Turkish Journal of Agriculture - Food Science and Technology, 14(2): 325-337, 2026
DOI: https://doi.org/10.24925/turjaf.v14i2.325-337.7781

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Comparative Economics on Rice (*Oryza sativa* L.) Production of Climate Smart Agriculture Adopted Farmers and Non-Adopted Farmers of Kapilvastu District, Nepal

Sunita Regmi[1,a], Sudip Ghimire[1,b,*], Shreeja Acharya[1,c]

[1]*Faculty of Agriculture, Agriculture and Forestry University, Nepal*
[*]*Corresponding author*

ARTICLE INFO

Research Article

Received : 20.04.2025
Accepted : 01.02.2026

Keywords:
Benefit-cost ratio
Climate-smart agriculture
Chi-square tests
Integrated pest management
Rice

ABSTRACT

Rice (*Oryza sativa*) is a vital staple crop, yet its production is increasingly threatened by climate variability. Climate-Smart Agriculture (CSA) offers potential strategies to improve productivity and resilience under changing climatic conditions. This study compared the economics of rice production between CSA-adopted and non-adopted farmers in Kapilvastu district, Nepal, hypothesizing that CSA adoption enhances farm profitability and resilience. A cross-sectional survey of 68 randomly selected farmers (34 CSA adopters and 34 non-adopters) was conducted using a multistage stratified random sampling technique. Data were analyzed using chi-square tests, independent *t*-tests, and Benefit Cost Ratio (BCR) analysis. Most households reported increased rainfall intensity, flood severity and frequency, hailstone severity, and hot days, irrespective of CSA adoption status. The total variable cost of production was significantly higher for non-adopted farmers (NRs 143,500), whereas total returns were significantly higher for CSA-adopted farmers (NRs 282,490). Rice cultivation was economically viable only under CSA adoption, with BCR values of 1.57 for CSA adopters and 0.98 for non-adopters. CSA-adopted farmers had greater access to training, credit, extension services, and education compared to non-adopters. Erratic rainfall was identified as a major production constraint by both groups. The findings highlight the economic and resilience benefits of CSA adoption in rice farming under climate variability.

[a] regmisunita1999@gmail.com https://orcid.org/0009-0001-8391-6350
[b] ghimiresudip858@gmail.com https://orcid.org/0000-0003-2795-1351
[c] shreejacharya56@gmail.com https://orcid.org/0009-0000-4493-7581

This work is licensed under Creative Commons Attribution 4.0 International License

Introduction

Rice (*Oryza sativa* L.) is the primary food crop for over 3.5 billion people (Acharya et al., 2024; Bhatt et al., 2024). It ranks second globally, following maize (Papageorgiou & Skendi, 2018), and is a staple for over half of the world's population, with about 90% produced and consumed in the Asia-Pacific region (Bhatt & Ghimire, 2024; Papademetriou, 2000). Agriculture remains the backbone of the economy in Nepal, with rice occupying a prominent position as the most significant cereal crop. It covers 1.49 million ha, contributing approximately 28% of the agricultural Gross Domestic Product (GDP) (MoALD, 2021). Kapilvastu is a major rice-producing district in Nepal's Terai region which spans 66,170 ha of rice fields, yielding 232,035 t annually with an average productivity of 3.51 tha^{-1} (MoALD, 2021). Despite this, the region faces challenges in meeting the rising demand for rice due to climatic variability, traditional agricultural practices, and limited technological advancements.

Rice productivity in Nepal is increasingly constrained by climate change, characterized by erratic rainfall patterns, hailstorms, rising temperatures, and unavailability of quality inputs (Ghimire et al., 2023). These factors have escalated production costs, lowered yields, and exacerbated food insecurity in vulnerable regions. Compounding this issue, traditional farming practices and inadequate knowledge of effective fertilizer use further hinder productivity (Yadav et al., 2024). The absence of robust economic data comparing traditional and climate-adaptive practices creates a significant knowledge gap, limiting farmers' ability to assess the true costs and benefits of their farming systems. Despite its importance, rice productivity in Nepal struggles to meet increasing demand, exacerbated by the limited adoption of modern technologies and the impacts of climate change.

Climate is one of the components that significantly influence agricultural production (Chhetri & Ghimire,

2023). Climate change threatens agriculture, with notable declines in rice yields. Nepal is highly vulnerable to climate change, necessitating adaptive strategies for agricultural development (Gentle & Maraseni, 2012). In several parts of the world, the impact of climate change has been seen clearly. There will be a 21% decline in winter wheat yield, a 17.3% decline in winter barley yield, and a 33.6% decline in spring by the end of the century (Wang et al., 2018). High rainfall intensity in an erratic manner, followed by hailstone during rice harvesting and unavailability of quality inputs, has increased production costs and reduced rice productivity. Agricultural production has declined, and crop diseases have increased due to climate change, while insufficient knowledge of fertilizer management has worsened these challenges (Acharya et al., 2024; Gautam et al., 2024). Following the same cropping pattern as before also decreases crop yield. The problem of food deficit can be seen more shortly if the issue of climate change is not addressed through the adaptation measures.

Climate Smart Agriculture (CSA), introduced by the Food and Agriculture Organization (FAO) in 2010, aims to foster sustainable farming practices under changing climatic conditions. CSA has emerged as a transformative approach to mitigate climate risks, integrating precision irrigation, Integrated Pest Management (IPM), and resilient cropping systems (Hussain et al., 2022). CSA integrates practices that increase agricultural productivity to support livelihoods and food security, enhance resilience by adapting farming systems to climate variability and reduce greenhouse gas emissions where possible (Ghimire & Poudel Chhetri, 2023). Examples of CSA practices include the use of drought-resistant crop varieties, efficient water management, conservation tillage, integrated pest management, and agroforestry systems (Abhilash et al., 2021). In addition to mitigating climate risks, CSA fosters sustainability by aligning with national food security and development goals (FAO, 2013). Despite its benefits, the adoption of CSA practices in Nepal remains uneven, largely due to a lack of awareness, technical expertise, and financial resources.

The economic advantage of CSA can be explained through agricultural technology adoption and production efficiency theories. Adoption theory suggests that farmers adopt new technologies when the expected economic benefits outweigh those of existing practices, subject to constraints such as access to information, credit, education, and risk perception. CSA practices reduce climate-induced production risks and enhance expected returns, thereby encouraging adoption. From the perspective of production and efficiency theory, CSA improves technical and allocative efficiency by enabling farmers to produce higher output with available inputs through improved resource-use efficiency and reduced yield variability. Furthermore, human capital theory highlights that access to training, extension services, and institutional support enhances farmers' capacity to effectively implement CSA practices, leading to improved productivity and profitability. Therefore, CSA adoption is theoretically expected to generate higher returns and BCRs compared to conventional farming practices.

Evaluating the economic benefits of CSA adoption is essential given the critical role of rice in Nepal's food security and the increasing impacts of climate change (Pandeya et al., 2024). Kapilvastu provides a suitable context to compare the performance of CSA-adopted farmers with those relying on traditional methods. This study offers insights into the potential of CSA to improve rice productivity and resilience in Nepal by bridging the knowledge gap. This study examines the comparative economics of rice production between CSA adopters and non-adopters in Kapilvastu district, Nepal. While existing research emphasizes the adverse effects of climate change on agriculture, few studies explore the economic feasibility and practical benefits of CSA practices in rice farming within the Nepalese context.

A significant gap exists between potential and actual rice yields due to climate change, reliance on weather, and traditional agricultural practices. Information on the economics of rice production in Nepal remains limited. Many farmers struggle to calculate the true costs and returns of rice cultivation or to identify factors for improvement. This study aimed to compare the economics of rice production between farmers who have adopted CSA practices and those who have not. We hypothesized that adopting CSA practices significantly improves the economic outcomes of rice production compared to non-adopters. The findings offer valuable insights for agriculturists and stakeholders on the effectiveness and necessity of adopting technology to manage climate risks and mitigate the impacts of global warming. Additionally, the results help raise knowledge and awareness about climate change among farmers.

Materials and Methods

Study Site and Sampling Technique

This study was conducted in Kapilvastu Municipality, specifically in two purposefully selected villages, namely, Sauraha and Ramghat (Figure 1), which were part of the rice super zone implementation unit of Prime Minister Agriculture Modernization Project (PMAMP) from February 2022 to July, 2022. A rice super zone in Nepal is a large, strategically selected area where the government concentrates resources and agricultural innovations to transform rice farming into a more productive, market-oriented, and technology-driven system. Geographically, the study area is located between latitudes 27°25' to 27°49' and longitudes 82°41' to 83°14'. A multistage stratified random sampling method was used, selecting 68 farmers (34 CSA-adopted, 34 non-adopted) based on randomized proportional representation. The selection was carried out using Rao soft software (Version 2004) with 95% confidence level and 5% margin of error.

Data Collection

Primary data was collected directly from respondents involved in rice production at the study site. This data was obtained through direct interviews (Household survey), Focus Group Discussions (FGD), and Key Informant Interviews (KII) (Ghimire & Rauniyar, 2023). The household survey was conducted among sixty-eight respondents from two villages to gather data. Each interview was conducted with individual farmers. An initial interview schedule was developed based on preliminary findings from five households in the locality.

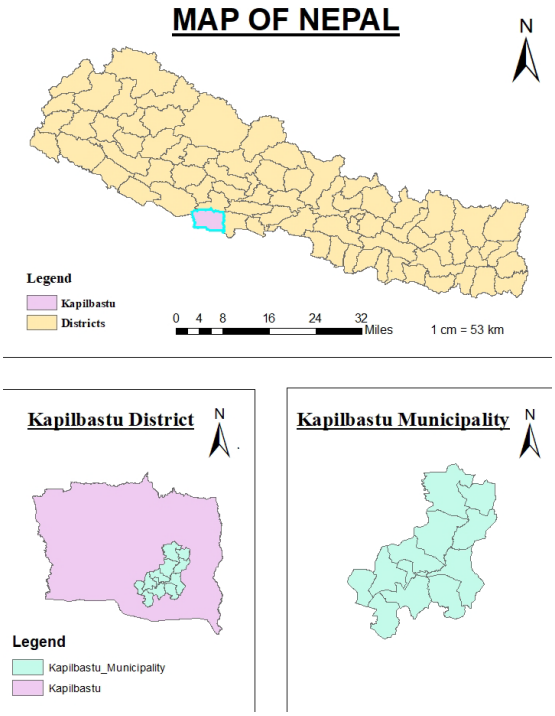

Figure 1. Map of Nepal showing study sites.

The final interview schedule was refined by incorporating feedback from the pretesting phase (Ghimire & Chhetri, 2023) and a pretested questionnaire (Supplementary 1). Four FGDs were held to understand the past and present climatic conditions and their effects on agricultural production. The discussion included experienced farmers, cooperative leaders, and local leaders. The KIIs were conducted with agro-vet professionals, lead farmers, and teachers to gain insights into changing climate conditions in the study area.

Secondary data was sourced from various journals, research articles, the statistical book of the Department of Agriculture Development (DADO), production and productivity data from the Ministry of Agriculture and Livestock Development (MoALD), and reports from the Intergovernmental Panel on Climate Change (IPCC) (Thapa et al., 2024). Ethical clearance was obtained from the Institutional Review Board (IRB) of Agriculture and Forestry University, Nepal.

Statistical Analysis

General descriptive method

The collected data underwent editing and local units of measurement were standardized to scientific units. Important primary data collected from households were entered into MS Excel 2019 and the Statistical Package for the Social Sciences (SPSS) program (Version 25.0) for further analysis. The data were analyzed using descriptive methods, specifically through frequencies and percentages.

Chi-Square test or test of independence

In order to study whether two variables were independent or associated with each other, chi-square was applied (Equation 1).

$$X2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \quad (1)$$

Where,

χ^2 = Chi-square,

O_{ij} = observed frequency of each ijth term,

E_{ij}= indicates expected frequency of ijth term, I = 1, 2, 3…….,r, and J = 1, 2, 3……k. This was tested at 0.05 or 0.01 level of probability for different degrees of freedom.

Indexing

Problems faced by respondents on adopting improved production technology of rice were ranked with the use of the index. Scaling techniques, which provide the direction and extremity attitude of the respondent towards any proposition was used to construct index (Ghimire & Rauniyar, 2023). The intensity of problems and measures were identified by using eight-point scaling technique using scores of 1.00, 0.875, 0.75, 0.625, 0.50, 0.375, 0.25 and 0.125. The formula given below was used to find the index (Equation 2).

$$\text{Iprob} = \frac{\Sigma SiFi}{N} \quad (2)$$

Where,

I_{prob} = Index value for intensity,

Σ = Summation,

S_i = Scale value of ith intensity,

F_i = Frequency of ith response, and

N = Total number of respondents.

Cost and return analysis

Total Variable Cost (TVC) was calculated by summing the expenses for all variable inputs, including seeds, fertilizers, plant protection measures, machinery usage, labor, and transportation (Dawadi et al., 2023). The formula is as follows (Equation 3).

$$TVC = CS + CF + CPP + +CL + CT \quad (3)$$

CS : C seed
CF : C fertilizer
CPP : C plant protection
CM : C machinery
CL : C labor
CT : C transportation

Where, cost of fertilizers includes Farmyard manure (FYM), urea, Di-ammonium phosphate (DAP) and potash,

$$C_{\text{Fertilizer}} = C_{\text{FYM}} + C_{\text{Urea}} + C_{\text{DAP}} + C_{\text{Potash}};$$

cost of plant protection includes pesticides and herbicides,

$$C_{\text{Plant protection}} = C_{\text{Pesticides}} + C_{\text{Herbicides}};$$

cost of machinery includes tillage, irrigation and threshing,

$$C_{\text{Machinery}} = C_{\text{Tillage}} + C_{\text{Irrigation}} + C_{\text{Threshing}},$$

cost of labor includes family labor and rental labor,

$$C_{\text{Labor}} = C_{\text{Family labor}} + C_{\text{Rental labor}},$$

and cost of transportation represents the cost of moving inputs to the farm and outputs to the market.

Total cost was calculated by adding TVC and Total Fixed Cost (TFC) as shown in Equation 4. TFC include land rental value, depreciation of tools and implements, interest on fixed capital (Equation 5).

Rice revenue or husk value was calculated by multiplying quantity produced by the average price of the harvesting period (Equation 6). Gross return was calculated by adding the total amount of rice grain and straw produced (Equation 7). The Benefit-Cost Ratio (BCR), an indicator of economic efficiency, was calculated as the ratio of gross return to total cost (Equation 8).

$$\text{Total cost} = \text{TFC} + \text{TVC} \quad (4)$$

$$\text{TVC} = \text{LRV} + \text{DTM} + \text{IFC} \quad (5)$$

LRV : Land rental value
DTM: Depreciation of tools and machinery
IFC : Interest on fixed capital

$$\text{RRH} = \text{QP} \times \text{Market price per unit} \quad (6)$$

RRH: Rice revenue or rice husk value
QP : Quantity produced

$$\text{Gross return} = \text{Rice revenue} + \text{Rice husk value} \quad (7)$$

$$\text{BCR} = \frac{\text{Gross return}}{\text{Total cost}} \quad (8)$$

Results and Discussion

Socio-Demographic Characters

Household head

The average age of the head of household for farmers who adopted CSA practices and those who did not is presented in Table 1. The mean age of adopters (52.59 years) and non-adopters (55.44 years) did not differ significantly, indicating that adoption of CSA practices does not significantly affect the age of the household head. The overall average age was 54.02 years.

Among sampled households, 76.5% were male-headed, while 23.5% were female-headed (Table 2). The chi-square test showed no significant association between CSA adoption and the gender of the head of household (χ^2 = 1.308, p = 0.235).

Education levels varied between adopters and non-adopters (Table 3). Among non-adopters, 67.6% of heads of household were illiterate, followed by 20.6% with primary education, and 8.8% with secondary education. In contrast, adopters had higher education levels, with 41.2% having primary education and 5.9% having higher education. The chi-square test indicated that education level was significantly associated with CSA adoption (χ^2 = 98.57, p = 0.043), suggesting that better-educated heads of household are more likely to adopt modern agricultural technologies.

Most households were Hindu (75%), with the remaining 25% being Muslim (Table 4). CSA adoption was not significantly associated with religion (χ^2 = 0.706, p = 0.401).

Table 1. Age of household head of sample.

Farmers group	Mean	MD	t-test
Adopted farmer (n=34)	52.59	-2.853	-1.475^{ns}
Non-adopted farmer (n=34)	55.44		(0.613)
Overall (n=68)	54.015		

ns = non-significant; MD: Mean difference

Table 2. Gender of household head.

Gender of household head	Overall (n=68)	Farmers group		Chi-square value
		Non-adopted farmer (n=34)	Adopted farmer (n=34)	
Male	52 (76.5%)	24 (70.6%)	28 (82.4%)	1.308^{ns}
Female	16 (23.5%)	10 (29.4%)	6 (17.6%)	(0.235)

ns = non-significant.

Table 3. Education level of household head.

Education of household head	Farmers group		Overall (n=68)	Chi-square value
	Non-adopted farmer (n=34)	Adopted farmer (n=34)		
Illiterate	23 (67.6%)	13 (38.2%)	36 (52.9%)	98.57** (0.043)
Primary	7 (20.6%)	14 (41.2%)	21 (30.9%)	
Secondary	3 (8.8%)	5 (14.7%)	8 (11.75%)	
Higher	0 (0%)	2 (5.9%)	2 (2.95%)	
Graduate	1 (2.9%)	0 (0.0%)	1 (1.45%)	

** = significant at p≤0.01.

Table 4. Religion of household head.

Religion of household head	Overall (n=34)	Farmers group		Chi Square value
		Non-adopted farmer (n=34)	Adopted farmer (n=34)	
Hindu	51 (75%)	27 (79.4%)	24 (70.6%)	0.706^{ns}
Muslim	17 (25%)	7 (20.6%)	10 (29.4%)	(0.401)

ns = non-significant.

Table 5. Response on weather parameters and climate hazards.

Weather parameters	Changes	Overall (n=68)	Farmers group		Chi-square value
			Non-adopted farmer (n=34)	Adopted farmer (n=34)	
Rainfall intensity	Increased	57 (83.8%)	30 (88.2%)	27 (79.4%)	1.486 (0.476) ns
	Decreased	7 (10.3%)	2 (5.9%)	5 (14.7%)	
	Same	4 (5.9%)	2 (5.9%)	2 (5.9%)	
Rainfall duration	Increased	16 (23.5%)	8 (23.5%)	8 (23.5%)	0.000 (1.000) ns
	Decreased	48 (70.6%)	24 (70.6%)	24 (70.6%)	
	Same	4 (5.9%)	2 (5.9%)	2 (5.9%)	
Drought severity	Increased	8 (11.8%)	4 (11.8%)	4 (11.8%)	23.568 (0.000) ***
	Decreased	39 (57.4%)	11 (32.4%)	28 (82.4%)	
	Same	21 (30.9%)	19 (55.9%)	2 (5.9%)	
Flood severity	Increased	52 (76.5%)	21 (61.8%)	31 (91.2%)	11.687 (0.003) ***
	Decreased	4 (5.9%)	2 (5.9%)	2 (5.9%)	
	Same	12 (17.65%)	11 (32.4%)	1 (2.9%)	
Flood frequency	Increased	38 (55.9%)	24 (70.6%)	14 (41.2%)	6.610 (0.037) **
	Decreased	4 (5.9%)	2 (5.9%)	2 (5.9%)	
	Same	26 (38.2%)	8 (23.5%)	18 (52.9%)	
Drought frequency	Increased	24 (35.3%)	16 (47.1%)	8 (23.5%)	10.687 (0.005) ***
	Decreased	35 (51.5%)	11 (32.4%)	24 (70.6%)	
	Same	9 (13.25%)	7 (20.6%)	2 (5.9%)	
Hail stone severity	Increased	41 (60.3%)	30 (88.2%)	11 (32.4%)	27.445 (0.000) ***
	Decreased	4 (5.9%)	2 (5.9%)	2 (5.9%)	
	Same	23 (33.85%)	2 (5.9%)	21 (61.8%)	
Strom amount and severity	Increased	47 (69.15%)	21 (61.8%)	26 (76.5%)	1.722 (0.189) ns
	Decreased	0 (0%)	0 (0%)	0 (0%)	
	Same	21 (30.85%)	13 (38.2%)	8 (23.5%)	
Number of hot days	Increased	52 (76.5%)	25 (73.5%)	27 (79.5%)	0.363 (0.834) ns
	Decreased	2 (2.9%)	1 (2.9%)	1 (2.9%)	
	Same	14 (20.5%)	8 (23.5%)	6 (17.5%)	
Number of monsoon days	Increased	7 (10.2%)	2 (5.9%)	5 (14.5%)	2.361 (0.307) ns
	Decreased	45 (66.15%)	22 (64.7%)	23 (67.6%)	
	Same	16 (23.5%)	10 (29.4%)	6 (17.6%)	

ns = non-significant, ** = significant at p≤0.01, *** = significant at p≤0.001.

Perception of Farmer on Climate Change

Response on change in various weather parameters and climate induce hazards

Farmers' perceptions of climate change regarding various weather parameters and climate-induced hazards are presented in Table 5, comparing CSA adopters and non-adopters.

- Significant differences between adopters and non-adopters:
- Drought severity: 82.4% of adopters perceived a decrease, compared to 32.4% of non-adopters (Chi-square: 23.568, p = 0.000).
- Drought frequency: 70.6% of adopters reported a decrease versus 32.4% of non-adopters (Chi-square: 10.687, p = 0.005).
- Flood severity: 91.2% of adopters perceived an increase, compared to 61.8% of non-adopters (Chi-square: 11.687, p = 0.003).
- Flood frequency: 41.2% of adopters reported an increase, versus 70.6% of non-adopters (Chi-square: 6.610, p = 0.037).
- Hailstone severity: 61.8% of adopters perceived stability, while 88.2% of non-adopters reported an increase (Chi-square: 27.445, p = 0.000).
- No significant differences between adopters and non-adopters:
- Rainfall intensity (Chi-square: 1.486, p = 0.476),
- Rainfall duration (Chi-square: 0.000, p = 1.000),
- Storm amount and severity (Chi-square: 1.722, p = 0.189),
- Number of hot days (Chi-square: 0.363, p = 0.834),
- Number of monsoon days (Chi-square: 2.361, p = 0.307).

These results indicate that CSA adoption is associated with differences in the perception of key climate hazards, particularly drought, flood, and hailstone severity, while other weather parameters were perceived similarly by both groups.

Adaptation Practices Adopted by Farmers Against Climate Change

Table 6 presents the adaptation practices adopted by CSA-adopted and CSA non-adopted farmers against climate change. The Chi-square test revealed a significant association between CSA adoption status and most climate adaptation practices at the 1% level of significance, indicating a clear difference in adaptive behavior between the two groups.

Water management practices were more widely adopted by CSA farmers. The use of pump sets was observed among all CSA-adopted farmers (100%), compared to only 11.8% of non-adopted farmers (Chi-square: 53.684, p = 0.000), highlighting improved access to supplemental irrigation under CSA. Drainage management was practiced by both groups, with slightly higher adoption among CSA farmers (76.5%) than non-adopters (64.7%). Drainage management was widely practiced by both groups likely due to regional water policies and availability of basic drainage infrastructure. These practices enhance water availability and can improve yield stability under climate variability. However, rainwater harvesting did not show a significant difference between CSA-adopted and non-adopted farmers (Chi-square: 0.066, p = 0.768), suggesting limited diffusion of this practice across both groups.

Input use efficiency and soil fertility management practices were predominantly adopted by CSA farmers. All CSA farmers used leaf color charts (100%) to optimize nitrogen application, whereas none of the non-adopted farmers practiced this method (Chi-square: 68.000, p = 0.000). Similarly, improved Farmyard Manure (FYM) management and soil testing were significantly more common among CSA farmers, with 100% and 73.5% adoption, respectively, compared to no adoption among non-adopted farmers (Chi-square: 53.684 and 39.535, p = 0.000). Integrated Pest Management combined with chemical control was practiced by 79.4% of CSA farmers, while none of the non-adopted farmers adopted this approach, reflecting better pest management efficiency among CSA adopters. These measures enhance nutrient use efficiency, improve soil fertility, and reduce pest-related crop losses, contributing to higher productivity and resilience under climate stress.

Crop and varietal management practices also showed strong differentiation between the two groups. All CSA-adopted farmers used short-duration rice varieties (100%), drought-tolerant varieties (100%), and hybrid varieties (100%), whereas adoption among non-adopted farmers ranged from 0% to 29.4%. Direct-seeded rice (DSR) was adopted by 29.4% of CSA farmers, while none of the non-adopted farmers practiced it (Chi-square: 11.724, p = 0.001). Green manuring was practiced by 79.4% of CSA farmers compared to only 8.8% of non-adopters (Chi-square: 34.358, p = 0.000), indicating improved soil health management under CSA.

Table 6. Adaptation practices adopted by farmers against climate change.

CSA component	Adaptation practices	Status	Overall (n=68)	Non-adopted farmers (n=34)	CSA-adopted farmers (n=34)	Chi-square value
Water management practices	Pump set use	Yes	38 (55.9%)	4 (11.8%)	34 (100%)	53.684*** (0.000)
		No	30 (44.1%)	30 (88.2%)	0 (0%)	
	Drainage management	Yes	48 (70.6%)	22 (64.7%)	26 (76.5%)	1.133ns (0.287)
		No	20 (29.4%)	12 (35.3%)	8 (23.5%)	
	Rainwater harvesting	Yes	23 (33.8%)	11 (32.4%)	12 (35.3%)	0.066ns (0.768)
		No	45 (66.2%)	23 (67.6%)	22 (64.7%)	
Input use efficiency and soil fertility management	Leaf color chart	Yes	34 (50.0%)	0 (0%)	34 (100%)	68.000*** (0.000)
		No	34 (50.0%)	34 (100%)	0 (0%)	
	Improved FYM	Yes	38 (55.7%)	4 (11.8%)	34 (100%)	53.684*** (0.000)
		No	30 (44.3%)	30 (88.2%)	0 (0%)	
	Soil testing	Yes	25 (36.8%)	0 (0%)	25 (73.5%)	39.535*** (0.000)
		No	43 (63.2%)	34 (100%)	9 (26.5%)	
	Chemical + IPM	Yes	27 (39.7%)	0 (0%)	27 (79.4%)	44.780*** (0.000)
		No	41 (60.3%)	34 (100%)	7 (20.6%)	
Crop and varietal management practices	Drought-tolerant variety	Yes	44 (64.7%)	10 (29.4%)	34 (100%)	37.091*** (0.000)
		No	24 (35.3%)	24 (70.6%)	0 (0%)	
	Short-duration variety	Yes	34 (50.0%)	0 (0%)	34 (100%)	68.000*** (0.000)
		No	34 (50.0%)	34 (100%)	0 (0%)	
	Hybrid variety	Yes	44 (64.7%)	10 (29.4%)	34 (100%)	37.091*** (0.000)
		No	24 (35.3%)	24 (70.6%)	0 (0%)	
	Direct-seeded rice (DSR)	Yes	10 (14.7%)	0 (0%)	10 (29.4%)	11.724*** (0.001)
		No	58 (85.3%)	34 (100%)	24 (70.6%)	
	Green manuring	Yes	30 (44.1%)	3 (8.8%)	27 (79.4%)	34.358*** (0.000)
		No	38 (55.9%)	31 (91.2%)	7 (20.6%)	
Climate-resilient adjustment practices	Relay cropping	Yes	24 (35.3%)	0 (0%)	24 (70.6%)	37.091*** (0.000)
		No	44 (64.7%)	34 (100%)	10 (29.4%)	
	Planting time shifting	Yes	39 (57.4%)	5 (14.7%)	34 (100%)	50.564*** (0.000)
		No	29 (42.6%)	29 (85.3%)	0 (0%)	
	Harvesting time shifting	Yes	38 (55.9%)	4 (11.8%)	34 (100%)	53.684*** (0.000)
		No	30 (44.1%)	30 (88.2%)	0 (0%)	
Widely adopted practice	Seed priming	Yes	68 (100%)	34 (100%)	34 (100%)	0 ns (1.000)
		No	0 (0%)	0 (0%)	0 (0%)	

ns = non-significant, *** = significant at p≤0.001.

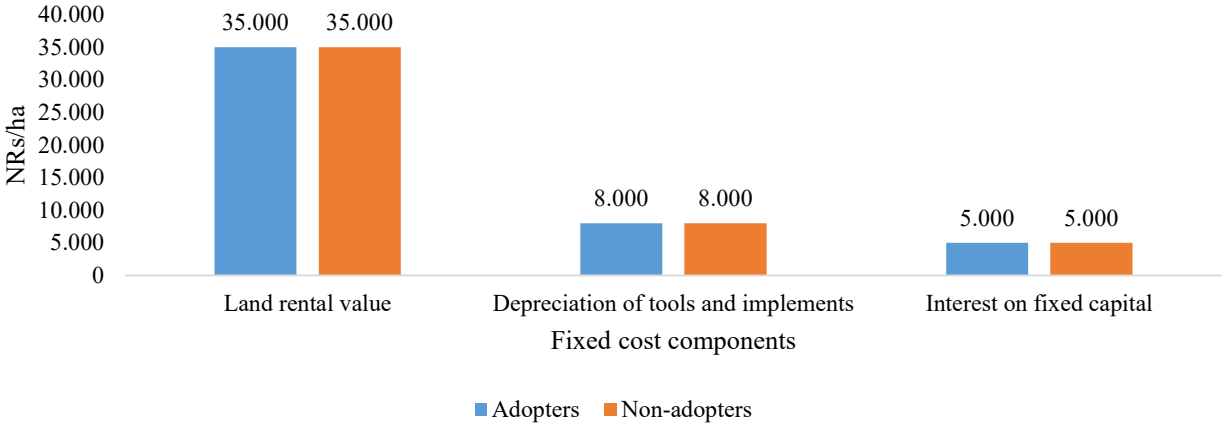

Figure 2. Fixed costs per hectare.

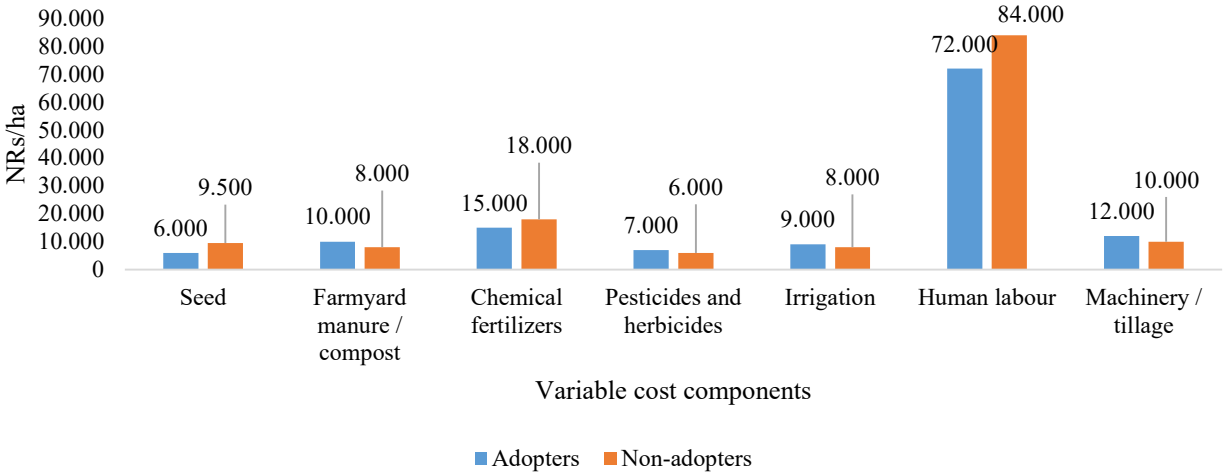

Figure 3. Variable cost components.

Climate-resilient adjustment practices, such as relay cropping and calendar-based adjustments, were almost exclusively adopted by CSA farmers. Relay cropping was practiced by 70.6% of CSA farmers, whereas none of the non-adopted farmers adopted this practice (Chi-square: 37.091, p = 0.000). Shifting of planting time and harvesting time was implemented by all CSA farmers (100%), compared to only 14.7% and 11.8% of non-adopted farmers, respectively (Chi-square: 50.564 and 53.684, p = 0.000), demonstrating greater adaptive flexibility among CSA adopters.

Seed priming was the only adaptation practice adopted uniformly by both CSA-adopted and non-adopted farmers (100%), indicating its widespread acceptance irrespective of CSA status. This might be likely due to its simplicity, low cost, and widespread awareness in the region.

Cost of Production

Total fixed cost

Fixed costs per hectare were estimated at NRs 48,000, which include land rental value, depreciation of tools and implements, interest on fixed capital (Figure 2). These costs are incurred regardless of the level of production and represent the baseline investment required to maintain productive capacity. The inclusion of fixed costs highlights the substantial financial commitment required to operate a rice farm.

Total variable cost

Variable costs cover inputs that change with the scale of production, fixed costs reflect long-term and essential investments that ensure the farm remains functional and capable of sustaining productivity. The economic analysis of rice production revealed notable differences between CSA adopter and non-adopter farmers in terms of input use, cost, and productivity. For seed, CSA adopter farmers utilized improved drought-tolerant varieties at a cost of NRS 6,000 per hectare, with a unit price of NRS 30 per kilogram, while non-adopter farmers used local non-CSA varieties costing NRS 9,500 per hectare. Non-adopters used more seed because of lower quality, less efficient sowing methods, and risk management, whereas CSA adopters use recommended seed rates efficiently, which reduces input cost and improves overall productivity. The cost of farmyard manure or compost was NRS 10,000 per hectare for adopters and NRS 8,000 for non-adopters, applied at approximately 2,000 NRS per tons of well-decomposed material for adopters and mixed-quality material for non-adopters (Figure 3). Chemical fertilizers (Urea, DAP, and potash) were applied at recommended doses by CSA adopter farmers, costing NRS 15,000 per hectare, whereas non-adopter farmers applied fertilizers haphazardly exceeding the recommended doses, incurring a cost of NRS 18,000 per hectare. The higher fertilizer use among non-adopted farmers may be attributed to limited knowledge of recommended fertilizer

doses, the belief that higher fertilizer application results in higher yields, and the absence of guidance or extension support. Similarly, expenditures on pesticides and herbicides were NRS 7,000 and NRS 6,000 for adopters and non-adopters, respectively, reflecting differences in pest management practices. Irrigation costs were higher among CSA adopters (NRS 9,000/ha) due to the use of pump and canal systems, compared to NRS 8,000/ha for non-adopters relying mostly on manual or flood irrigation. Human labor was a major component of variable cost, with CSA adopters spending NRS 72,000 per hectare for 120 days of skilled and unskilled labor (NRS 600/day), whereas non-adopters spent NRS 84,000, relying primarily on unskilled labor. Machinery and tillage costs amounted to NRS 12,000 for adopters, who used tractors and harrows, and NRS 10,000 for non-adopters employing bullock-drawn implements or manual tools. Consequently, TVC were NRS 131,000 for CSA adopters and NRS 143,500 for non-adopters.

Rice Productivity

The analysis highlights a significant difference in productivity between CSA-adopted and non-adopted farmers. The overall productivity across all farmers was 2.916 t ha^{-1} (Table 7). However, CSA-adopted farmers achieved a notably higher average productivity of 3.44 t ha^{-1} compared to 2.39 t ha^{-1} for non-adopted farmers, resulting in a mean difference of 1.05 t ha^{1}. The t-test value of 5.209 and the p-value of 0.025 confirm that this difference is statistically significant at the 5% level. Rice husk per ha was 729 kg for adopter whereas 597.5 kg for non-adopters. The rice husk was valued at NRs 10 per kg. The rice husk contributed an additional NPR 7290/ha to the gross return of CSA adopters and NPR 5975/ha for non-adopters.

While the higher productivity among CSA-adopted farmers can be partially attributed to the adoption of climate-smart agriculture practices, other factors likely contributed to these differences. These include better soil fertility management, timely access to irrigation, more efficient use of inputs such as seed and fertilizers, improved labor management, and overall adherence to recommended farming techniques. It is important to note that CSA adoption alone does not fully explain the yield differences, and site-specific conditions and farmer management practices also play a significant role.

Total Cost and Return from Rice Production Per ha

Rice yields were higher for CSA adopters at 3.44 t/ha versus 2.39 t/ha for non-adopters. Figure 4 illustrates the difference in economics between CSA adopters and non-adopters in a bar chart.

At a market price of NPR 80,000/t, CSA adopters achieved higher rice revenue (NPR 275,200/ha) and rice husk value (NPR 7,290/ha), leading to a gross return of NPR 282,490/ha and a net return of NPR 103,490/ha, with a BCR of 1.58, indicating profitable production. Non-adopters obtained lower rice revenue (NPR 183,200/ha) and rice husk value (NPR 5,975/ha), resulting in a gross return of NPR 189,175/ha and a marginally negative net return (–NPR 2,325/ha), with a BCR of 0.98, suggesting near break-even performance (Figure 5).

Field observations and farmer interviews support these results. Many CSA-adopted farmers reported that the use of recommended fertilizer doses, timely planting, and integrated pest management practices helped reduce input costs while maintaining higher yields. One farmer noted that by following CSA methods, he spent less on unnecessary fertilizers and labor, but my rice yields improved, which made the investment worthwhile. Such real-world experiences illustrate the cost-effectiveness of CSA practices beyond the numerical BCR values.

Table 7. Productivity of rice production (t ha^{-1}).

Variables	Overall (n=68)	Adopted farmer (n=34)	Non-adopted farmer (n=34)	Mean difference	t-test
Productivity (t ha^{-1})	2.916	3.44	2.39	1.05	5.209*** (0.025)

*** = significant at p≤0.001.

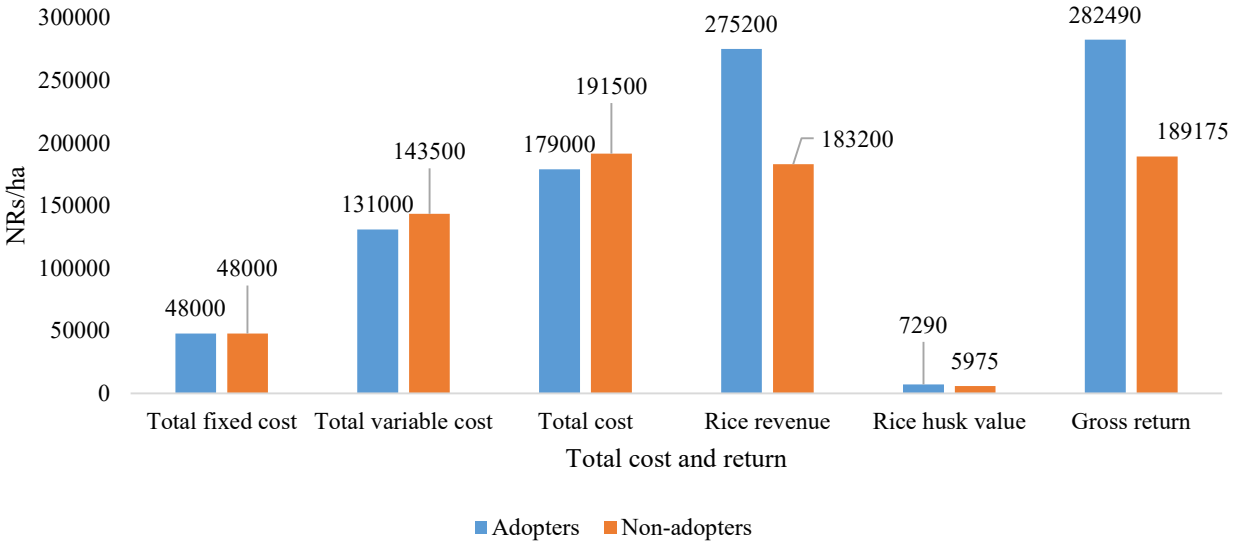

Figure 4. Economical comparison of fixes and variable cost as well as gross return among adopters and non-adopters.

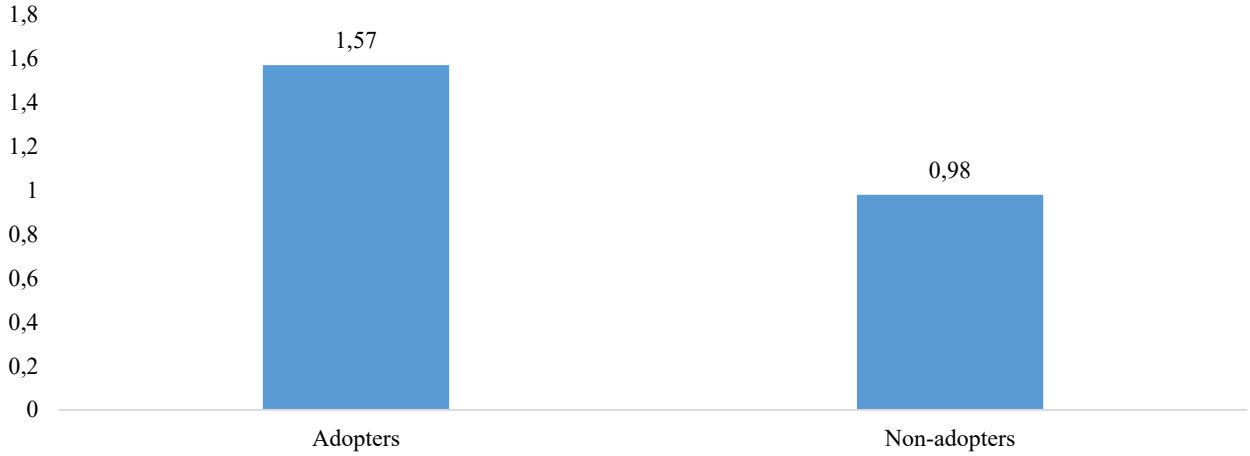

Figure 5. Benefit cost ratio among adopters and non-adopters.

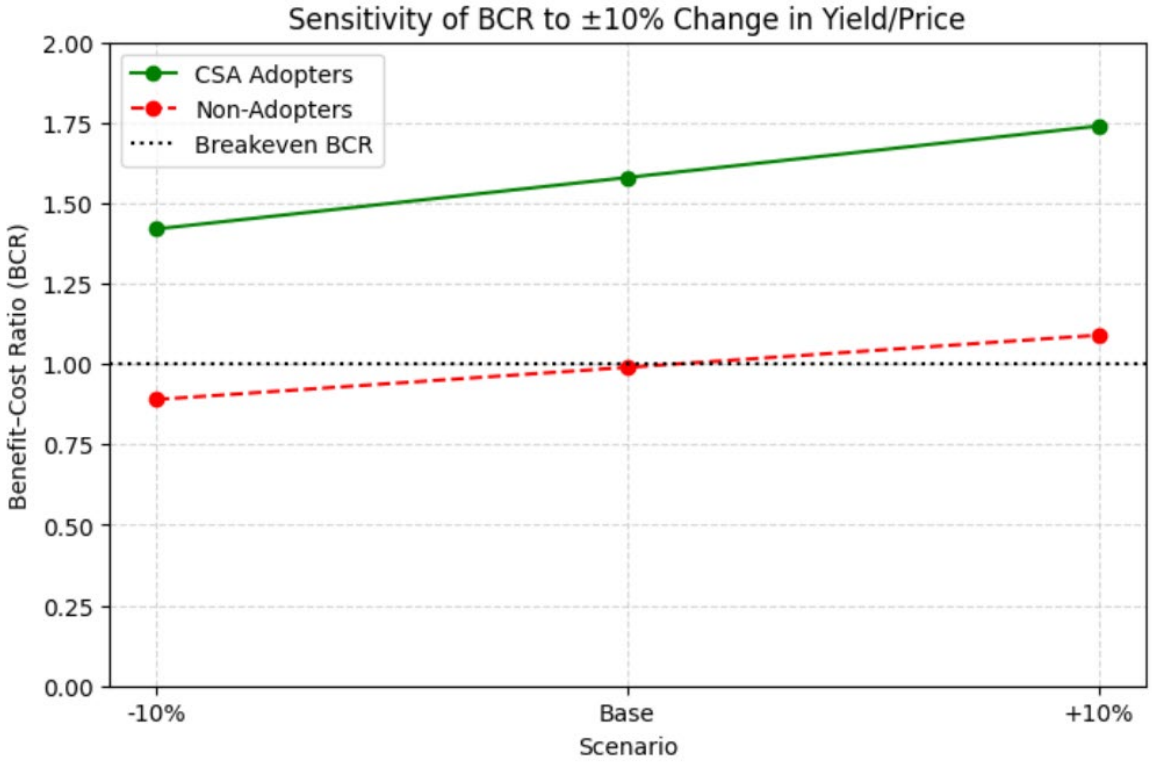

Figure 6. Graphical sensitivity analysis showing the impact of ±10% change in rice yield or price on BCR for CSA adopters and non-adopters.

Sensitivity Analysis

Sensitivity analysis was conducted to examine the impact of a ±10% change in rice yield or market price on BCR. For CSA adopters, a 10% reduction in yield or price decreased the BCR from 1.58 to 1.42, whereas a 10% increase raised the BCR to 1.74, demonstrating the resilience and profitability of CSA practices under moderate adverse conditions (Figure 6). In contrast, BCR for non-adopters was more vulnerable, decreasing to 0.89 under a 10% decline in yield or price, and increasing only to 1.09 with a 10% improvement. These results indicate that CSA adoption not only enhances productivity and profitability but also provides a buffer against climatic and market risks, whereas non-adopters remain economically susceptible.

Factor affecting adoption of technology

Table 8 outlines the factors influencing technology adoption among farmers who have adopted CSA and those who have not. Among the CSA-adopted farmers, 82.35% of respondents were members of organizations, whereas none of the CSA non-adopted farmers were members. Additionally, approximately 79.4% of CSA-adopted farmers had received training on climate interventions, compared to only 20.6% of CSA non-adopted farmers. Furthermore, 97.1% of CSA-adopted farmers received subsidies from government and non-governmental organizations, while only 11% of CSA non-adopted farmers did. All the CSA-adopted farmers had access to irrigation facilities and extension services, in contrast to none of the CSA non-adopted farmers having irrigation

facilities and only 14.7% having access to extension services. Access to credit services was available to 85.29% of CSA-adopted farmers, whereas only 20.58% of CSA non-adopted farmers had access.

The observed differences in technology adoption can be attributed to several socio-economic and institutional factors. Membership in farmer organizations likely facilitates knowledge sharing, access to training, and collective bargaining for inputs. Access to formal training, extension services, and irrigation improves farmers' technical capacity and confidence in adopting CSA practices. Similarly, financial support through subsidies and credit enables farmers to invest in inputs and implement new technologies. Demographic factors such as education level, age, and social networks may also influence adoption, as better-educated or younger farmers are often more open to innovations and risk-taking. These factors collectively explain why CSA adoption is higher among certain farmer groups, highlighting that adoption is influenced by both institutional support and individual characteristics, not solely by the technology itself.

Problem Faced by Respondents

The respondents in the study faced various challenges. Through FGDs, and KIIs, five significant problems were identified, and respondents were asked to rank them. Table 9 presents the ranking of problems faced by farmers based on their Relative Importance Index (RII) scores, categorized into non-adopted farmers, adopted farmers and an overall ranking for all respondents. The results indicate that weather parameters are the most critical issue across all groups, ranked first with the highest RII scores (0.717 for non-adopted, 0.882 for adopted and 0.799 overall). This highlights the pervasive impact of erratic weather patterns, such as droughts and floods, on agricultural activities, especially for adopted farmers who are more attuned to climate variability due to their practices. Respondents reported adopting several strategies, including timely planting based on seasonal forecasts, diversifying crops to reduce risk, using drought-tolerant or flood-resistant varieties, and participating in early warning systems provided by local extension services to cope with these weather-related challenges. Some farmers also mentioned accessing crop insurance schemes where available and practicing water management techniques such as small-scale irrigation or water harvesting to mitigate the impacts of erratic rainfall.

The unavailability of improved varieties and quality seeds was ranked second overall (RII = 0.63), with non-adopted farmers perceiving it as a slightly greater challenge (RII = 0.694, Rank II) compared to adopted farmers (RII = 0.58, Rank III) which suggests that non-adopted farmers face significant constraints in accessing high-quality inputs, which may hinder their agricultural productivity. Lack of securities was ranked third overall (RII = 0.608), with non-adopted farmers reporting a higher concern (RII = 0.665, Rank III) than adopted farmers (RII = 0.553, Rank IV), likely reflecting the greater financial and livelihood risks faced by non-adopted farmers.

The high incidence of diseases and pests ranked fourth overall (RII = 0.556). Interestingly, this issue is more prominent for adopted farmers (RII = 0.6, Rank II) than non-adopted farmers (RII = 0.512, Rank IV). This may be due to adopted farmers' increased awareness of crop health or the vulnerability of their high-yield varieties to pests and diseases. Labor shortages were consistently ranked as the least critical problem (Rank V) across all groups, with relatively low RII values (0.30 for non-adopted, 0.405 for adopted, and 0.393 overall). This suggests that labor shortages have a comparatively smaller impact on agricultural activities, possibly due to mechanization or alternative labor sources.

Table 8. Factor affecting adoption of technology.

Factors	Status	Overall (n=68)	Non-adopted farmer (n=34)	Adopted farmer (n=34)	Chi-square value
Member of organization	Yes	28 (41.20%)	0 (0%)	28 (82.35%)	47.6***
	No	40 (58.82%)	34 (100%)	6 (17.64%)	(0.000)
Training	Yes	34 (50.00%)	27 (79.40%)	34 (100%)	23.5***
	No	34 (50%)	7 (20%)	0 (0%)	(0.000)
Subsidy	Yes	37 (54.45%)	4 (11.80%)	33 (97.10%)	60.1***
	No	31 (45.55%)	30 (88.20%)	1 (2.90%)	(0.000)
Irrigation facility	Yes	34 (50.00%)	0 (0%)	34 (100%)	94.3***
	No	34 (50.00%)	34 (100%)	0 (0%)	(0.000)
Extension services	Yes	39 (57.35%)	5 (14.70%)	34 (100%)	64.4***
	No	29 (42.65%)	29 (85.20%)	0 (0%)	(0.000)
Credit services	Yes	36 (52.93%)	7 (20.58%)	29 (85.29%)	31.1***
	No	32 (40.05%)	27 (79.41%)	5 (14.70%)	(0.000)

*** = significant at p≤0.001.

Table 9. Ranking of problems faced by respondents.

Problems	Non-adopted farmer		Adopted farmer		Overall	
	RII	Rank	RII	Rank	RII	Rank
Labor shortage	0.30	V	0.405	V	0.393	V
Unavailability of improved varieties and quality seeds	0.694	II	0.58	III	0.63	II
Weather parameters	0.717	I	0.882	I	0.799	I
High incidence of Disease and pests	0.512	IV	0.6	II	0.556	IV
Lack of securities	0.665	III	0.553	IV	0.608	III

Table 10. Ranking of influencing factors of rice production.

Factors	Non-adopted farmers		Adopted farmers		Overall	
	RII	Rank	RII	Rank	RII	Rank
Higher income	0.30	V	0.405	V	0.393	V
Higher demand and market access	0.694	II	0.58	III	0.63	II
Land suitability	0.717	I	0.882	I	0.799	I
Adaptation to climate change	0.512	IV	0.6	II	0.556	IV
As a staple food	0.665	III	0.553	IV	0.608	III

Influencing Factors of Rice Production

The five major influencing factors of rice production listed by respondents were identified through FGD, survey and KIIs and respondents were asked to rank them. Table 10 illustrates the ranking of factors influencing rice production among non-adopted and adopted farmers, as well as an overall ranking based on the Relative Importance Index (RII). The findings revealed that land suitability was consistently ranked as the most critical factor (Rank I) across all groups, with the highest RII scores (0.717 for non-adopted farmers, 0.882 for adopted farmers, and 0.799 overall). This highlights the pivotal role of suitable land conditions in ensuring optimal rice production, particularly for adopted farmers who likely rely on specific land characteristics to implement climate-smart practices. This reflects the pivotal role of site-specific characteristics such as topography, soil fertility, water availability, and drainage in determining optimal rice production. Farmers indicated that fields with favorable slope, fertile soil, and good water retention capacity allowed for better crop establishment, higher yields, and more effective implementation of climate-smart practices. Consequently, land suitability remains the foremost consideration for farmers when planning rice production.

Higher demand and market access was ranked as the second most influential factor overall (RII = 0.63), though its importance varies between groups. Non-adopted farmers ranked it second (RII = 0.694), while adopted farmers placed it third (RII = 0.58). This indicates that market access and demand are significant motivators for non-adopted farmers to engage in rice production, whereas adopted farmers may prioritize other factors, such as climate adaptation. As a staple food ranks third overall (RII = 0.608), with non-adopted farmers assigning it greater importance (RII = 0.665, Rank III) compared to adopted farmers (RII = 0.553, Rank IV). Rice production is largely driven by its essential role in meeting household food security needs. Conversely, adopted farmers may focus more on economic and environmental considerations. Adaptation to climate change ranked fourth overall (RII = 0.556), with adopted farmers perceiving it as a more influential factor (RII = 0.6, Rank II) than non-adopted farmers (RII = 0.512, Rank IV). This reflects the growing awareness among adopted farmers of the need to adapt rice production practices to mitigate the impacts of climate change.

Higher income consistently ranked as the least influential factor across all groups, with relatively low RII values. This indicates that while economic benefits are important, they are not the primary motivator for rice production compared to other factors such as land suitability and market access.

Generalizability and Limitations

While this study provides valuable insights into the economic performance of CSA adoption in rice farming, the findings should be interpreted in light of certain limitations. The study was conducted in Kapilvastu district with a relatively small sample size (n = 68), which may limit the generalizability of the results to other regions with different agro-ecological, socio-economic, and institutional contexts. Farmer behavior, access to resources, and climate risks can vary substantially across districts and farming systems. Therefore, the results may not fully represent all rice-growing areas of Nepal or other countries. However, the study offers context-specific evidence on the economic benefits of CSA adoption and provides a useful analytical framework that can inform future studies and policy interventions. Larger, multi-location studies with longitudinal data are recommended to enhance the external validity of the findings.

Conclusion and recommendations

CSA adoption significantly enhances economic profitability, climate resilience, and sustainability in rice production. This study revealed that farmers who adopted Climate-Smart Agriculture (CSA) practices achieved significantly higher returns from rice production due to the effective utilization of climate-smart technologies. The profitability of rice production is closely linked to factors such as yield, sales price, and efficient resource management, coupled with cost-effective production strategies. CSA-adopted farmers were better equipped to optimize these parameters, revealing the importance of targeted interventions to enhance agricultural sustainability. The research identified key constraints impeding rice production, including erratic rainfall patterns, hailstorms during harvest, and limited access to quality agricultural inputs. These challenges not only escalated production costs but also negatively impacted productivity. In response to these challenges, farmers implemented various adaptive practices such as using irrigation pumps, leaf color charts to assess nutrient requirements, conducting soil tests, adopting hybrid seed varieties, and employing pest control measures. These strategies collectively contributed to mitigating the adverse impacts of climate change on rice production.

Several actionable recommendations emerge from this study to promote the adoption and effectiveness of CSA technologies. Policymakers should implement government-supported training programs, field demonstrations, and strengthened extension services to provide farmers with technical guidance. Financial support through subsidies for climate-resilient seeds, irrigation systems, and mechanization, along with low-interest credit

schemes, can enable smallholder farmers to invest in these technologies. Additionally, developing localized weather forecasting, crop insurance programs, and promoting mechanization can mitigate climate-related risks and reduce labor dependency. Such integrated measures can create an enabling environment that enhances farm-level profitability, strengthens climate resilience, and promotes sustainable rice production.

Declarations

Authors Contributions

All the authors contributed equally during the preparation of manuscript.

Acknowledgements

The authors are thankful to the Agriculture and Forestry University, Nepal, for facilitating throughout the research period. The authors feel much privileged to Ms. Yam Kumari Shrestha, Mr. Rabindranath Chaube, Ms. Trisana GC, Ms. Debaki Bhusal, Ms. Asmita Bhattarai, Ms. Baishali Dawadi, Ms. Anju Ghimire, Ms. Sujata Gnawali, Mr. Santosh Kohar, Mr. Maniram Poudel and Mr. Shivalal Ghimire for their valuable suggestions, encouragement and constructive comments throughout the research.

Funding Statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical Approval

The survey conducted in this study was reviewed and approved by the Institutional Review Board of Agriculture and Forestry University (AFU-IRB). The AFU registration number is 1-1-148-2017.

Data Availability Statement

Data will be made available on request.

Declaration of Competing Interest

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

References

Abhilash, Rani, A., Kumari, A., Singh, R. N., & Kumari, K. (2021). Climate-Smart Agriculture: An Integrated Approach for Attaining Agricultural Sustainability. In *Climate Change and Resilient Food Systems* (pp. 141–189). Springer Singapore. https://doi.org/10.1007/978-981-33-4538-6_5

Acharya, M., Ghimire, S., Gautam, N., Acharya, M., Ghimire, S., & Gautam, N. (2024). Evaluating the impact of mulching and fertilizer combinations in maximizing cucumber (*Cucumis sativus* L.) growth and production. *Technology in Horticulture 2024 1:E012*, *4*(1), 0–0. https://doi.org/10.48130/TIHORT-0024-0009

Acharya, S., Ghimire, S., Thapa, R., Bhattarai, P., Chhetri, B. P., & Gautam, B. (2024). Evaluation of Spring Season Local and Improved Rice Genotypes on Growth, Yield, and Yield Attributing Characters in Gorkha District, Nepal. *Journal La Lifesci*, *5*(2), 109–125. https://doi.org/10.37899/JOURNALLALIFESCI.V5I2.923

Bhatt, H., Ghimire, S., Paudel, S., & Bashyal, M. (2024). Response of spring rice (Oryza sativa L.) varieties to different nitrogen application methods at Nawalparasi West, Nepal. *Turkish Journal of Agriculture - Food Science and Technology*, *12*(4), 631–643. https://doi.org/10.24925/TURJAF.V12I4.631-643.6702

Bhatt, S., & Ghimire, S. (2024). Quantifying the impact of nitrogen levels on spring maize varieties (Zea mays L.) in Kanchanpur, Nepal. *Innovations in Agriculture 7: 1-10*, *7*, 1–10. https://doi.org/10.3897/IA.2024.124217

Chhetri, B., & Ghimire, S. (2023). Gender differentiated impacts of climate change on agriculture in Nepal: A review. *Innovations in Agriculture*, 01–08. https://doi.org/10.25081/IA.2023-021

Dawadi, B., Ghimire, S., & Gautam, N. (2023). Assessment of Productivity, Profit, and Problems Associated with Wheat (Triticum aestivum L.) Production in West Nawalparasi, Nepal. *AgroEnvironmental Sustainability*, *1*(2), 122–132. https://doi.org/10.59983/S2023010205

FAO. (2013). *Climate-smart agriculture*. https://www.fao.org/4/i3325e/i3325e.pdf

Gautam, N., Ghimire, S., Kafle, S., Dawadi, B., Gautam, N., Ghimire, S., Kafle, S., & Dawadi, B. (2024). Efficacy of biofertilizers and chemical fertilizers on growth and yield of cowpea varieties. *Technology in Agronomy 2024 1:E007*, *4*(1), 0–0. https://doi.org/10.48130/TIA-0024-0004

Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy*, *21*, 24–34. https://doi.org/10.1016/J.ENVSCI.2012.03.007

Ghimire, S., & Chhetri, B. P. (2023). Menace of Tomato Leaf Miner (Tuta absoluta [Meyrick,1917]): Its Impacts and Control Measures by Nepalese Farmers. *AgroEnvironmental Sustainability*, *1*(1), 37–47. https://doi.org/10.59983/S2023010106

Ghimire, S., & Kumar Rauniyar, U. (2023). Economic Analysis of Acid Lime Production and Marketing in Nepal: A Benefit-Cost Perspective from Nawalpur East District. *Journal of Agriculture and Environment for International Development (JAEID)*, *117*(2), 5–22. https://doi.org/10.36253/jaeid-14510

Ghimire, S., & Poudel Chhetri, B. (2023). *Climate Resilience Agriculture: Innovations and Best Practices for Sustainable Farming*. Eliva press. https://www.elivapress.com/pl/book/book-1912848825/

Ghimire, S., Poudel Chhetri, B., & Shrestha, J. (2023). Efficacy of different organic and inorganic nutrient sources on the growth and yield of bitter gourd (Momordica charantia L.). *Heliyon*, *9*(11), e22135. https://doi.org/10.1016/J.HELIYON.2023.E22135/ASSET/F4F5B73C-F031-4CE4-95E5-F30072EC7347/MAIN.ASSETS/GR1.JPG

Hussain, S., Amin, A., Mubeen, M., Khaliq, T., Shahid, M., Hammad, H. M., Sultana, S. R., Awais, M., Murtaza, B., Amjad, M., Fahad, S., Amanet, K., Ali, A., Ali, M., Ahmad, N., & Nasim, W. (2022). Climate Smart Agriculture (CSA) Technologies. *Building Climate Resilience in Agriculture: Theory, Practice and Future Perspective*, 319–338. https://doi.org/10.1007/978-3-030-79408-8_20

MoALD. (2021). *Statistical Information on Nepalese Agriculture 2076/77 (2019/20)*. https://moald.gov.np/wp-content/uploads/2022/04/STATISTICAL-INFORMATION-ON-NEPALESE-AGRICULTURE-2076-77-2019-20.pdf

Pandeya, S., Gajurel, A., Mishra, B. P., Devkota, K., Gyawali, B. R., & Upadhaya, S. (2024). Determinants of Climate-Smart Agriculture Adoption Among Rice Farmers: Enhancing Sustainability. *Sustainability (Switzerland)*, *16*(23), 10247. https://doi.org/10.3390/SU162310247/S1

Papademetriou, M.K. (2000). Rice production in the Asia-Pacific region: issues and perspectives. In Minas K. Papademetriou, F. J. Dent, & E. M. Herath (Eds.), *Bridging the rice yield gap in the Asia-Pacific region* (pp. 4–25). FAO. https://d1wqtxts1xzle7.cloudfront.net/50181743/935563974-libre.pdf?1478596348=&response-content-disposition=inline%3B+filename%3DBridging_the_rice_yield_gap_in_Asia_Paci.pdf&Expires=1736777275&Signature=XIW3rehNmgLbgDjGe1UICiYYSFHidcULLmqVThXar2ga~M8-EQ7RUns5Wtg~mmOlTCidUjcUaB~n1f4mVZtS4x8JFcpVERzjG7ji3UiVXlpX88PXk1XgJZWVzeSPISzNCilt8D1z7eNd2~~unpr1lFY7xWdZf8S32QisdS1GcIyb4JObt2oqPDpOwUMn2jQK4osJ4954VzLd8GtXag8qiW3xL2zRZvkMvIZ0ce--q-5yjlPbM~6BY9kilEPqxfJTrcRtmL3yENMPxFgMDfTTyg-WYYSTI-CpbNSGyOpEgenhHnVrBK-KlZCLzianp3ee-EMe0SolpzsCyeV~HGMQcQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA#page=10

Papageorgiou, M., & Skendi, A. (2018). Introduction to cereal processing and by-products. *Sustainable Recovery and Reutilization of Cereal Processing By-Products*, 1–25. https://doi.org/10.1016/B978-0-08-102162-0.00001-0

Thapa, R., Ghimire, S., Bhattarai, P., Acharya, S., Chhetri, B. P., & Tharu, R. K. (2024). A Comprehensive Assessment of Apple Production in Jumla District, Nepal: Status, Economics, Marketing and Challenges. *Turkish Journal of Agriculture - Food Science and Technology*, *12*(2), 159–178. https://doi.org/10.24925/TURJAF.V12I2.159-178.6452

Wang, J., Vanga, S. K., Saxena, R., Orsat, V., & Raghavan, V. (2018). Effect of Climate Change on the Yield of Cereal Crops: A Review. *Climate 2018, Vol. 6, Page 41*, *6*(2), 41. https://doi.org/10.3390/CLI6020041

Yadav, M., Ghimire, S., Dhital, M., & Tharu, R. (2024). Response of carrot (Daucus carota Linn.) to different doses and sources of nitrogen in Sindhuli, Nepal. *Fundamental and Applied Agriculture*, *8*(4), 1. https://doi.org/10.5455/faa.169660