



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

Abhishek Naik^{1†}, Samir Ranjan Dash², Kiran Sourav Das¹, Shilpa Bahubalendra³ and Priya Ranjan Mohanty¹

¹Department of Extension Education, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar-751003, Odisha, India

²Krishi Vigyan Kendra, Odisha University of Agriculture and Technology, Jharsuguda-768202, Odisha, India

³Department of Agricultural Extension and Communication, Faculty of Agriculture Sciences, Siksha O Anusandhan (Deemed to be University), Bhubaneswar-751003, Odisha, India

†Corresponding Author: Abhishek Naik; naikabhsihek17@gmail.com

Abbreviation: Nat. Env. & Poll. Technol.

Website: www.neptjournal.com

Received: 27-03-2025

Revised: 16-05-2025

Accepted: 26-05-2025

Key Words:

Climate-resilient agriculture
Climate-resilient technologies
Climate change
NICRA
Rank-Based Quotient (RBQ)
Kendall's coefficient (W)

Citation for the Paper:

Naik, A., Dash, S.R., Das, K.S., Bahubalendra, S. and Mohanty, P. R., 2026. 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. *Nature Environment and Pollution Technology*, 25(1), B4330. <https://doi.org/10.46488/NEPT.2026.v25i01.B4330>

Note: From 2025, the journal has adopted the use of Article IDs in citations instead of traditional consecutive page numbers. Each article is now given individual page ranges starting from page 1.



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ABSTRACT

Climate change poses significant challenges to agriculture, necessitating the adoption of climate-resilient technology. Rising global temperatures, a direct consequence of climate change, negatively impact agricultural productivity, threaten farmers' livelihoods, and affect 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 approximately 17.4% to India's GDP, this decline in production could cost the economy up to 1.5% of its GDP each year. Thus, adopting climate-resilient agricultural technologies has become crucial in the current agro-ecological context. However, 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 National Innovations in Climate Resilient Agriculture (NICRA) farmers in the 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 the highest among financial constraints. Among the 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 [$W = 0.64$, $\chi^2(2) = 77.00$, $p < 0.001$], indicated a strong consensus in the rankings. Data was 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 sustainable and adaptive farming systems in the region.

INTRODUCTION

Climate change poses a significant threat to agriculture and food security, making it a key priority under the United Nations 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 worldwide. Growing urbanization and industrial activity, coupled with climate change, have resulted in alarming levels of water shortages globally. Nearly one-fifth of the world's population lives in areas with

water scarcity (Kohli & Grover 2024). Risk can be minimized through structural and non-structural interventions, mass empowerment, planning strategies, 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, which is 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). Farmers perceive climate variability and identify increasing temperatures. Rain delays increase soil dryness, which is a critical factor affecting cultivation (Ratakonda et al. 2024). Rising temperatures are expected to have a significant impact on agriculture in India. According to the IPCC (2007), since 2020 temperatures have 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 the severity and extent of the temperature rise (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 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, which was later renamed the 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 demonstration, financial support, and capacity building. Although 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 their implementation (Rao et al. 2016).

Interconnected behavioral, economic, and institutional barriers constrain the adoption of climate-resilient agricultural technologies. 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, such as drip irrigation and water storage systems (Mohokar et al. 2019). Region-specific studies reveal how these barriers manifest differently across agroecological zones in India. For example, pest outbreaks and flood vulnerabilities dominate in deltaic regions (Majumder et al. 2020), whereas 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 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 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 the constraints faced by farmers in the NICRA villages of the Jharsuguda district of Odisha, thereby enabling targeted policy interventions for accelerated technology adoption.

Despite extensive studies on the constraints faced by farmers in adopting climate-resilient technologies, limited research has focused 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 in Jharsuguda is lacking. Furthermore, the role of extension services and government support in overcoming these constraints remains to be explored. 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, limiting generalizability. As a single researcher, in social science studies, results are shaped by human behavior and localized interactions, making broad abstraction difficult. Future research with larger multisite samples is recommended.

MATERIALS AND METHODS

The research was conducted using an ex-post facto research design (Das et al. 2024). The Jharsuguda district of Odisha was purposively selected as the locale for this study. Farmers in the Jharsuguda district of Odisha face several climate-induced challenges that impact 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, Odisha. Purposive and random sampling techniques were used in 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, resulting in a sample size of 60 respondents from

the NICRA village.

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

Each constraint was assessed based on the hindrance experienced during 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 used 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 the respondents. Rank-Based Quotient (RBQ) was calculated as follows:

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

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

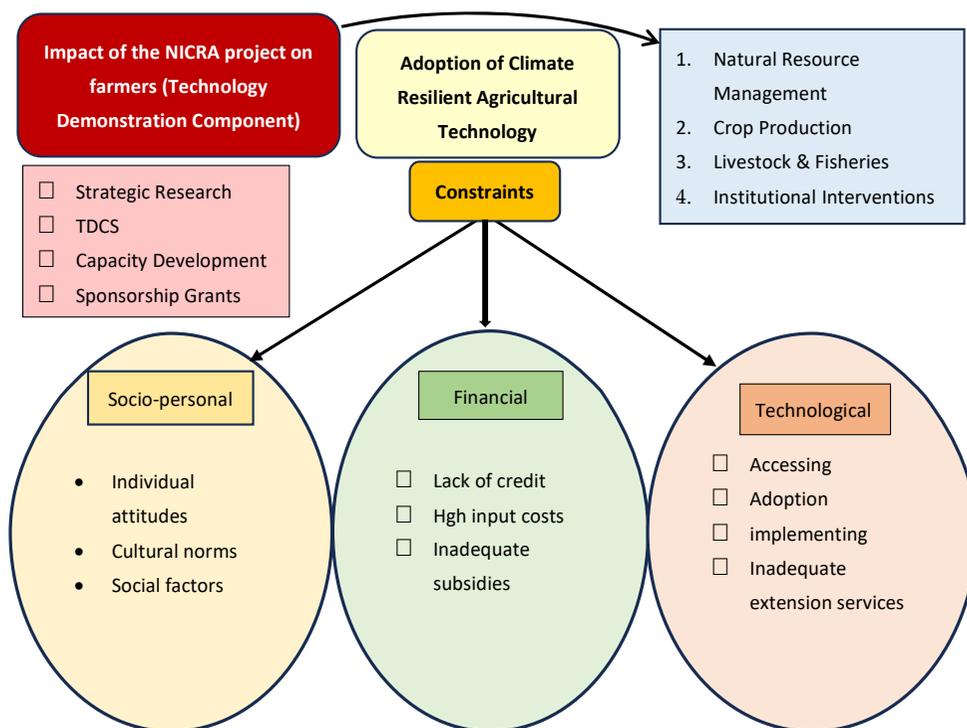


Fig. 1: Conceptual model of the research.

N = total number of respondents

n = Number of ranks

In addition, a comparison of various broad constraints used in the specific study was performed using Kendall's coefficient of concordance approach (Kendall & Smith

1939). As the ranks were tied between judges in the present study, the following formula was used to measure correction factors between tied ranks (Mallik et al. 2023a):

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

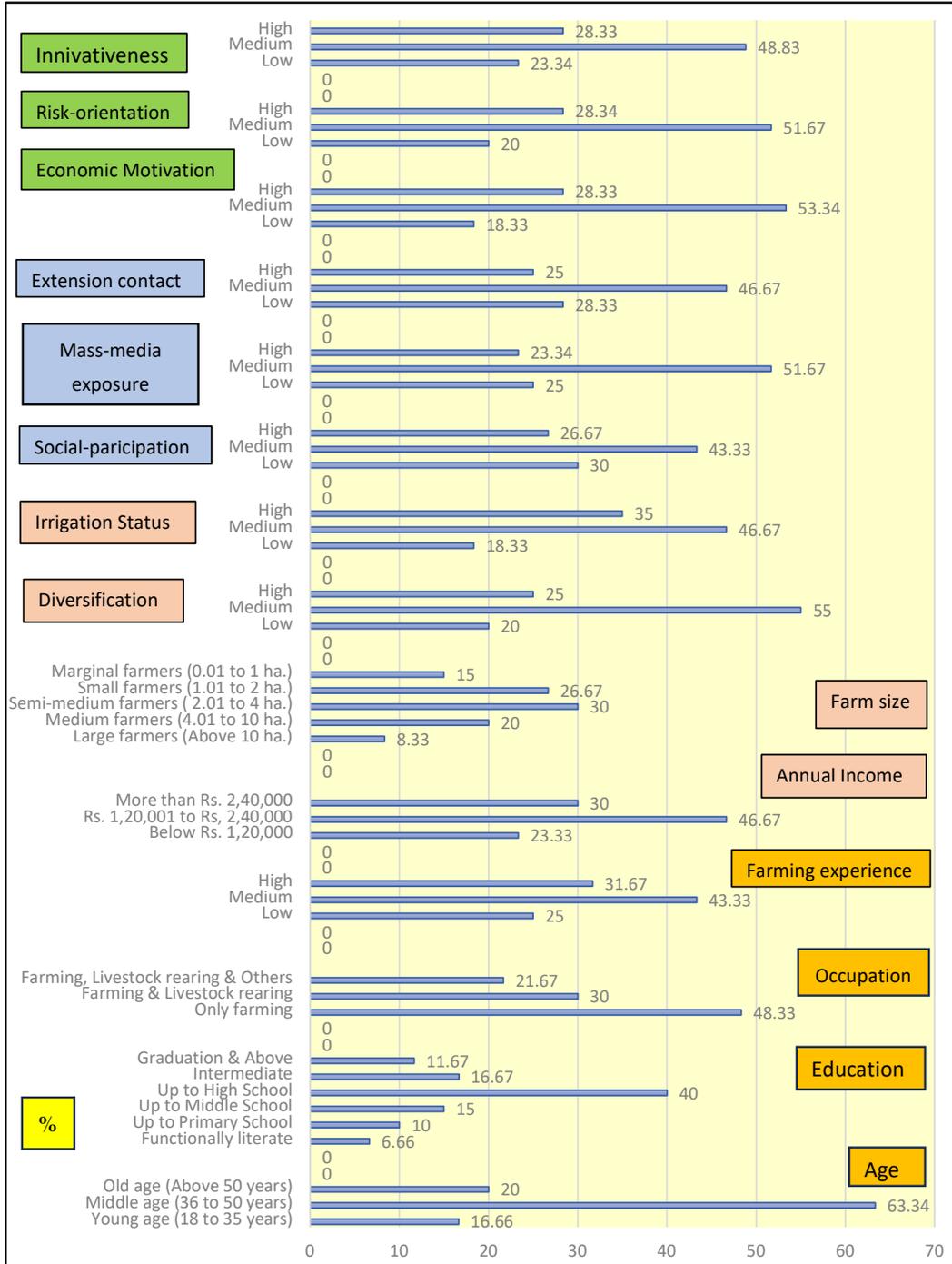


Fig. 2: Socio-economic profile analysis of Farmers from the NICRA Adopted Village (n=60).

m = number of respondents (farmers) = 60

n = number of items (constraint categories) = 3

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

\bar{R} = mean of the rank sums

Kendall's coefficient of concordance (Kendall's W) was used to evaluate the agreement or consistency between different judges or respondents to certain objects, ranging from 0 to 1, where zero denotes the nonexistence of agreement between judges and 1 denotes perfect agreement (Kendall & Smith, 1939). To validate the ranking consistency, Kendall's Coefficient of Concordance (W) was applied. Asymptotic

significance tests are agreed upon assuming a large sample, while Monte Carlo significance offers robust validation for smaller samples through random resampling. Together, these confirm the statistical reliability of the constraint rankings.

RESULTS AND DISCUSSION

A detailed analysis of the socio-economic profile is illustrated in Fig. 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 in the region. Irrigation access

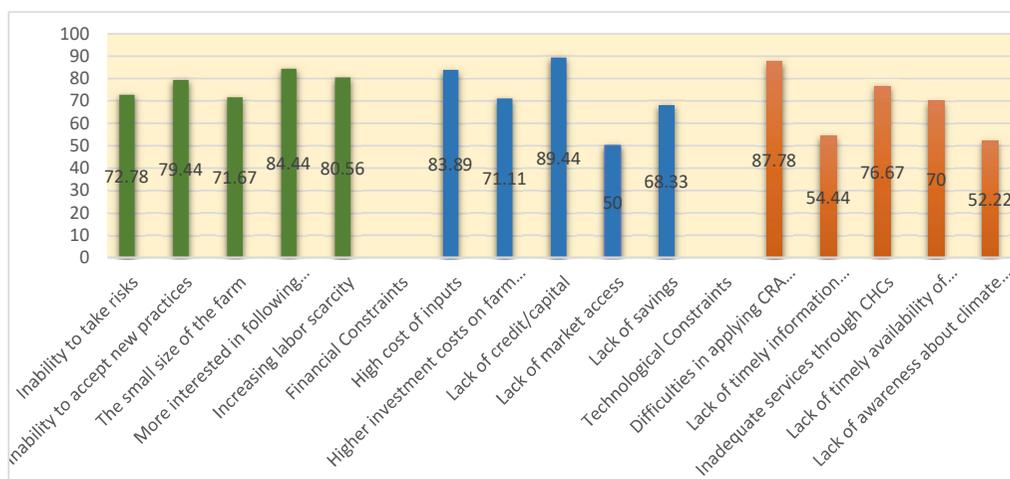


Fig. 3: The bar diagram illustrating the constraints based on their RBQ% score.

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
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
Financial Constraints					
High cost of inputs	33 (55.00%)	25 (41.66%)	2 (03.34%)	83.89	II
Higher investment costs for 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
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

(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, which increases their vulnerability to climate shocks. Most farmers had semi-medium landholdings (30%) and 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 suggest a trend wherein marginal and small farmers show disproportionately lower risk orientation and innovation 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 within 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 study 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.

Table 2 presents the statistical analysis of the RBQ scores across socio-personal, financial, and technological constraints, revealing notable differences in the degree of variability perceived by respondents. Among the three categories, socio-personal constraints exhibited the highest level of consensus, as reflected by 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 are uniformly experienced and recognized by farmers. The relatively consistent responses within this category may be attributed to the 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.

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

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

Constraints	RBQ Score (%)				
	Q1	Q2	Q3	Q4	Q5
Socio-Person	Yellow	Orange	Yellow	Red	Orange
Financial	Orange	Yellow	Red	Green	Yellow
Technological	Red	Green	Orange	Yellow	Green

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

Similarly, technological constraints, with a range of 35.56%, reflect uneven exposure and access to innovations such as Custom Hiring Centers and improved seed varieties. These variations indicate systemic disparities in service delivery and institutional outreach under the NICRA framework.

Table 1 shows the RBQ scores and ranks of the constraints. Fig. 3 illustrates a bar diagram of the constraints faced by the respondents, whereas Figs. 5, 6, and 7 depict radar charts for each category of constraints, namely, socio-personal, financial, and technological constraints. As is evident from Table 1 and Figs. 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%) was the most significant barrier. Farmers are reluctant to adopt new practices because of 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 in agriculture. As Jharsuguda is an industrially developed district, many farmers have diversified their income sources, contributing to the decline in the availability of agricultural labor. 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 regarding 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 the 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).

To address socio-personal constraints, regular training programs on climate-resilient technologies should be conducted to build confidence among farmers, particularly among 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 workforce shortages and ensure that youth remain engaged in farming activities.

As presented in Table 1 and Fig. 6, financial constraints are 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

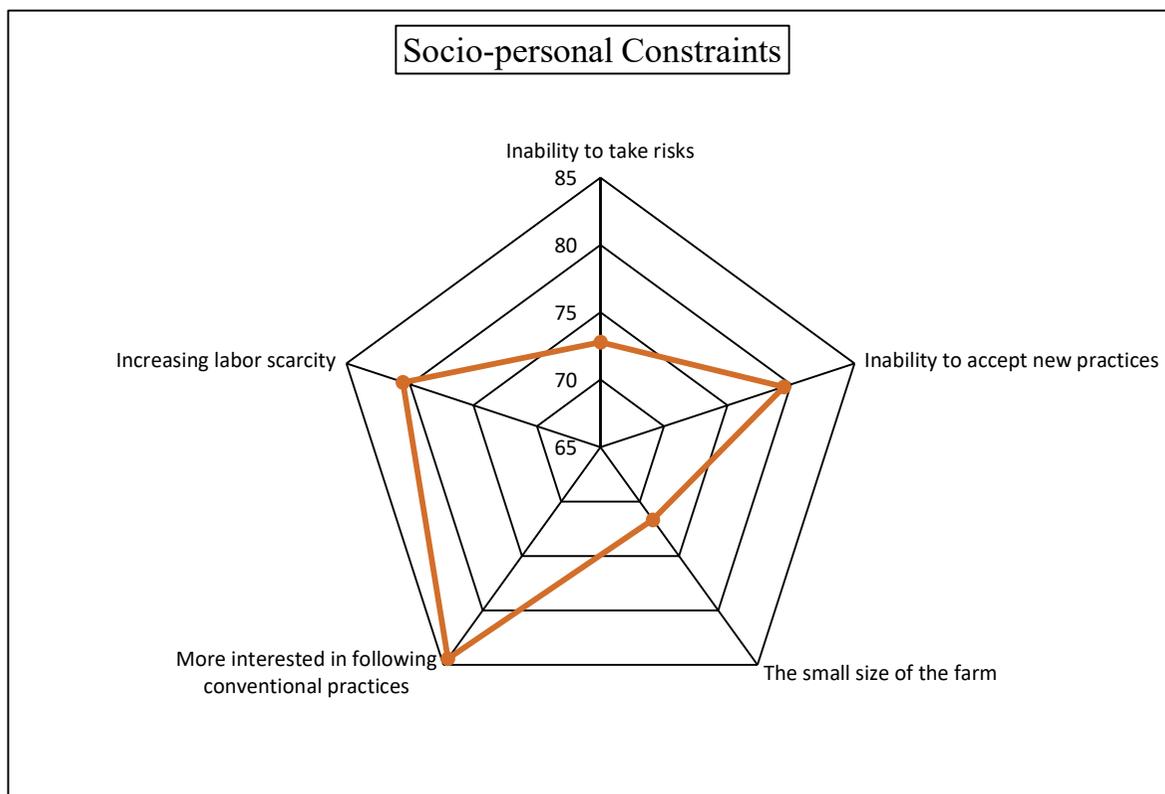


Fig. 5: Radar chart depicting the RBQ% in the context of socio-personal constraints faced by the respondents in the study area.

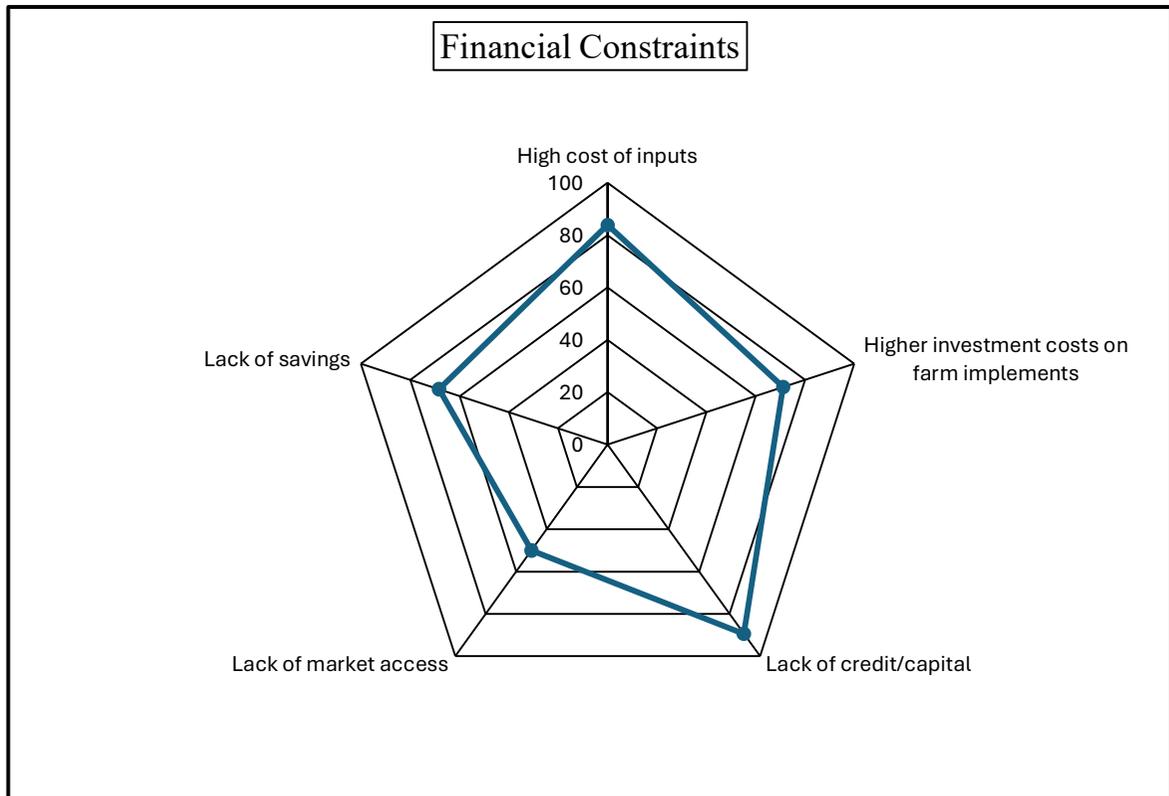


Fig. 6: Radar chart depicting the RBQ% in the context of financial constraints faced by the respondents in the study area.

limitation for the farmers. Most farmers are 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 the 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, although it still posed challenges for farmers in selling their produce at competitive prices. These findings align with those of Jasna et al. (2015), Pabba et al. (2022), Shanabhoga et al. (2023), and Shende et al. (2023).

Strengthening institutional financial support and enhancing farmers' financial literacy should improve their access to credit and capital. Implementing subsidy programs that specifically target small and marginal

farmers can help make agricultural inputs more affordable to them. 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 enhance financial security. Improving market linkages and developing infrastructure to help farmers obtain better prices for their produce can also ensure economic viability.

Table 1 and Fig. 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 find 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 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 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 effectively plan climate-smart practices. Finally, the lack of awareness about climate change (RBQ = 52.22%) was ranked as the least severe constraint; however, 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).

Government agencies and agricultural extension services should intensify farmer training on climate-resilient technologies to overcome technological constraints by 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. Establishing seed banks at the village level and ensuring the timely distribution of improved seeds can facilitate adoption. Additionally, leveraging digital platforms to provide real-time weather and market advisories can enhance farmers' decision-making and resilience to climate uncertainties.

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

For further analysis, Kendall's coefficient of concordance was used. Table 2 depicts Kendall's W mean value calculations for each constraint category, in Table 3. In Fig. 7, the average ranks were assigned as follows: 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 of 120. For example, based on the assumed data and the computed W of 0.64. Fig. 8 illustrates a radar chart showing the comparative ranking of various constraints using Kendall's W mean value. Table 3 depicts a detailed analysis of Kendall's coefficient of concordance.

From Tables 3 and 4, it is 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 the respondents

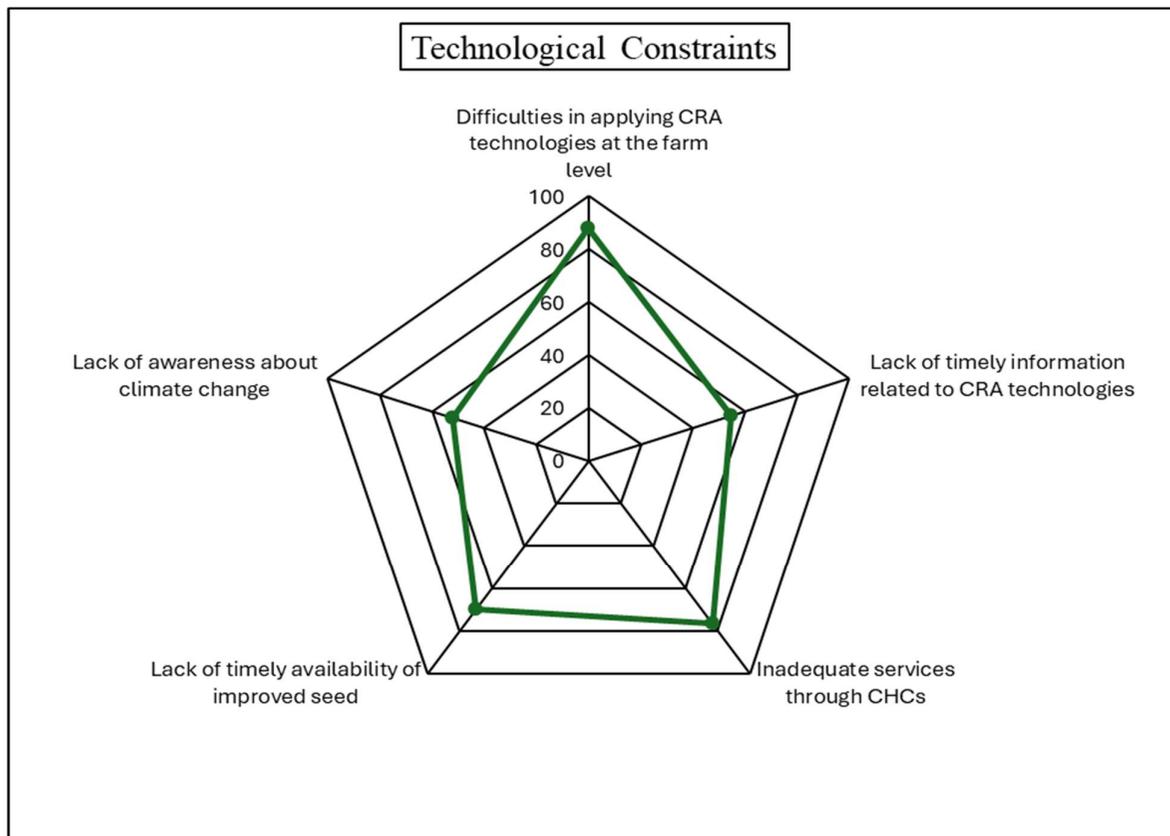


Fig. 7: Radar chart depicting the RBQ% in the context of technological constraints faced by the respondents in the study area.

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 (degrees of freedom = $k-1$, where $k = 3$ conditions). Both the asymptotic (theoretical) p-values were .000, confirming that the observed agreement was highly statistically significant ($p < .001$). This implies that the likelihood of such an agreement occurring by chance is virtually zero. There was a strong, statistically significant agreement among respondents in their rankings of the three conditions. The consistency in rankings led to detectable differences between the conditions (Friedman test) and a high concordance measure (Kendall's W). This result is robust across theoretical and simulation-based methods.

The Kendall's W value of 0.64 (indicating strong agreement) and the highly significant chi-square statistic ($\chi^2(2) = 77.00, p < .001$) 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 this study, particularly the prominence of financial and socio-personal barriers, were consistently perceived across the respondent groups, 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 the challenges. The low p-values ($< .001$) confirm that the observed rankings are statistically significant and not due to chance, reinforcing the reliability of the RBQ outcomes. In the socio-personal domain, the top constraint was the preference for conventional practices (RBQ = 84.44%), supported by Kendall's W, highlighting a strong consensus among farmers. This finding aligns with the 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%) were highlighted. The large effect size ($W = 0.64$) supports the need for focused policy measures regarding practical training and infrastructure improvements. The strengths of this analysis lie in its methodological rigor,

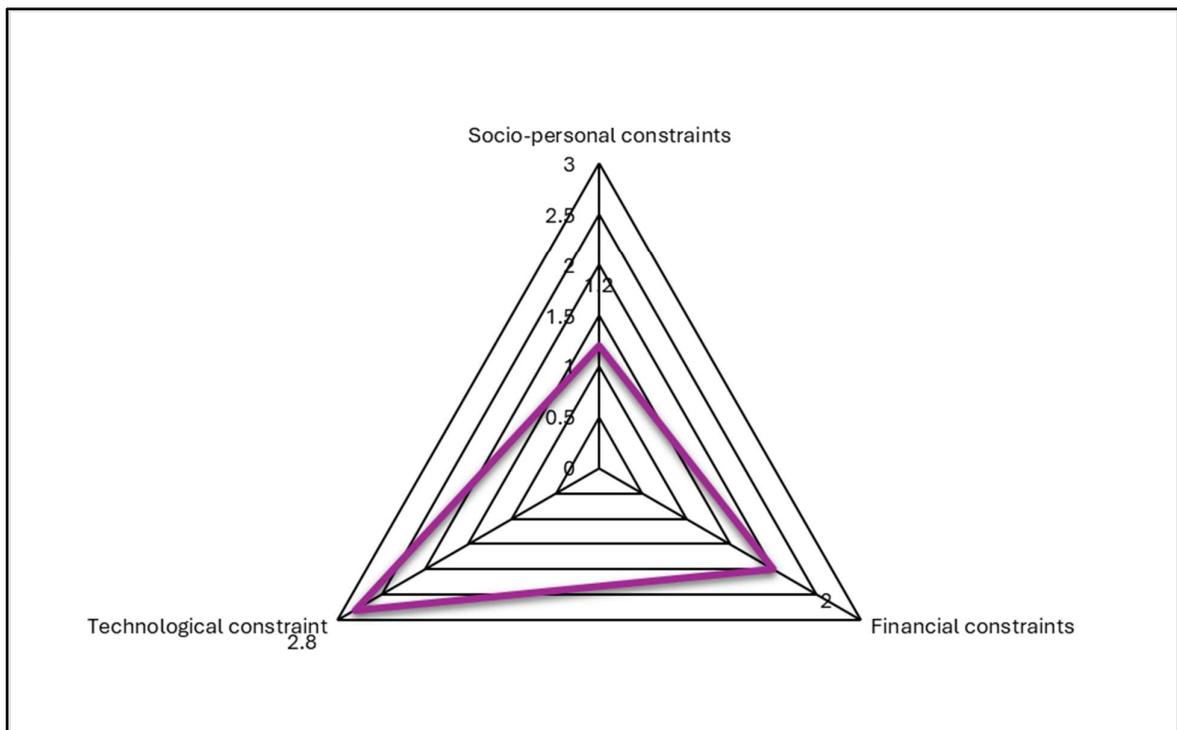


Fig. 8: Radar chart depicting the comparative ranking of various constraints through Kendall's W mean value.

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

combining the RBQ to rank constraints with Kendall's W to measure consensus, thus providing a robust mixed-methods approach. This interpretation is aligned with that of Mallick et al. (2023a).

The statistical significance of the constraints, particularly 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 Kendall's $W = 0.64$ and $\chi^2(2) = 77.00$, $p < .001$, which strengthens the credibility by demonstrating that the constraints identified through the 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. (2023b).

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 who are hesitant to take risks. Extension personnel and scientists must play active roles 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 in 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 and drought-tolerant seed varieties at affordable rates. This will ensure that 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 their resilience. Financial support and follow-up interventions are required to sustain these activities. Although methodologically robust, the present study is limited by its quantitative orientation. Future research should adopt a mixed-methods approach to capture the nuanced behavioral and experiential dimensions of constraint perception. Qualitative interviews and focus groups can yield a deeper understanding of farmer psychology, risk aversion, and systemic trust issues regarding 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 farm-level implementation. If implemented effectively, these interventions can enhance farmers' adaptive capacity and contribute to sustainable agricultural development. Table 5 shows the policy matrix highlighting major

Table 5: 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-VCRM, State Agri Department, MANREGA

constraints, suggested actions concerning the constraints, and the implementing agency.

CONCLUSIONS

This study comprehensively analyzed the socio-personal, financial, and technological constraints affecting the adoption of climate-resilient agricultural technologies by farmers in the NICRA villages of Jharsuguda district, Odisha. To translate the 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 the 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. Scaling up successful interventions through digital platforms, village-level cooperatives, and decentralized climate services can further enhance their reach and impact. These findings provide a policy roadmap for institutional actors seeking to mainstream adaptive agriculture in vulnerable areas.

ACKNOWLEDGEMENTS

I sincerely thank the Head of the Department, Department of Extension Education, and all faculty members of the College of Agriculture, OUAT, Bhubaneswar, and the SMS Staff members of KVK, Jharsuguda, for their guidance and support. Special appreciation goes to Biswajit Mallick (Ph.D. 3rd year) for his constant motivation and insightful suggestions. I'm grateful to the Ph.D. seniors for their encouragement throughout the study. My heartfelt thanks to the farmers, Krishak Sathis, VAWs of the Tharkuspur NICRA village, and the agricultural department staff of the Jharsuguda block for their cooperation and valuable contributions to this research.

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