACT

Climate change poses significant challenges to agriculture, necessitating the adoption of climate-resilient technologies. Rising global temperatures, a direct consequence of climate change, negatively impact agricultural productivity, threaten farmers' livelihoods, and food availability. The studies suggest that this warming trend could lead to a 4.5-9% drop in crop yields, depending on how severe and widespread the temperature rise is. Since agriculture contributes about 17.4% to India's GDP, this decline in production could cost the economy up to 1.5% of its GDP each year. Thus, it has become crucial to adopt climate-resilient agricultural technologies in the wake of the current agro-ecological context. However, predominantly various socio-personal, financial, and technological constraints hinder their adoption. With this background, the current study was undertaken using an ex-post facto research design to uncover and quantify the constraints faced by the NICRA (National Innovations in Climate Resilient Agriculture) farmers in Jharsuguda district of Odisha, India. The study identified these constraints using the Rank-Based Quotient (RBQ) method and ranking. The findings revealed that the strongest socio-personal constraint was a preference for conventional practices (RBQ = 84.44%). The lack of credit or capital (RBQ = 89.44%) ranked highest in financial constraints. Among technological constraints is the difficulty in implementing climate-resilient technologies (RBQ = 87.78%). The Rank-Based Quotient (RBQ) method, supplemented by Kendall's coefficient of concordance [$W = 0.64$, χ^2 (2) = 77.00, $p < 0.001$], indicated strong consensus in rankings. The data were collected from 60 NICRA farmers through structured interviews. The results highlight the need for targeted interventions such as enhanced training, financial support, mechanization access, and timely input supply to promote climate-resilient agriculture. Addressing these impediments will facilitate a sustainable and adaptive farming system in the region.

INTRODUCTION

Climate change poses a significant threat to agriculture and food security, making it a key priority under the United Nations within the Millennium Development Goals (Vinaya & Shivamurthy, 2021). Its effects are felt worldwide, but Countries like India, where agriculture sustains most of the population, are particularly vulnerable. Rising global temperatures directly result from climate change, harming agricultural productivity and jeopardizing farmers' livelihoods and food availability (Thakor & Joshi, 2022). The increasing frequency and intensity of extreme weather events, such as droughts and floods, have profound implications for food security and the livelihoods of millions of farmers. The growing urbanization and industrial activity, coupled with climate change, have resulted in an alarming level of water shortage globally. Nearly one-fifth of the world's population lives in areas of water scarcity (Kohli & Grover, 2024). The risk can be minimized through structural and non-structural interventions, mass empowerment, planning strategy, and advanced awareness (Mallik et al. 2023b).

India has experienced notable climatic shifts over the past century, including a temperature rise of approximately 0.7°C, leading to more unpredictable and severe weather patterns. The Indian monsoon, crucial for the country's agriculture, has exhibited significant changes, with a gradual decline in rainfall over central India since the 1950s and a threefold increase in widespread extreme rainfall events between 1950 and 2015 (Harikrishna et al. 2021). The farmers perceive climate variability and identify increasing temperatures. Due to rain delays, the soil dryness increases, which is a critical factor affecting cultivation (Ratakonda et al. 2024). Rising temperatures are expected to have a major impact on agriculture in India. According to IPCC (2007), Since 2020 temperature increased by 0.5–1.2°C, 0.88–3.16°C by 2050, and 1.56–5.44°C by 2080. Studies suggest that this warming trend could lead to a 4.5–9% drop in crop yields, depending on how severe and widespread the temperature rise is (Naik et al. 2025). Since agriculture contributes about 17.4% to India's GDP, this decline in production could cost the economy up to 1.5% of its GDP each year. Recognizing the seriousness of the issue, the Indian government has placed greater emphasis on research and development to help farmers adapt to climate change and protect agricultural productivity (NICRA Annual Report, 2021).

India's National Action Plan on Climate Change has identified agriculture as one of the eight key national missions, aiming to sustain food production amidst climate change while promoting adaptation and mitigation strategies. In response, the Indian Council of Agricultural Research (ICAR) launched the National Initiative on Climate Resilient Agriculture (NICRA) in 2011, later renamed National Innovations in Climate Resilient Agriculture under the XII Five-Year Plan (Rehman et al. 2021). NICRA focuses on enhancing agricultural resilience through research, technology demonstrations, financial support, and capacity building. While the initiative has introduced climate-resilient technologies in project villages, their adoption remains limited, reducing overall climate resilience. Recognizing these challenges, this study aims to analyze the constraints hindering farmers' adoption of climate-resilient technologies and explore strategies to improve implementation (Rao et al. 2016).

The adoption of climate-resilient agricultural technologies remains constrained by interconnected behavioral, economic, and institutional barriers. Farmers' deep-rooted resistance to abandoning traditional practices emerges as the most persistent obstacle, often outweighing climate vulnerability perceptions (Jasna et al. 2015). This behavioral inertia interacts with structural challenges, including acute shortages of specialized farm implements, skilled labor deficits, and prohibitive upfront costs for essential infrastructure like drip irrigation and water storage systems (Mohokar et al. 2019). Region-specific studies reveal how these barriers manifest differently across agroecological zones - while pest outbreaks and flood vulnerabilities dominate in deltaic regions (Majumder et al. 2020), semi-arid zones face compounded stresses from erratic input markets and institutional failures (Naik et al. 2022). Critically, extension system weaknesses appear universal, with poor Custom Hiring Center operations, untimely subsidy disbursements, and training programs that fail to account for farmers' literacy levels and technical comprehension (Shende et al. 2023). The constraints demonstrate spatial heterogeneity, with non-NICRA villages experiencing more severe knowledge and resource gaps (Acharitha et al. 2022), indicating that place-specific policy responses are necessary. Emerging evidence highlights how cultural perceptions and risk aversion mediate these adoption decisions, requiring nuanced behavioral interventions alongside technological solutions (Shanabhoga et al. 2023). Therefore, a variety of adaptation strategies to mitigate the negative effects of climate change and maintain their livelihoods are urgently needed (FAO, 2009). Adaptation in the agriculture sector means addressing the negative impacts of climate change and making use of the opportunities that often come with a changing climate (Loria & Bhardwaj, 2016). The existing literature has documented various adoption constraints; however, a critical methodological gap remains in systematically quantifying and prioritizing these barriers using robust statistical approaches. The proposed study addresses this gap by employing the Rank-Based Quotient (RBQ) and Kendall's Coefficient of Concordance to empirically rank constraints faced by farmers in the NICRA villages of Jharsuguda district, Odisha, thereby enabling targeted policy interventions for accelerated technology adoption.

Despite the extensive studies on constraints faced by farmers in adopting climate-resilient technologies, limited research focuses specifically on NICRA-adopted villages in Jharsuguda, Odisha. Most studies have addressed general challenges at the national or state level, but an in-depth, localized analysis of socio-personal, institutional, and technological constraints in NICRA villages of Jharsuguda is lacking. Furthermore, the role of extension services and government support in overcoming these constraints remains underexplored. Hence, the present study aims to document the constraints faced by farmers from the NICRA-adopted village during the adoption process of Climate-resilient technologies in the Jharsuguda district of Odisha. The study's findings are based on a small sample (n = 60) from a single NICRA village, which limits generalizability. As a single-researcher, social science study, results are shaped by human behavior and localized interactions, making broad abstraction difficult. Future research with larger, multi-site samples is recommended.

2. MATERIALS AND METHODS

The research was carried out using an ex-post facto research design (Das et al. 2024). The Jharsuguda district of Odisha was selected purposively as the locale for the study. The farmers in Jharsuguda district, Odisha, confront several climate-induced challenges impacting food production. These challenges include early-season droughts in rainfed areas, untimely and unseasonal rainfall affecting both rainfed and irrigated lands, industrial accidents, and extreme events such as heatwaves, droughts, and floods. To address these issues, the Krishi Vigyan Kendra (KVK) in Jharsuguda implemented the National Innovations in Climate Resilient Agriculture (NICRA) project in the villages of Bhoimunda and Tharkaspur. Purposive and random sampling technique was used for this study. From the Jharsuguda block, one village, Tharkaspur, was selected purposively as the location where the NICRA project was functioning. The respondents were selected through simple random sampling, thus amounting to a sample size of 60 respondents from the NICRA village.

A structured and pretested interview schedule was developed for the study. It was used to assess the socio-economic profile of the respondents, along with identifying and quantifying the constraints faced by farmers. These constraints were categorized into socio-personal, financial, and technological domains. The conceptual model of the research is illustrated in Figure 1.

Each constraint was assessed based on the hindrance experienced during the adaptation. The constraints were quantified using a three-point continuum scale of “severe”, “moderate”, and “low” constraints with scores assigned as 3, 2, and 1, respectively. The Rank-Based Quotient (RBQ) method was utilized to systematically compile, organize, and analyze the collected data. This approach involved ranking the identified constraints based on respondents' feedback and calculating the RBQ using the formula (Sabarathnam, 1988).

Constraints with higher RBQ scores were considered more significant, reflecting the severity assigned by respondents. Rank-Based Quotient (RBQ) was calculated as follows.

$$RBQ = \frac{\sum_{i=1}^{n} fi(n+1-i) \times 100}{N \times n} \quad \dots (1)$$

where f_i = frequency of the respondent for the i^{th} rank of the problem

N = total number of respondents

n = Number of ranks

In addition, a comparison of various broad constraints used in the specific study was done by using the formula of Kendall's coefficient of concordance approach (Kendall and Smith, 1939). As ranks were tied between judges in the present study, below formula is appropriate to measure correction factors between tied ranks (Mallik et al., 2023a).

$$W = \frac{12 \sum_{i=1}^{n} (R_i - \bar{R})^2}{m^2 (n^3 - n)} \qquad \ldots (2)$$

m = number of respondents (farmers) = 60

n = number of items (constraint categories) = 3

Ri = total rank sum for the i^{th} category

$\bar{R}$ = mean of the rank sums

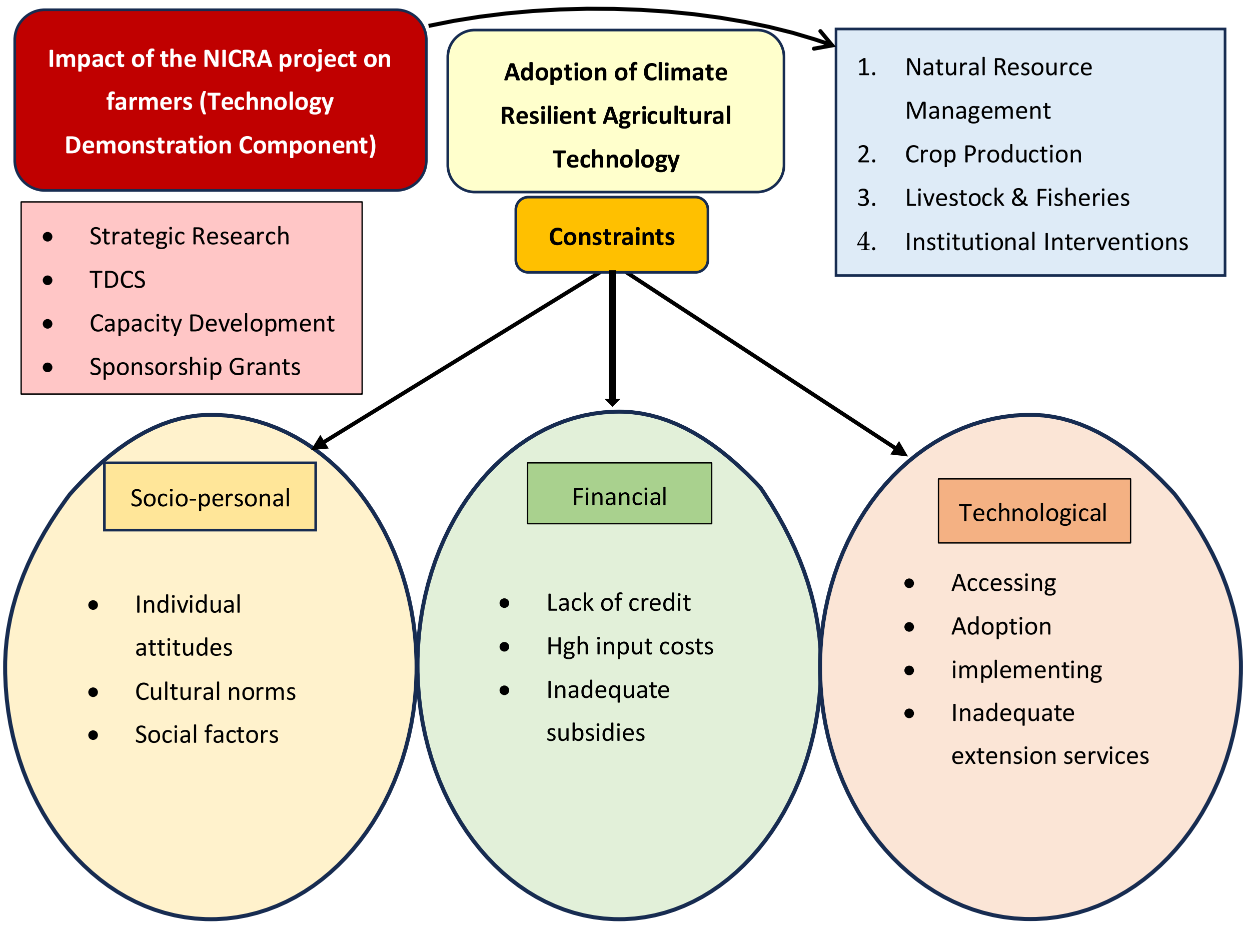

Fig. 1: Conceptual model of the research

Kendall's coefficient of concordance (Kendall's W) is accustomed to evaluating agreement or consistency between different judges or respondents to certain objects, ranging from 0 to 1. Where zero denotes nonexistence of agreement at all between judges, and 1 denotes perfect agreement (Kendall and Smith, 1939). To validate ranking consistency, Kendall's Coefficient of Concordance (W) was applied. Asymptotic significance tests agreement assuming a large sample, while Monte Carlo significance offers robust validation for smaller samples through random resampling. Together, they confirm the statistical reliability of constraint rankings.

3. RESULTS

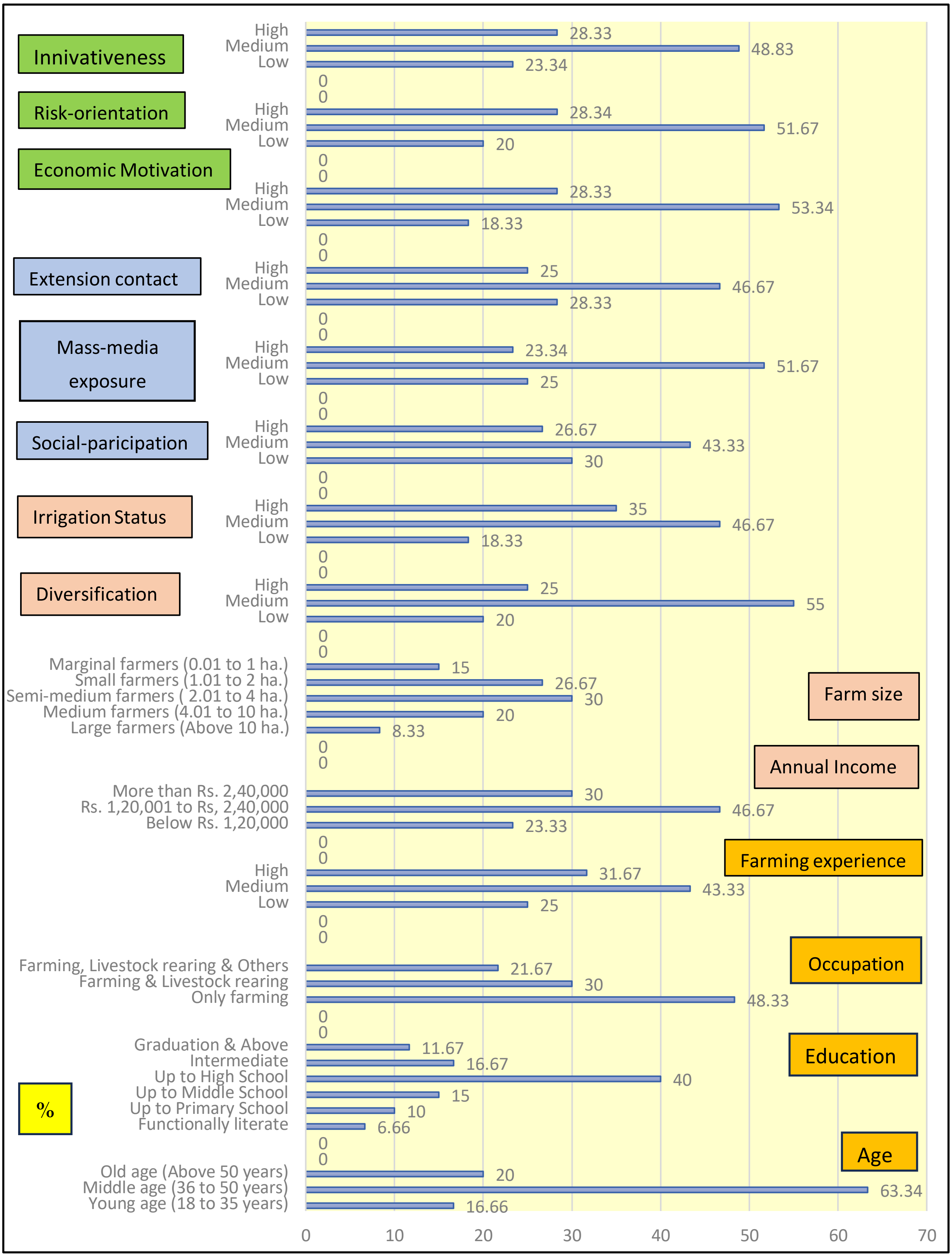

Fig. 2: Socio-economic profile analysis of Farmers from the NICRA Adopted Village (n=60)

Detailed analysis of the socio-economic profile of the respondents is illustrated in Figure 2, revealing low levels of innovativeness (48.83%), risk orientation (51.67%), and economic motivation (53.34%), which hinder technology adoption. Limited extension contact (46.67%) and social participation (51.67%) further restrict knowledge dissemination. Irrigation access (46.67%) was found to be inadequate, posing significant challenges in coping with climate variability. The study also observed low levels of diversification (55%), suggesting that most farmers rely on a limited range of crops and income sources, increasing their vulnerability to climate shocks. Most farmers had semi-medium landholdings (30%), annual incomes between Rs. 1,20,001 and Rs. 2,40,000 (46.67%), and medium farming experience (43.33%). Education levels were mostly intermediate (16.67%), while the majority were young farmers (63.34%), indicating potential for future skill development. Farm size and behavioral variables suggests a trend wherein marginal and small farmers show disproportionately lower risk orientation and innovativeness levels. This implies that resource-constrained groups are not only financially vulnerable but also behaviorally hesitant, which collectively limits their responsiveness to climate-smart interventions. Conversely, semi-medium landholders, who form the majority (30%), tend to exhibit medium to high risk orientation, indicating a greater potential for technology adoption if appropriately supported. Understanding these factors is crucial for designing targeted interventions, addressing financial and technological constraints, and ensuring the successful adoption of climate-resilient agriculture under the NICRA framework. Collecting farmer-specific data helps identify region-specific challenges, enabling the design of targeted interventions that address financial constraints through institutional credit and subsidies, enhance extension services to improve awareness, and promote risk-taking behavior through demonstration programs. Therefore, integrating socioeconomic profile analysis with the constraints perceived by farmers is vital for ensuring the successful implementation of climate-resilient agriculture under the NICRA framework in the research area. Similar findings have been confirmed by Pise et al. (2018), Babu (2019), Pabba et al. (2021), Singh et al. (2022), and Naik et al. (2025) in their respective studies.

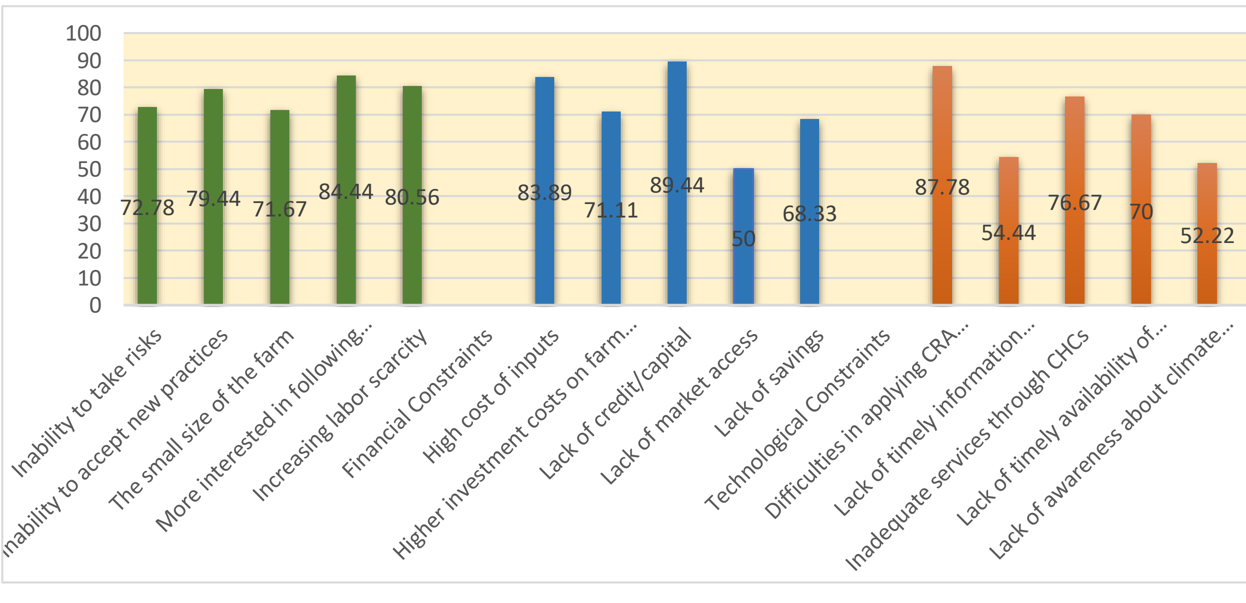

Fig. 3: The bar diagram illustrating the constraints based on their RBQ% score

Table 1: Rank-Based Quotient (RBQ) Scores and Rankings for Constraints in the Adoption of Climate-Resilient Technologies by NICRA Farmers [Sample size (n)=60; *f* = Frequency, %= Percentage]

Constraint	Severe *f* (%)	Moderate *f* (%)	Lower *f* (%)	RBQ (%)	Rank
A. Socio-personal Constraints					
Inability to take risks	21 (35.00%)	29 (48.34%)	10 (16.66%)	**72.78**	**IV**
Inability to accept new practices	33 (55.00%)	17 (28.33%)	10 (16.66%)	**79.44**	**III**
The small size of the farm	25 (41.67%)	19 (31.67%)	16 (26.67%)	**71.67**	**V**
More interested in following conventional practices	36 (60.00%)	20 (33.33%)	4 (06.67%)	**84.44**	**I**
Increasing labor scarcity	35 (58.34%)	15 (25.00%)	10 (16.66%)	**80.56**	**II**
B. Financial Constraints					
High cost of inputs	33 (55.00%)	25 (41.66%)	2 (03.34%)	**83.89**	**II**
Higher investment costs on farm implements	24 (40.00%)	20 (33.33%)	16 (26.67%)	**71.11**	**III**
Lack of credit/capital	41 (68.33%)	19 (31.66%)	0 (00.00%)	**89.44**	**I**
Lack of market access	7 (11.67%)	16 (26.67%)	37 (61.66%)	**50.00**	**V**
Lack of savings	14 (23.33%)	35 (58.34%)	11 (18.34%)	**68.33**	**IV**
C. Technological Constraints					
Difficulties in applying CRA technologies at the farm level	44 (73.33%)	10 (16.66%)	6 (10.00%)	**87.78**	**I**
Lack of timely information related to CRA technologies	7 (11.67%)	24 (40.00%)	29 (48.33%)	**54.44**	**IV**
Inadequate services through CHCs	29 (48.33%)	20 (33.34%)	11 (18.33%)	**76.67**	**II**
Lack of timely availability of improved seed	22 (36.67%)	22 (36.67%)	16 (26.67%)	**70.00**	**III**
Lack of awareness about climate change	6 (10.00%)	22 (36.67%)	32 (53.33%)	**52.22**	**V**

Table 2: RBQ Variability and Dispersion Table by Constraint Category

Category	Mean RBQ (%)	Standard Deviation	Minimum RBQ (%)	Maximum RBQ (%)	Range	No. of Constraints
Financial	72.55	15.35	50.00	89.44	39.44	5
Socio-personal	77.78	5.41	71.67	84.44	12.77	5
Technological	68.22	15.03	52.22	87.78	35.56	5

Table 2 depicts the statistical analysis of RBQ scores across socio-personal, financial, and technological constraints, revealing notable differences in the degree of variability perceived by the respondents. Among the three categories, socio-personal constraints exhibited the highest level of consensus, as reflected in a low standard deviation (5.41) and a narrow RBQ range (12.77%). This suggests that challenges such as a preference for conventional practices, labor scarcity, and resistance to new methods were uniformly experienced and recognized by farmers. The relatively consistent responses within this category may be attributed to shared cultural norms and behavioral tendencies prevalent in the study area. In contrast, financial and technological constraints showed greater variability, with standard deviations of 15.35 and 15.03, respectively. The financial constraint category, with the widest range (39.44%), indicates that experiences with issues such as credit access, input costs, and savings differed significantly among farmers, likely influenced by factors such as landholding size, income level, and prior access to institutional support. Similarly, technological constraints, with a range of 35.56%, reflect uneven exposure and access to innovations like Custom Hiring Centers and improved seed varieties. These variations point toward systemic disparities in service delivery and institutional outreach under the NICRA framework.

🔴 Red = Very high constraint (RBQ > 85%), 🟠 Orange = High constraint (RBQ 75–85%), 🟡 Yellow = Moderate constraint (RBQ 60–75%), 🟢 Green = Low constraint (RBQ < 60%)

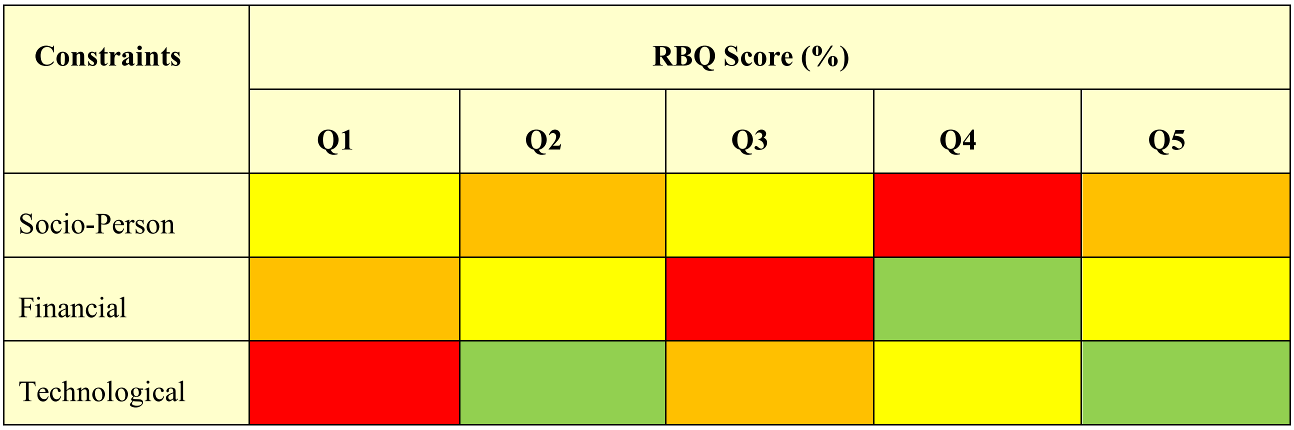

Fig. 4: Composite Heat Map Depicting Severity of Constraints in Adoption of Climate-Resilient Technologies among NICRA Farmers

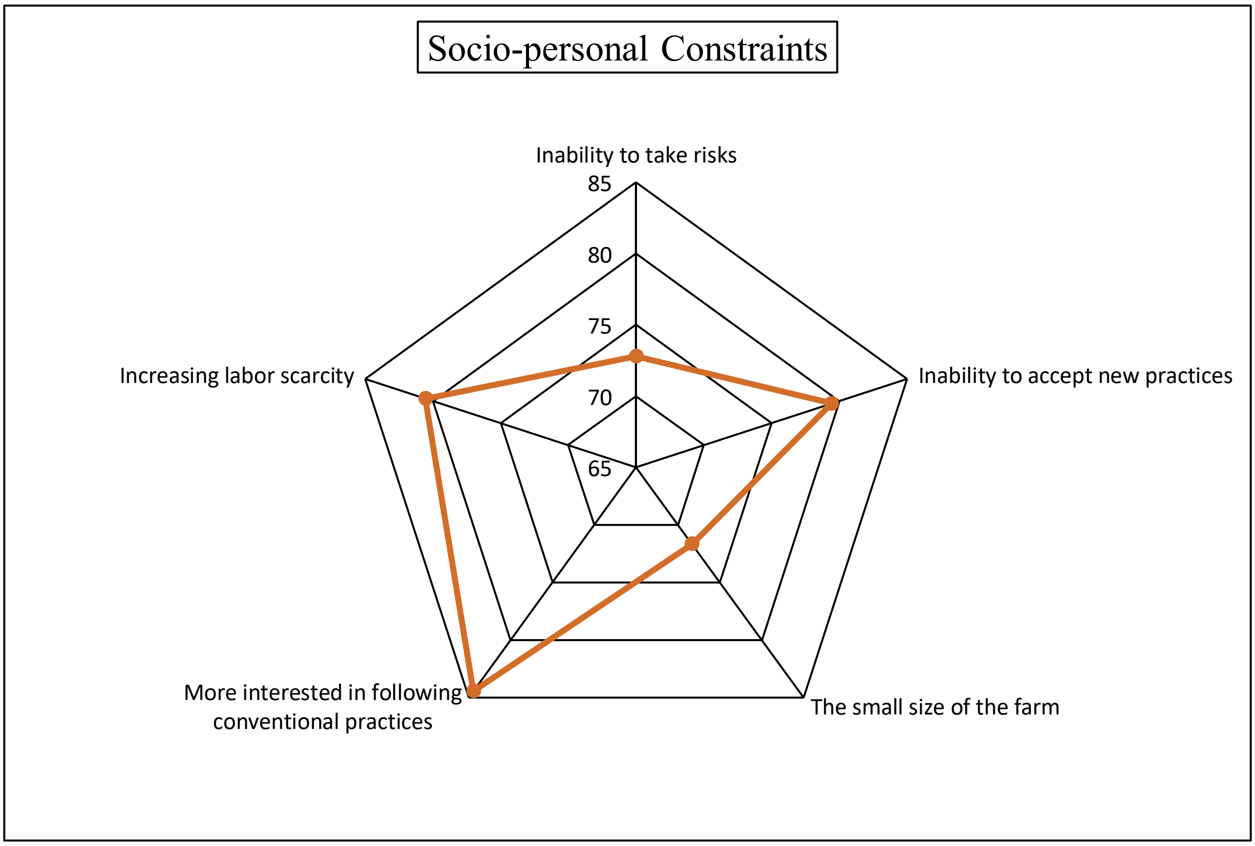

Fig. 5: Radar chart depicting the RBQ% in the context of socio-personal constraints faced by the respondents in the study area

Table 1 depicts the RBQ scores and ranks for the constraints. Figure 3 illustrates a bar diagram concerning the constraints faced by the respondents, whereas Figures 5,6, and 7 depict the radar charts for each category of constraints, namely socio-personal constraints, financial constraints, and technological constraints, respectively. As is evident from Table 1 and Figures 3 and 4, among the socio-personal constraints faced by farmers in the selected NICRA villages, a strong preference for conventional practices (RBQ = 84.44%) emerged as the most significant barrier. Farmers exhibited reluctance toward adopting new practices due to their deep-rooted belief in traditional methods. The second major constraint was the increasing scarcity of labor (RBQ = 80.56%), primarily due to a shift in the younger population toward industrial employment rather than agriculture. As Jharsuguda is an industrially developed district, many farmers have diversified their income sources, contributing to the decline in agricultural labor availability. The inability to adopt new agricultural practices (RBQ = 79.44%) ranked third, largely influenced by climatic uncertainties such as droughts and erratic rainfall patterns, which created apprehensions about the viability of the new technique. The inability to take risks (RBQ = 72.78%) and small farm size (RBQ = 71.67%) were ranked fourth and fifth, respectively. Land fragmentation over generations has reduced farm sizes, making large-scale adoption of climate-resilient agricultural technologies challenging. These findings are in alignment with previous studies by Mohokar et al. (2019), Acharitha et al. (2022), and Naik et al. (2022).

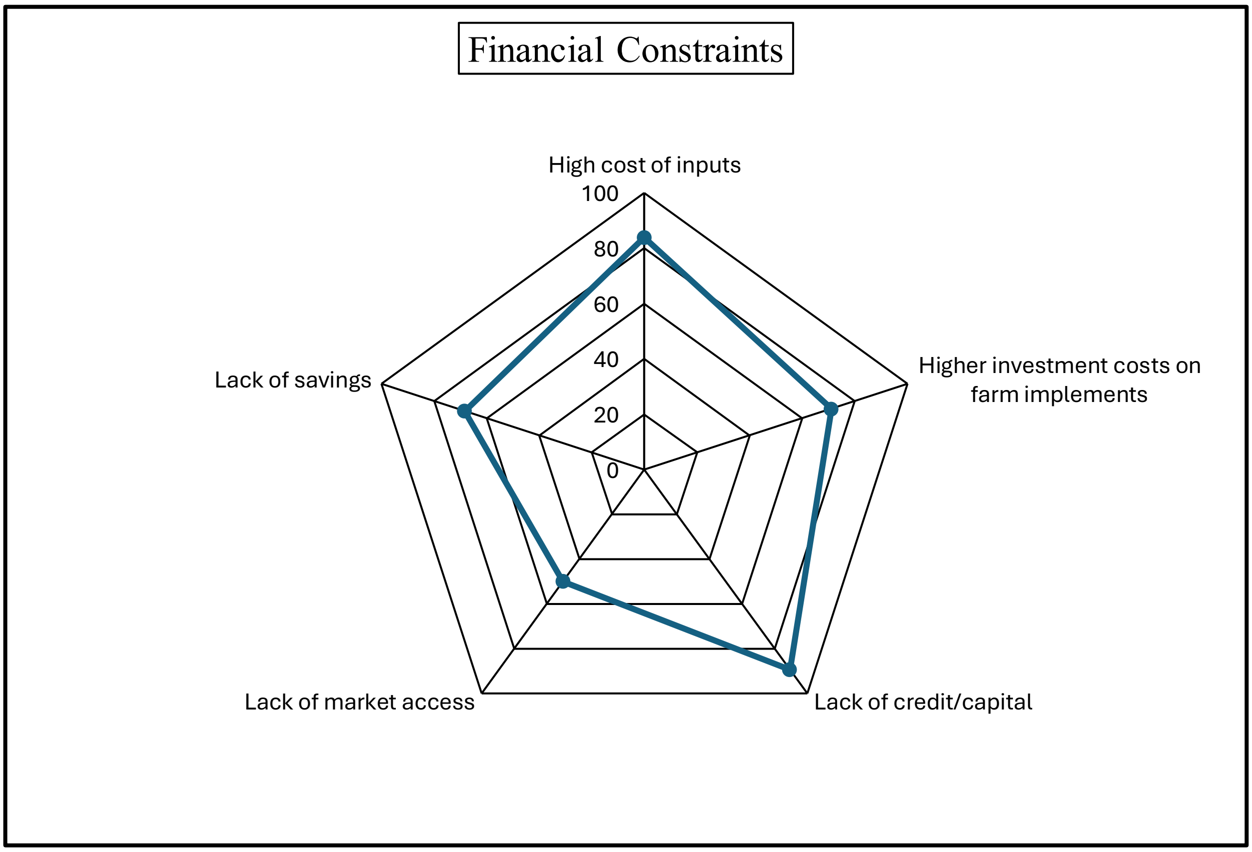

Fig. 6: Radar chart depicting the RBQ% in the context of financial constraints faced by the respondents in the study area

To address socio-personal constraints, regular training programs on climate-resilient technologies should be conducted to build confidence among farmers, particularly smallholders hesitant to take risks. Large-scale demonstrations of successful climate-resilient practices can motivate farmers to transition from conventional to adaptive techniques. Additionally, policy interventions should focus on incentivizing agricultural labor to mitigate the issue of workforce shortages, ensuring that youth remain engaged in farming activities.

As presented in Table 1 and Figure 6, financial constraints posed significant barriers to the adoption of climate-resilient agricultural technologies. The lack of credit or capital (RBQ = 89.44%) was identified as the most critical financial limitation. A majority of the farmers were small and marginal, with limited access to institutional financial support and inadequate financial literacy, further restricting their ability to invest in climate-resilient technologies. The high cost of agricultural inputs (RBQ = 83.89%) was ranked second, as escalating prices of seeds, fertilizers, and pesticides made technology adoption financially burdensome. The third major constraint was the high investment cost for farm implements (RBQ = 71.11%), as expensive machinery such as rotavators, planters, and seed drills remained out of reach for many farmers, despite subsidy programs. The lack of savings (RBQ = 68.33%) was another notable constraint, as most farmers relied solely on agriculture for income, leaving little scope for investment in climate adaptation. Lastly, limited market access (RBQ = 50.00%) was ranked as the least significant financial constraint, though it still posed challenges for farmers in selling their produce at competitive prices. These findings align with the research of Jasna et al. (2015), Pabba et al. (2022), Shanabhoga et al. (2023), and Shende et al. (2023).

Strengthening institutional financial support and enhancing financial literacy among farmers should be carried out to improve their access to credit and capital. Implementing subsidy programs that specifically target small and marginal farmers can help make agricultural inputs more affordable. Establishing Custom Hiring Centers (CHCs) for mechanization at subsidized rates can be undertaken, thus allowing smallholders access to expensive farm implements. Promoting savings and cooperative banking models tailored to farmers' needs can be incorporated to enhance financial security. Improving market linkages and developing infrastructure to help farmers obtain better prices for their produce can also be undertaken to ensure economic viability.

Table 1 and Figure 7 highlight that among the technological constraints, the most pressing issue was the difficulty in implementing climate-resilient technologies at the farm level (RBQ = 87.78%). Farmers found it challenging to adopt these technologies without adequate financial and technical assistance. Additionally, the lack of coordination among farmers in collective decision-making and resource-sharing further hindered implementation. Inadequate services from Custom Hiring Centers (CHCs) (RBQ = 76.67%) ranked as the second most significant constraint, as farmers expressed dissatisfaction with the limited availability of mechanization services during peak agricultural seasons. The third constraint was the lack of timely availability of improved seeds (RBQ = 70.00%), which created difficulties in adopting drought-resistant and climate-resilient crop varieties. The lack of timely information on climate-resilient agricultural technologies (RBQ = 54.44%) was ranked fourth, as poor access to extension services and inadequate information dissemination made it difficult for farmers to plan climate-smart practices effectively. Finally, the lack of awareness about climate change (RBQ = 52.22%) was ranked as the least severe constraint, yet it still highlighted the need for more effective extension strategies to educate farmers about the long-term benefits of climate-resilient practices. These findings corroborate those of Babu (2019), Majumdar et al. (2020), Naik et al. (2022), and Acharitha et al. (2022).

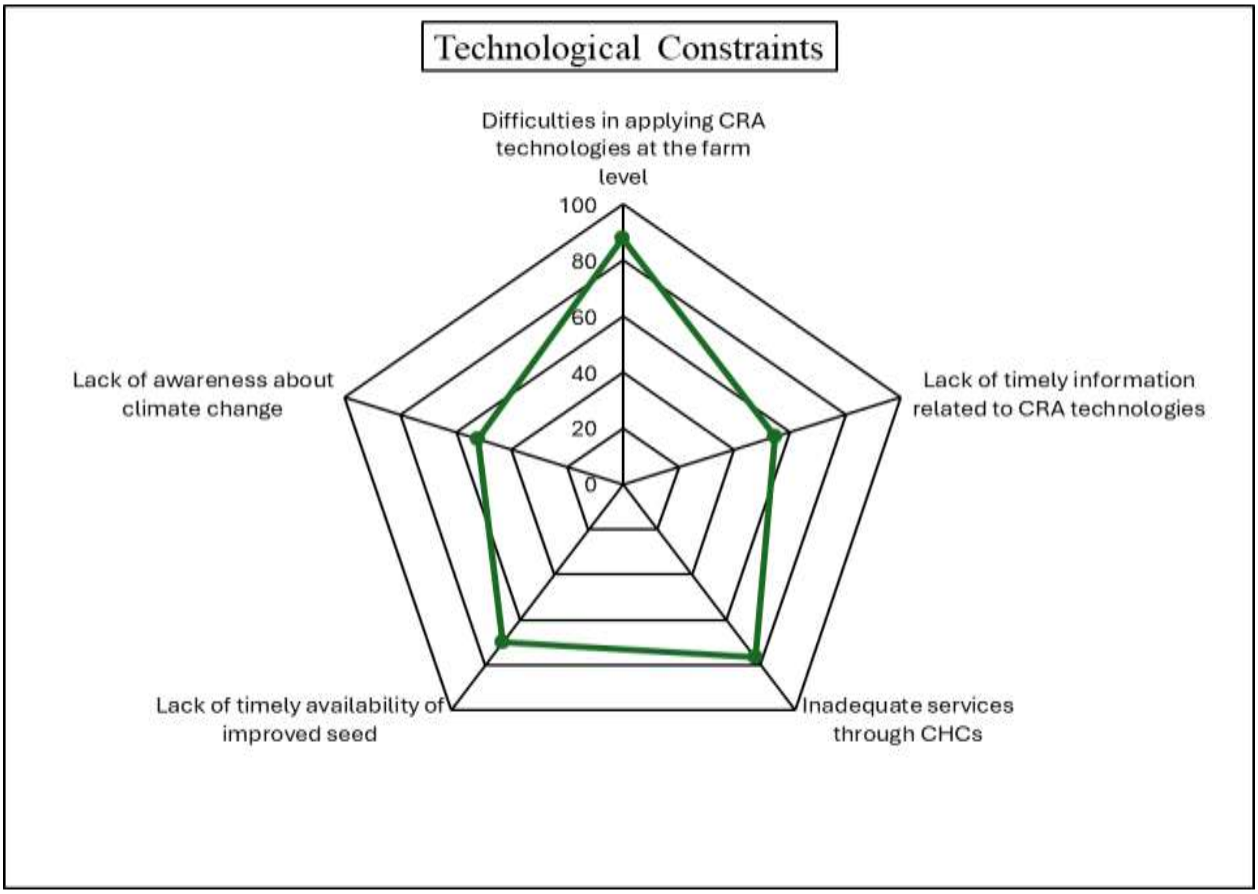

Fig. 6: Radar chart depicting the RBQ% in the context of technological constraints faced by the respondents in the study area

Government agencies and agricultural extension services should intensify farmer training on climate-resilient technologies to overcome technological constraints, emphasizing practical demonstrations and field trials. Strengthening CHCs by ensuring the timely availability of farm machinery and expanding their reach to remote areas can enhance mechanization services. Establishing seed banks at the village level and ensuring the timely distribution of improved seeds can further facilitate adoption. Additionally, leveraging digital platforms to provide real-time weather and market advisories can enhance farmers' decision-making and resilience against climate uncertainties.

For further analysis, Kendall’s coefficient of concordance approach was used. Table 2 depicts Kendall’s W mean value calculations for each constraint category. In Table 3. And Figure 7, average ranks were assigned as: socio-personal constraints at 1.2, financial constraints at 2.0, and technological constraints at 2.8. These yield total rank sums of 72, 120, and 168, respectively, with a mean total rank $\overline{R}$ of 120. Illustrative, based on the assumed data and the computed W of 0.64. Figure 7 illustrates a radar chart showing various constraints' comparative ranking through Kendall’s W mean value. Table 3 depicts the detailed analysis of Kendall’s coefficient of concordance.

Table 3: Calculation of Average Rank and Total Rank of Constraint Category

Constraint Category	Kendall’s W mean value
Socio-personal	1.2
Financial	2.0
Technological	2.8

From Tables 3 and 4, it was evident that Kendall’s W value of 0.64 (on a scale of 0 to 1) indicates a strong agreement among the 60 respondents in their rankings of the three conditions. This suggests that respondents consistently ordered the conditions similarly. The Friedman test (used for comparing rankings across multiple conditions) yielded a chi-square statistic of 77.00 with 2 degrees of freedom (degree of freedom = k−1, where k = 3 conditions). Both the asymptotic (theoretical) p-values were .000, confirming that the observed agreement is highly statistically significant ($p < .001$). This means the likelihood of such an agreement occurring by chance is virtually zero. There is strong, statistically significant agreement among respondents in their rankings of the three conditions. The consistency in rankings led to detectable differences between conditions (Friedman test) and a high concordance measure (Kendall’s W). This result is robust across both theoretical and simulation-based methods.

The Kendall’s W value of 0.64 (indicating strong agreement) and the highly significant chi-square statistic (χ^2 (2) = 77.00, $p < .001$) validate the Rank-Based Quotient (RBQ) method used in this study. Both the Asymptotic Significance and Monte Carlo Significance values were 0.000, reinforcing the robustness of the test results. This statistically confirms that the constraint rankings reported in the study, particularly the prominence of financial and socio-personal barriers, were consistently perceived across the respondent group, thereby enhancing the credibility and reliability of the RBQ-derived conclusions. These results confirm that farmers consistently ranked constraints similarly, and a “preference for conventional practices” (RBQ = 84.44%) emerged as the top socio-personal barrier, reflecting a shared perception of challenges. The low p-values (< .001) confirm that the observed rankings are statistically significant and not due to chance, reinforcing the RBQ outcomes' reliability. In the socio-personal domain, the top constraint is the preference for conventional practices (RBQ = 84.44%), supported by Kendall’s W, highlighting strong consensus among farmers. This finding aligns with cultural inertia and risk aversion common in agrarian communities. Additionally, labor scarcity (RBQ = 80.56%) and the inability to adopt new practices (RBQ = 79.44%) further underscore systemic issues that require interventions such as training and mechanization, including the establishment of Custom Hiring Centers (CHCs). In terms of financial constraints, the "lack of credit/capital" (RBQ = 89.44%) and "high input costs" (RBQ = 83.89%) are particularly critical, reinforcing the urgency of addressing these financial barriers through improved institutional credit and targeted subsidy programs. Regarding technological constraints, the difficulty in implementing CRA technologies at the farm level (RBQ = 87.78%) and inadequate CHC services (RBQ = 76.67%) are highlighted. The large effect size (W = 0.64) supports the need for focused policy measures on practical training and infrastructure improvements. The strengths of this analysis lie in its methodological rigor, combining RBQ to rank constraints with Kendall's W to measure consensus, thus providing a robust mixed-methods approach. The interpretation is aligned with the approach used by Mallick et al. (2023a).

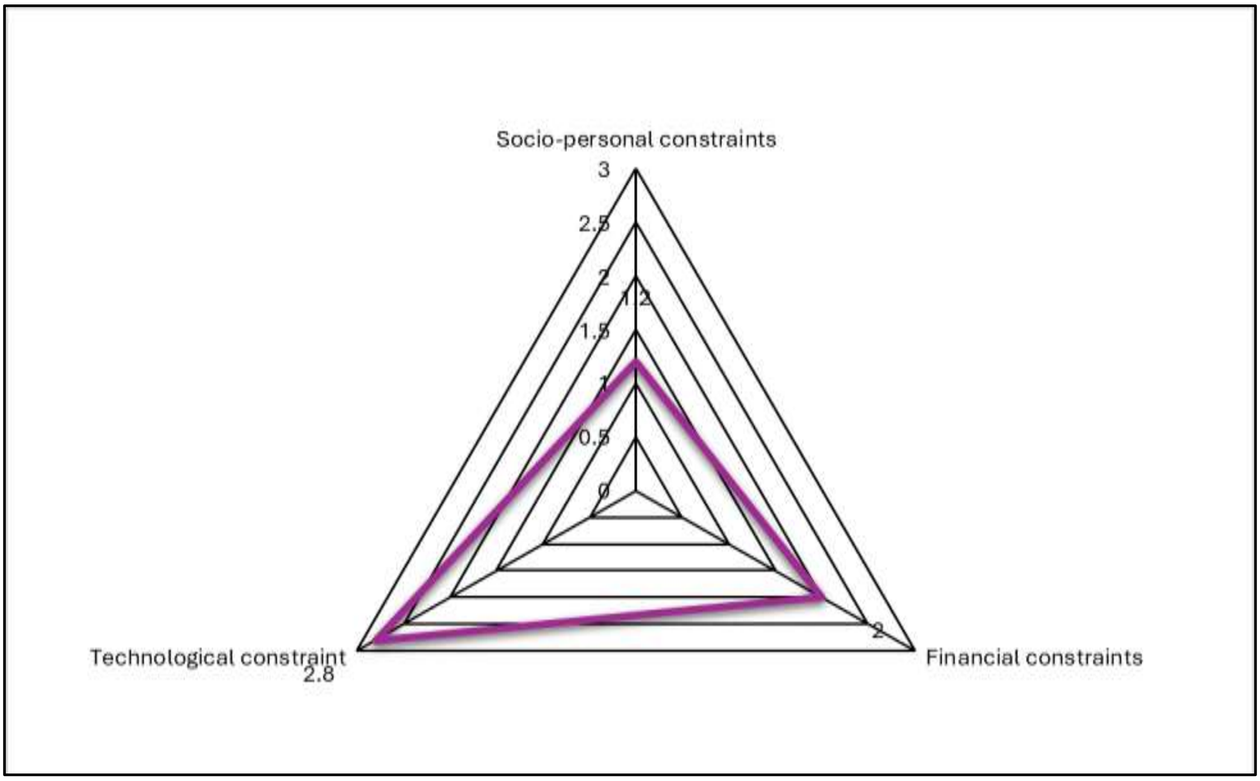

Fig. 8: Radar chart depicting the comparative ranking of various constraints through Kendall's W mean value

Table 4: Test for Kendall's Coefficient of Concordance (Kendall's W)

Test for Kendall's Coefficient of Concordance (Kendall's W)	Values
N (Number of respondents)	60
Kendall's W	0.64
Chi-Square	77.00
Degrees of Freedom	2

Asymptotic Significance	.000
Monte Carlo Significance	.000
99% Confidence Interval (CI) Lower Bound	.000
99% Confidence Interval (CI) Upper Bound	.000

The statistical significance of the constraints, particularly the financial barriers, justifies recommendations for enhanced credit access, subsidies, and CHC expansion. Moreover, the local specificity of the study, with a focus on Jharsuguda, fills a critical gap in localized NICRA research and emphasizes the need for region-specific interventions. Areas for further exploration include obtaining qualitative insights to understand why farmers resist change, conducting temporal analysis by repeating the study post-intervention, and testing Kendall's W in other NICRA districts to determine the broader generalizability of these findings. The statistical analysis demonstrated by Kendall's W = 0.64 and χ^2 (2) = 77.00, $p < .001$, strengthens the credibility by demonstrating that the constraints identified through RBQ are both consistent and statistically significant. This dual validation supports targeted interventions, such as financial literacy programs, scalable demonstrations of climate-resilient technologies, and strengthening CHCs and seed distribution systems, to enhance the adoption of climate-resilient technologies in Jharsuguda. The interpretation is aligned with the approach used by Mallick et al. (2023a).

4. DISCUSSION

Regular training programs and large-scale demonstrations of climate-resilient technologies should be conducted to enhance farmers' knowledge and encourage adoption, particularly among small and marginal farmers hesitant to take risks. Extension personnel and scientists must play an active role in these initiatives. Expanding Custom Hiring Centers (CHCs) in NICRA villages can help address labor shortages and improve farm efficiency. Community-managed CHCs should ensure timely access to farm machinery, with revenue reinvested for maintenance and expansion. Popularizing water-saving techniques such as low-cost rainwater harvesting structures, poly-mulching, and zero-energy cooling systems for vegetable storage can improve resource efficiency and enhance resilience to erratic rainfall. Village-level seed banks should be established to provide high-quality, drought-tolerant seed varieties at affordable rates. This will ensure farmers have reliable access to improved crop varieties suited to changing climatic conditions. Encouraging integrated farming systems (IFS), mushroom and marigold cultivation, poultry, and small-scale fisheries can improve farmers' livelihoods and resilience. Financial support and follow-up interventions should be provided to sustain these activities. The present study, while methodologically robust, is limited by its quantitative orientation. Future research should adopt a mixed-methods approach to capture the nuanced behavioral and experiential dimensions behind constraint perception. Qualitative interviews and focus groups can yield a deeper understanding of farmer psychology, risk aversion, and systemic trust issues in the adoption of climate-resilient agricultural technologies. Climate-resilient technology adoption should be demand-driven, with real-time problem-solving demonstrations and timely availability of critical inputs to ensure effective implementation at the farm level.

These interventions, if implemented effectively, can enhance farmers' adaptive capacity and contribute to sustainable agricultural development. Table 4 shows the policy matrix highlighting major constraints, suggested actions concerning the constraints, and mentioning implementing agency.

Table 4: Policy Matrix Highlighting Major Constraints in the Adoption of Climate-Resilient Technologies

Constraint	Recommended Action	Implementing Agency
Lack of credit/capital	Expand access to institutional credit through SHGs, cooperative banks, and KCC schemes	NABARD, Regional Rural Banks, State Agri Dept
Difficulty in applying CRA technologies	Conduct on-farm demonstrations and provide technical training through KVKs and CHCs	ICAR-KVKs, ATMA, Panchayat CHCs
High cost of agricultural inputs	Offer input subsidies and bulk procurement schemes for quality seeds and inputs	Department of Agriculture, State Govt
Preference for conventional practices	Promote behavioral change via farmer field schools, progressive farmer exposure visits	ICAR, State Extension Services
Labor scarcity	Strengthen mechanization support through well-equipped and locally managed CHCs	NICRA-VCRMC, State Agri Department, MANREGA

5. CONCLUSIONS

The study comprehensively analyzed the socio-personal, financial, and technological constraints affecting the adoption of climate-resilient agricultural technologies among farmers in the NICRA villages of Jharsuguda district, Odisha. To translate findings into actionable insights, this study recommends a multi-pronged policy approach. Socio-personal barriers can be addressed through farmer-led knowledge platforms, participatory extension, and risk mitigation training. Financial bottlenecks require expanded institutional credit schemes, targeted subsidies for inputs, and revolving funds for local Custom Hiring Centers (CHCs). On the technological front, enhancing CHC infrastructure, establishing seed banks, and introducing mobile-based agro-advisory services are imperative. To build long-term resilience, future strategies must embed climate-smart practices into local development planning, encourage youth engagement in agri-innovation, and promote community-based adaptation models. Scaling up successful interventions through digital platforms, village-level cooperatives, and decentralized climate services can further enhance reach and impact. These findings provide a policy roadmap for institutional actors seeking to mainstream adaptive agriculture in vulnerable regions.

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