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Climate change perception and adaptation strategies of rice seed growers in Chitwan district, Nepal

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A R T I C L E I N F O

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A B S T R A C T

The rice seed sub-sector plays a vital role in the self-sufficiency of rice grain and food security in the context of changing climate. Thus, it is imperative to understand the perception of rice seed growers towards climate change and identify the major adaptation strategies against climate change along with their significant determinants. In this light, our study used data from 223 rice seed growers in the Chitwan district of Nepal using purposive sampling followed by simple random sampling from Bharatpur Metropolitan City and Madi Municipality. Descriptive statistics were used to illustrate perception and adaptation strategies. The growers were categorized as adopters or non-adopters of strategies using the adoption index. Probit regression was used to determine the significant determinants of the adoption of strategies. The findings revealed that 71% of growers perceived climate change: increased temperature and decreased frequency of rainfall. Varietal selection, green manuring, planting time, improved water management and nutrient management were the major adaptation strategies adopted in the study area. From the regression analysis, years of formal education, experience, contact with extension agents and training were found to be significant determinants of the adoption of strategies. The farmers of Madi were found to be more likely to adopt the adaptation strategies. It is therefore recommended that the local and provincial-level governments explore the institutional service provision system and socio-economic characteristics while considering the location for better farm-level adoption of strategies. The study is useful for policymakers to deliberately target formal education, extension services and training for increased adoption of adaptation strategies in the face of climate change. The identified adaptation strategies and their significant determinants are applicable for the rice seed farming system in similar agro-ecological regions globally.

1. Introduction

Climate change is a burning issue of the globe in this century. The global temperatures have been expected to increase by 1.4 °C–5.8 °C by the year 2100 (Khanal and Kattel, 2017). Nepal is highly vulnerable to the threats of global climate change despite its minimal contribution to the emission of greenhouse gases (Gentle and Maraseni, 2012), as Nepal is ranked the fourth most "climate-vulnerable nation" around the globe (Gairhe and Adhikari, 2018). McSweeney et al. (2010) have forecasted the temperature of Nepal to rise by 1.8°C by 2030 and 2.8°C by 2060, and Selvaraju (2014) projected extreme rainfall in monsoons but a cumulative fall of precipitation by 20 mm–100 mm by 2050. The change in climate alters the trend of climatic parameters like rainfall and precipitation, at both temporal and spatial domains, as well as affects resource availability, viz., land, water biodiversity, etc., ultimately affecting the agriculture sector and food security (Shahzad et al., 2021).

Currently, the change in climate affects all the pillars of the food system, viz., availability, accessibility, quality, utilization and stability (Addis and Abirdew, 2021). In the farming system of Nepal, rice is the primary cereal crop in terms of production and cultivated land area, thus bearing a huge economic importance and immense role in food security (Thapa and Bhusal, 2020; Simkhada and Thapa, 2022). However, Nepal is unable to fulfill the demand for rice in the country, and this could be attributed to the inability to shorten the demand-supply gap for rice seed in the country (Gauchan, 2017). The annual demand for rice seed in Nepal is 67 thousand metric tons, but only 18 thousand metric tons of rice seed are available to the rice seed growers in the country (MoALD, 2022). In order to ensure the self-sufficiency and increased production of rice, various acts, policies, directives, projects and programs, viz., National Seed Vision (2013–2025), National Seed Policy, National Seed Act, Seed Management, Production and Supply Directives, Improved Seeds for Farmers Programme (KUBK-ISFP), etc. have played a crucial role.

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Despite the ingenuous attempts to ensure food security and self-sufficiency in Nepal, the rice-farming system is vulnerable to climate change as year-round irrigation is available to only 18% of the total arable land and nearly 46% of the cultivated land is monsoon-dependent (Regmi, 2020; Upendram et al., 2023). The rice production system of Nepal is particularly monsoon-dependent, and the system is under threat due to erratic rainfall, long-spelled drought, delayed monsoons, and a rise in temperature (Karn, 2014). The rice farms in the Terai region of Nepal, in particular, have faced the adverse impacts of changing climate in all three aspects: area, production and productivity (Khanal et al., 2018; Krupnik et al., 2021). Furthermore, exceeding 29.9 °C during the daytime maxima leads to a decline in rice productivity (Karn, 2014; Olufemi et al., 2020). The alteration of rainfall has a notable impact on the area under rice cultivation in Nepal (Poudel and Kotani, 2013; Chandio et al., 2021; Rayamajhee et al., 2021). More than 50 thousand hectares of rice-growing area were affected by erratic rainfall from 2013 to 2014 (Khadka et al., 2020; Regmi, 2020) and nearly 127 thousand hectares of land faced natural calamities from 2017 to 2018 (Chaudhary et al., 2020; Upendram et al., 2023). Thus, in addition to the poor production of rice seeds, the rice seed sub-sector is threatened by the changing climate of the country (Chandio et al., 2021; Joshi et al., 2021; Choudhary et al., 2022).

Chitwan district of Nepal is highly vulnerable to climate change as it is a hub for rice seed production in the Terai region of the Bagmati Province of Nepal (Dawadi et al., 2022). The evidence on the threats of changing climate on agriculture, specifically rice crops, in the case of Chitwan district has been reported by several authors (Paudel et al., 2014; Khanal and Kattel, 2017; Dawadi et al., 2022). This could be attributed to the change in patterns of climatic parameters leading to biotic and abiotic stresses, and to address this, farmers have started altering their agricultural practices (Paudel et al., 2014). The productivity of rice in the Terai region has faced a severe decline due to climatic variability (Karn, 2014). However, very few studies have emphasized climate change studies in the rice seed sub-sector of Chitwan (Hampton et al., 2016).

In the rice seed sub-sector, it is inevitable to understand the perceptions of growers towards climate change as their perceptions determine their choice of adaptation strategy (Devkota et al., 2018b). However, farmers' decisions to adopt the adaptation strategies are determined by various socio-economic, demographic and institutional factors (Addis and Abirdew, 2021). Thus, it is imperative to determine the significant factors affecting the adoption of such strategies so as to develop proper intervention measures that ultimately improve the adaptive capacities of farmers (Devkota et al., 2018b). Multiple studies have been done around the globe to determine the perception of climate change and its impact on agriculture. Although perceptions might deviate from reality, perceptions are the key to addressing various socio-economic constraints (Lolig et al., 2014). Smit and Wandel (2006) have reported that how individuals adapt to the changing climate is dependent on situations, and thus it might vary across regions at the spatial and temporal level. Thus, to develop strategies against climate change, it is vital to understand climate change, identify the strategies against climate change impacts, and identify the determinants of such strategies (Addis and Abirdew, 2021).

In this context, this study determines the perception of rice seed growers towards climate change, identifies the major climate change adaptation strategies and ultimately determines the factors affecting the adoption of such strategies in the rice seed sub-sector of Chitwan district. The findings from this study can be useful for the rice seed farming systems of similar agro-ecozones as well as for seed companies and policymakers.

2. Research methods

2.1. Analytical framework of the study

The analytical framework of this study is shown in Fig. 1 below. This study emphasizes perceptions towards climate change, climate change adaptation, and the factors affecting the adoption of such strategies. The adoption of different strategies is determined by various socio-demographic factors like age, education level, location of growers, experience in farming, as well as by the institutional factors like involvement in cooperatives, visits to extension agents and participation in training. It is imperative to identify the significant determinants of adoption so as to promote and encourage the adoption of climate change adaptation strategies.

2.2. Study area

The study was done in Bharatpur Metropolitan City and Madi Municipality of Chitwan district of Nepal (Fig. 2). The district was selected because it lies in the Terai region of Nepal and is a hub for rice seed production in the Bagmati Province (Joshi et al., 2019). Furthermore, Bharatpur and Madi were chosen purposively for the study because the two local levels have higher rice seed production in the district (AKC, 2021).

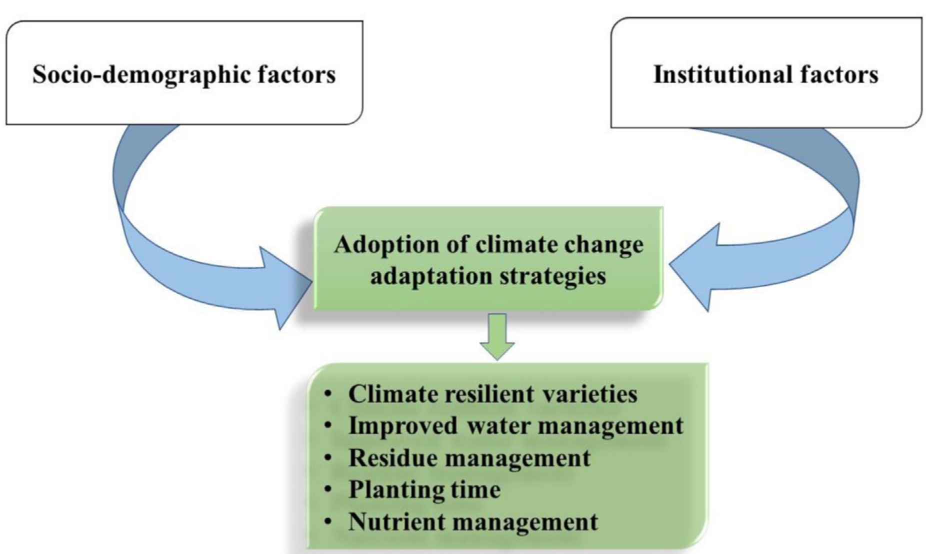

Fig. 1. The analytical framework of the study.

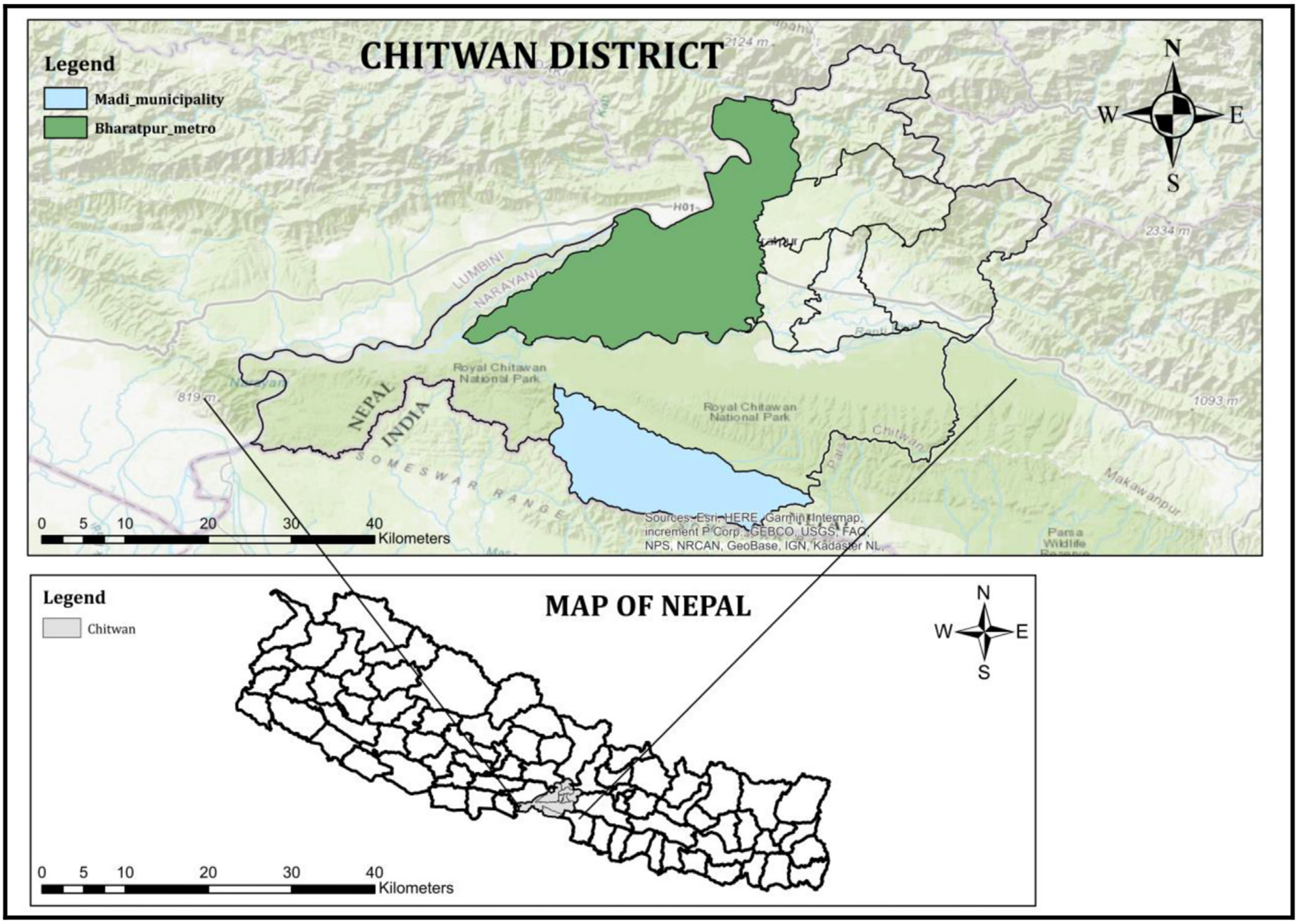

Fig. 2. Map of Nepal showing the study area (Source: ArcGIS 10.8).

Chitwan lies at 27.5291° N latitude and 84.3542° E longitude, in the southwestern corner of the Bagmati Province, with an area of 2238 sq. km. The district ranges in altitude from 144 to 180 m above sea level. The minimum temperature in the district is 7 °C with a maximum of 43 °C. The average annual rainfall here is 1968 mm (Khanal and Kattel, 2017).

2.3. Sample size and sampling design

We employed a purposive sampling technique for the interview schedule from Bharatpur Metropolitan City and Madi Municipality as these local levels have high rice seed production in the district. In the respective municipalities, the purposive sampling technique was followed again, to select the largest rice seed producing ward. Ultimately, a simple random sampling technique was followed to sample the rice seed growers in each ward. The sampling frame for the study was prepared from the roster obtained from the Prime Minister Agriculture Modernization Project (PMAMP), the Agriculture Knowledge Center (AKC), and the Agriculture Section of the local levels. The sample size (n) was estimated using Slovin's formula shown in Equation (1) below.

$$n = \frac{N}{1 + N.e^2} \quad [1]$$

Where, N is the population size, n is the sample size to be estimated, and e is the margin of error (kept at 5% in our study). Thus, the sample size was calculated to be: $n = \frac{503}{1+(503*0.05^2)} = 223$.

After the calculation of the total sample size in the district, the sample size to be taken from Bharatpur and Madi was estimated using proportionate random sampling. The sample size to be taken from the Bharatpur Metropolitan City was thus calculated as $n_1 = (351/503) * 223 = 156$, and the sample size for the Madi Municipality was calculated as $n_2 = (152/503) * 223 = 67$.

The primary data was collected in March 2023. In order to identify the adaptation strategies against climate change, a Focus Group Discussion (FGD) was conducted with relevant stakeholders, viz., Community Based Seed Producers (CBSPs), seed companies, farmer groups, local experts in climate change, cooperatives, PMAMP, AKC, and agriculture sections. The FGD aimed to gather insights and perspectives from the stakeholders regarding their practices and experiences in adapting to climate change. A Key Informant Interview (KII) was done with the experts from AKC Chitwan, the chairperson of seed companies and CBSPs to further validate the information collected from respondents and the focus group. The relevant secondary data were obtained from various literature.

2.4. Perception of rice seed growers in Chitwan towards change in climatic parameters

Frequency, percentage, and mean were used to determine the farmers' perceptions of climate change. For this purpose, the respondents were first interviewed if they had felt any change in climate over the past 12 years (2010–2021), similar to the approach used by authors (Khanal and Kattel, 2017; Regmi et al., 2022). If they had felt any such changes, then the respondents were asked particularly about the temperature and precipitation. If the respondents felt that they had experienced changes in temperature, they were further asked if they felt the summer and winter temperatures were increasing, decreasing, or if they didn't notice much change. Similarly, they were asked if they felt the rainfall frequency and intensity were increasing, decreasing, or unnoticed during the last 12 years. Their responses were tabulated, and the respective frequencies and percentages were also calculated. The data were then subjected to a measure of association with respect to the two locations: Bharatpur and Madi, by applying Pearson's Chi-squared test. The perception of respondents towards the changing climate was triangulated with the actual trend of rainfall and precipitation during the last 12 years in the district and relevant literature related to trend analysis of Chitwan's climatic parameters. The climatic variables of the Chitwan district, along with their patterns over the last decade, were assessed using the data obtained from NASA Power (POWER | Data Access Viewer (nasa.gov)).

2.5. Prioritization of adaptation strategies and calculation of adoption index

Through the FGD, five key adaptation strategies (Table 1) were identified and prioritized, taking into consideration the evaluation criteria (Appendix 2). These strategies were recognized as important by the participants in adapting to climate change over the last three years. For the identification of strategies, we also used the guidance note from DELWP (2020). These strategies were not only recognized as relevant but also prioritized in terms of their potential effectiveness in addressing the impacts of climate change. For example, strategies like varietal selection and improved water management have also been prioritized as adaptation strategies against climate change in the National Climate Change Policy-2019 of Nepal. The prioritized strategies in this study have been extensively researched and recognized as vital for addressing the multifaceted challenges posed by climate change in Chitwan (Khanal et al., 2018; Upendram et al., 2023).

In our study, we calculated the average adoption index (I*) of the identified strategies in order to categorize the respondents as adopters or non-adopters. An arbitrary value of '1' was given for the adoption of a strategy, while a value of '0' was given for the non-adoption of a strategy. In order to give appropriate weight to the adaptation strategies, an expert survey was done with five experts. The experts were asked to provide relative weight on a scale of 1–5 (1 = least significance, 2 = low significance, 3 = moderate significance, 4 = high significance, 5 = strong significance) for the five adaptation strategies based on the evaluation criteria (Appendix 3). The mentioned criteria have been used in various climate change related studies (Arfanuzzaman et al., 2016; Alamgir et al., 2023).

Thus, the obtained score of the respondent (I_i) was calculated by multiplying their score (1 or 0: adoption or non-adoption of a strategy) with the respective weights of the strategies (Appendix 3). The individual adoption index was calculated using formula given by Dongol (2004) which is shown in Equation (2) below.

$$\text{Adoption index}_i (I_i) = \frac{\text{Obtained Score}_i}{\text{Maximum Possible Score}_i} \times 100 \qquad [2]$$

After calculation of the adoption index for each respondent, the average adoption index (I*) was calculated using [3]. Based on the average adoption index, the respondent with adoption index (I_i) ≥ (I*) were considered as adopters and those with adoption index (I_i) < (I*) were considered as non-adopters. The average adoption index (I*) is represented in Equation (3) below.

$$\text{Average adoption index } (I^*) = \frac{\sum_{i=1}^{n} I_i}{n} \qquad [3]$$

Where,

I_i = adoption index of the ith respondent

n = total number of respondents (sample size).

2.6. Variables for the determinants of the adoption of adaptation strategies against climate change

The dependent variable in this study is the adoption of an adaptation strategy against the threats posed by climate change, which is a dummy variable that takes a value of either 1 or 0. The list of independent variables chosen as determinants for the adoption of climate change adaptation strategies is explained in Table 2 below.

2.7. Model specification for the determinants of the adoption of climate change adaptation strategies

The univariate Probit regression was used to examine the determinants of the adoption of climate change adaptation strategies. The model equation is specified in Equations (4) and (5) as follows (Gujarati, 2014).

Table 1
Climate change adaptation strategies identified and prioritized from FGD.

Rank	Adaptation strategies	Indicators	Role to cope with climate change
I	Resistant variety	Variety resistant to climate change threats like Sukkha series (drought) and Sub 1 series (flood)	Adapt to flood, drought and climatic hazards (Mandal and Singh, 2020)
II	Green manuring	In-situ and Ex-situ incorporation of green manures (*Sesbania sps., Crotolaria sps.,* etc.)	Maintain soil health, carbon sequestration and increase soil organic matter (Sarkar et al., 2020; Ansari et al., 2022; Elbasiouny et al., 2022; Shinde et al., 2022)
III	Changing planting time	Timing of crop sowing and harvesting	Escape the hazards of climate change (high temperature, rainfall), disease pest management and risk management (Mutandwa et al., 2019; Aryal et al., 2020)
IV	Improved water management	Alternate Wetting and Drying (AWD)	Reduce overall water consumption and decrease methane emission (Kumar and Rajitha, 2019; Anapalli et al., 2023)
V	Nutrient management	Soil test and split dose of the fertilizer application	Reduce greenhouse gas emissions, improve crop and soil health (Sapkota et al., 2021; Sonwani and Saxena, 2022; Zhou et al., 2023)

Table 2
Variables used for the determinants of the adoption of climate change adaptation strategies.

Variables	Explanation	Expected sign
Dependent variable		
Adoption of climate change adaptation strategies	1 = adoption index of respondent (I_i) ≥ average adoption index (I*) and 0 = I_i < I*	
Independent variables		
Location	1 = Bharatpur and 0 = Madi	+/−
Age	Age of the respondent in years	+/−
Education level	Years of formal education	+
Experience in rice seed production	Years of experience in rice seed production	+/−
Cooperative involvement	1 = Member of a cooperative and 0 = otherwise	+/−
Contact with extension agent	1 = Contact with extension agent in past year and 0 = otherwise	+
Training	1 = Participation in training on rice seed production and 0 = otherwise	+

$P_i = \Pr(\text{Adoption} = 1|X) = \Pr(I_i \geq I^*) = F(\beta X) \ldots$ [4]

Or, $\Pr(\text{Adoption} = 1|X) = \varphi(\beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n) \ldots$ [5]

Where, Pr (Adoption = 1|X) represents the likeliness of adoption given the predictor variables; $\varphi(.)$ represents the cumulative distribution function of the standard normal distribution; β_0 represents the intercept term; $\beta_1, \beta_2, \ldots, \beta_n$ are the coefficients estimated for each independent variable; and $X_1, X_2, \ldots, X_n$ represent the independent variables.

The coefficients ($\beta_1, \beta_2, \ldots, \beta_n$) were estimated using the Maximum Likelihood Estimation (MLE). The assessment of model fit using goodness-of-fit measures like the likelihood ratio (LR) test or pseudo-R-squared, were conducted to ensure the validity and reliability of the results. The following post Probit estimations were also carried out.

2.7.1. Marginal effects of the probit model

After the Probit regression, we calculated the marginal effects to obtain the estimates of the average change in the predicted probability of the adoption for a unit change in the predictor variable, provided other variables are held constant, thus allowing us to assess which factors have a larger or smaller impact on the probability of the outcome.

2.7.2. Hosmer-Lemeshow test for goodness-of-fit

The Hosmer-Lemeshow goodness-of-fit test was used to assess the adequacy of the model in predicting the observed outcomes. A non-significant result in the Hosmer-Lemeshow test provides evidence in support of the goodness-of-fit of the Probit model. It suggests that the model adequately captures the association between predictor variables and the outcome variable and that the predicted probabilities align well with the observed outcomes.

2.7.3. Area under the ROC curve (AUC)

We determined the area under the Receiver Operating Characteristic (ROC) curve, which is a commonly used measure of the predictive performance of a model in binary classification tasks, such as a Probit model (Pepe, 2000). Its value ranges from 0 to 1, with higher values (>0.7) indicating better discriminatory power, predictive accuracy and ability to classify individuals into their respective groups (Pepe, 2000).

2.8. Data analysis technique

The data entry was done in MS Excel, and the data analysis was done with the help of STATA Version 16. Descriptive statistics were used to gain meaningful insights and univariate Probit regression was run to obtain the maximum likelihood estimates for factors affecting the adoption of strategies.

3. Results

3.1. Socio-demographic and institutional characteristics of rice seed growers

The socio-demographic and institutional characteristics of the rice seed growers in Bharatpur Metropolitan City and Madi Municipality are presented in Table 3. Most of the variables were not found statistically different at either of the local levels, which was confirmed by an independent sample *t*-test. The number of members involved in rice seed production was significantly higher in Bharatpur ($p < 0.05$) compared to Madi. The average land size, on the other hand, was not statistically different for either of the local levels. Rice seed growers in Madi had significantly more years of experience than those in Bharatpur ($p < 0.10$). Similarly, the rice seed growers in Madi received a greater number of trainings compared to Bharatpur ($p < 0.001$). The rice seed growers in Madi visited extension agents more frequently compared to Bharatpur which was statistically significant ($p < 0.10$).

Table 3
Socio-demographic and institutional characteristics of rice seed growers in Chitwan.

Variables	Bharatpur	Madi	t-value	Pr (|T|>|t|)
Age (years)	55.65	56.87	−0.72 ns	0.47
Schooling (years)	9.35	10.12	−1.41 ns	0.16
Family size	5.66	5.55	0.36 ns	0.72
Economically active members (15–59 years)	3.66	3.79	−0.66 ns	0.50
Members involved	2.97	2.56	2.28**	0.02
Land size (ha)	0.689	0.596	0.84 ns	0.40
Experience (years)	7.96	8.97	−1.91*	0.057
No of training received	1.59	2.74	−3.3***	0.001
Contact extension agent (times)	2.44	3.179	−1.91*	0.057

Note: *, ** and *** represent significant at 10%, 5% and 1% levels, respectively and ns = non-significant.

3.2. Association of socio-demographic and institutional characteristics with location

The different socio-demographic and institutional variables and their associations with the location are shown in Table 4 below. Agriculture was the primary occupation of the majority of the respondents, and the category of occupation of the respondents was significantly associated ($p < 0.05$) with the location. The involvement of the rice seed growers in cooperatives and participation in training were not significantly associated with the location. In contrast, the contact of seed growers with the extension agent was significantly associated with the location ($p < 0.001$).

3.3. Perception of rice seed growers towards climatic parameters

The perception of rice seed growers towards changes in climatic parameters is illustrated in Fig. 3. The majority of the respondents (71%) perceived changes in climatic parameters during the time period of 2010–2021 AD. They perceived increasing temperatures in both summer and winter, decreasing rainfall frequency and increasing intensity of rainfall. The association of the farmers' perceptions of climatic parameters with the location of respondents is illustrated in Appendix 4.

Table 4
Association of socio-demographic and institutional variables with location of the study area.

Variable	Overall	Location		$\chi 2$ value	p-value
		Bharatpur	Madi		
Genderrowhead					
Male	183 (82.06)	129 (57.85)	54 (24.22)	0.139	0.708
Female	40 (17.94)	27 (12.11)	13 (5.83)		
Occupation					
Agriculture	174 (78.03)	116 (52.02)	58 (26.01)	4.07**	0.044
Other	49 (21.97)	40 (17.94)	9 (4.04)		
Cooperative involvement					
Yes	105 (47.09)	77 (34.53)	28 (12.56)	1.077	0.299
No	118 (52.91)	79 (35.43)	39 (17.49)		
Training					
Received	99 (44.39)	72 (32.29)	27 (12.11)	0.65	0.42
Not received	124 (55.61)	84 (37.67)	40 (17.94)		
Contact extension agent					
Contact	148 (66.37)	116 (52.02)	32 (14.35)	14.85***	0.001
No contact	75 (33.63)	40 (17.94)	35 (15.70)		
Total	223 (100)	156 (69.96)	67 (30.04)		

Notes: ** and *** represent significant at 5% and 1% levels, respectively. Figures in parentheses are relative percentage.

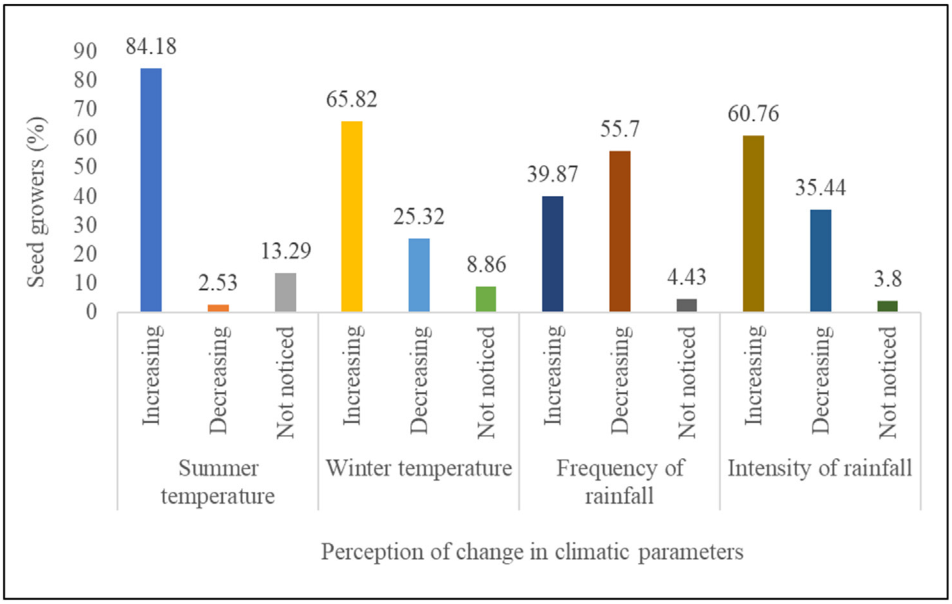

Fig. 3. Perception of rice seed growers towards change in climatic parameters of Chitwan (2010–2021).

3.4. Adaptation strategies against climate change in rice seed production and their association with location

The growers' adaptation strategies to cope with climate change were carefully analyzed based on the indicators (Table 1). The average adoption index (I*) for the selected five adaptation strategies was calculated to be 43.95% from Equation (3). Thus, the respondents with an adoption index (I_i) ≥ 43.95% (n = 149) were categorized as adopters, and others were categorized as non-adopters (n = 74) of the climate change adaptation strategies. The majority of growers were adopters of climate change adaptation strategies in the study area (Table 5) based on the adoption index. The adoption of climate change measures was found statistically significant ($p < 0.01$) for association with the locations.

The adoption of different climate change adaptation strategies in the study area is presented in Table 6 below. The adaptation strategies, viz., green manuring and change of planting time, were both statistically significant upon measuring their association with the local levels. In cases of changes in planting time, most of the growers practiced late sowing of rice to adapt to the changing climate.

3.5. Determinants of the adoption of climate change adaptation strategies

The results obtained from the Maximum Likelihood (ML) estimation using the Probit model to identify the significant determinants of the adoption of adaptation strategies are shown in Table 7 below. The Prob > χ^2 (<0.001) indicates the significance of the estimated coefficients or parameters in the model. This gives evidence to suggest that the corresponding predictor variable has a significant effect on our response variable.

The coefficients obtained from the ML estimates showed that the location of respondents (Bharatpur or Madi), years of formal education, and contact with extension agents were statistically significant at the 5% level, respectively. Similarly, the years of experience and participation in training were also found statistically significant at the 1% level, respectively. Except for location, the other significant variables were positively associated with the adoption of strategies. This means the direction and magnitude of the estimates for education level, experience, contact with extension agents, and participation in training were positively associated with adoption, while on moving from Madi to Bharatpur (0–1), the rice seed growers were less likely to adopt the strategies.

Table 5
Association of the adopter category with location of the study area.

Variable	Overall	Bharatpur	Madi	χ2 value	p-value
Adopter category					
Adopters	149 (66.82)	114 (51.12)	35 (15.70)	9.18***	0.00
Non-adopters	74 (33.18)	42 (18.83)	32 (14.35)		
Total	**223 (100)**	**156 (69.96)**	**67 (30.04)**		

Notes: *** represents significant at 1% level. Figures in parentheses are relative percentage.

3.6. Marginal effects and diagnostic tests of the regression model

The marginal effects of the independent variables and the output of the diagnostic tests–goodness-of-fit test and the area under the ROC curve–are explained below.

The results of the marginal effects obtained after running the Probit model are shown in Table 8 below. From the marginal effects, the coefficient for the location of the respondents (Bharatpur or Madi) was found statistically significant at the 10% level of significance. The coefficient (dy/dx) of −0.17 indicates that on moving from Madi to Bharatpur, rice seed growers are less likely to adopt climate change adaptation strategies by 17%. The years of formal education coefficient (dy/dx) was found to be statistically significant at the 5% level of significance. The marginal value of 0.023 can be interpreted as, with an additional year of formal education, the seed growers are more likely to adopt climate change adaptation strategies by 2.3%. Similarly, the years of experience, contact with extension agents, and receipt of training were all found statistically significant at the 1% level of significance, respectively. The marginal coefficient of 0.032 for years of experience can be interpreted as, with an additional year of farming experience, growers are 3.2% more likely to adopt climate change adaptation strategies in rice seed production. Similarly, the coefficient of 0.194 for visit to extension agents can be interpreted as, on moving from growers who did not visit extension agent to those who visited extension agents, the probability of adoption of climate change adaptation strategies increased by 19.4%. Similarly, the marginal value of 0.22 for participation in training can be interpreted as, on moving from growers who didn't receive any training to growers who had received training, growers are 22% more likely to adopt climate change adaptation strategies.

The goodness-of-fit test for the model used in our study (Table 9) was

Table 6
Association of adoption of different adaptation strategies with the local levels in Chitwan.

Adaptation strategy	Decision	Overall	Bharatpur	Madi	χ2	p-value
Selection of variety	Yes	101 (67.79)	78 (52.35)	23 (15.44)	0.09	0.76
	No	48 (32.21)	36 (24.16)	12 (8.05)		
Green manuring	Yes	88 (59.06)	63 (42.28)	25 (16.78)	2.89*	0.09
	No	61 (40.94)	51 (34.23)	10 (6.71)		
Planting time	Yes	97 (65.10)	73 (48.99)	24 (16.11)	0.24	0.62
	No	52 (34.90)	41 (27.52)	11 (7.38)		
Planting time followed	Late	62 (63.92)	51 (52.58)	11 (11.34)	4.52**	0.03
	Early	35 (36.08)	22 (22.68)	13 (13.40)		
Improved water management	Yes	106 (71.14)	82 (55.03)	24 (16.11)	0.15	0.70
	No	43 (28.86)	32 (21.48)	11 (7.38)		
Nutrient management	Yes	87 (58.39)	67 (44.97)	20 (13.42)	0.03	0.86
	No	62 (41.61)	47 (31.54)	15 (10.07)		
Total		149 (100)	114 (76.51)	35 (23.49)		

Notes: * and ** represent significant at 10% and 5% levels, respectively. Figures in parentheses are relative percentage.

Table 7
Maximum likelihood estimates for determinants of adoption of climate change adaptation strategies in Chitwan.

Adopted climate change measures (Ii ≥ I*)	Coefficient	Std Err.	z	p > z	[95% C.I.]	
Location	−0.49	0.25	−1.98**	0.048	−0.97	−0.01
Age	−0.01	0.01	−1.24	0.215	−0.03	0.01
Schooling	0.06	0.03	2.12**	0.034	0.01	0.13
Experience	0.09	0.03	3.02***	0.003	0.03	0.15
Cooperative Involvement	0.19	0.20	0.93	0.354	−0.21	0.59
Contact Extension agent	0.61	0.24	2.48**	0.013	0.12	1.08
Training	0.62	0.21	2.96***	0.003	0.21	1.02
Const	−1.65	0.76	−2.17	0.031	−3.15	−0.16
Log-likelihood	−105.84					
LR χ2 (7)	63.46***					
Prob > χ2	0.001					
Pseudo R^2	0.23					

Note: ** and *** represent significant at 5% and 1% levels, respectively.

found to be non-significant ($p = 0.3443$), ensuring a well-fitted model. This implies that the model captured the association among the dependent and independent variables and aligned well with the observed outcomes.

The visual representation of the performance of the Probit model is shown in Fig. 4 below. The area under the ROC curve (AUC) below shows the summary measure of the model's predictive performance. The AUC value of 0.7970 for our model suggests that the model has reasonably good discriminatory power in predicting the outcome variable. This implies that our model has the ability to correctly classify individuals into their respective groups.

Table 9
Hosmer-Lemeshow test for goodness-of-fit test of the Probit model.

Number of observations	Number of covariate patterns	Pearson χ2 (213)	Prob >χ2
223	221	215.60	0.3443

4. Discussion

4.1. *Perception of rice seed growers towards climatic parameters of Chitwan*

Our results concur with the trend analysis (Appendix 1) with respect to the increasing temperature of Chitwan over the last 12 years. Similarly, the experience of increased intensity of rainfall is in line with the increased precipitation observed in the graph, but it contrasts with the decreased frequency of rainfall perceived by the respondents (Islam et al., 2020). The impact of climate change on agricultural production, specifically rice production in Chitwan, has also been reported by several authors (Paudel et al., 2014; Khanal and Kattel, 2017; Dawadi et al., 2022). During the last decade of the 20th century, farmers in Chitwan experienced heavy precipitation, with a maximum temperature of 43 °C and a minimum temperature of 1.6 °C (Regmi et al., 2022). Furthermore, this led to a decline in the productivity of rice (Karn, 2014). A maximum of 0.019 °C/year and a minimum of 0.003 °C/year were observed, with a decline in rainfall of 42.2 mm (annual) and 34.6 mm (seasonal) during the early decades of the 21st century as per the trend analysis (Piya et al., 2013; Regmi et al., 2022). Our findings concur with Khanal and Kattel (2017) who studied the farmers' perceptions regarding the changing climate in Chitwan district, Nepal, in 2017. They reported that 87.5% of the respondents had experienced changes in climatic parameters (96% perceived elevated temperatures and 86% perceived declining rainfall).

A 30-year trend analysis (1990–2020) by Devkota et al. (2018a) reported that 80.7% of the rice farmers experienced temperature variation

Table 8
Marginal effects of the Probit regression for adoption of climate change adaptation strategies.

Variables	dy/dx	Std Err	z	p>|z|	[95% C.I.]		X
Location#	−0.17	0.09	−1.91*	0.057	−0.35	0.005	0.69
Age	−0.004	0.003	−1.24	0.216	−0.011	0.002	56.16
Schooling	0.023	0.011	2.13**	0.033	0.002	0.043	9.55
Experience	0.032	0.011	2.99***	0.003	0.012	0.052	8.26
Cooperative #	0.065	0.07	0.92	0.356	−0.073	0.203	0.46
Contact extension#	0.194	0.072	2.69***	0.007	0.053	0.335	0.66
Training#	0.22	0.073	2.96***	0.003	0.072	0.36	0.41

Notes: (#) dy/dx is for discrete change of dummy variable from 0 to 1. *, ** and *** represent significant at 10%, 5% and 1% levels, respectively.

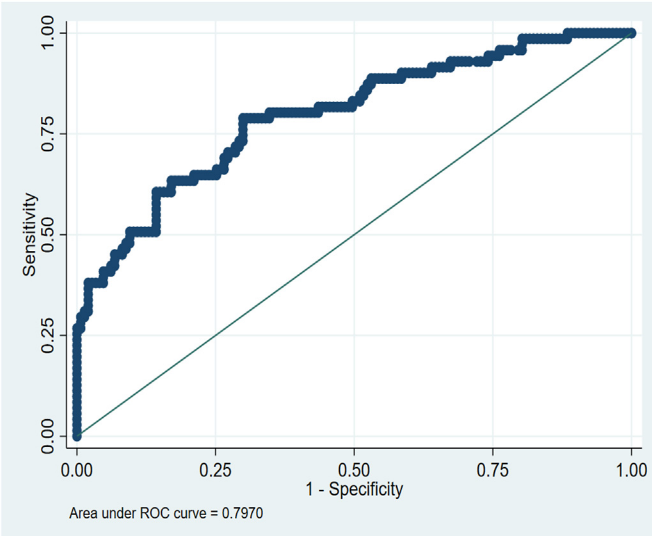

Fig. 4. Area under ROC curve (AUC) for the Probit regression estimates.

and 90% perceived decline in rainfall in Terai and the Hills of Nepal, which is similar to our study. A study by Khanal and Wilson (2019) in the hill and Terai districts of Nepal, including Chitwan, reported that 95% of respondents perceived increased summer season temperatures and 60% reported increased winter temperatures, which concurs with our results. Similarly, 58% of respondents perceived decreased rainfall. Regmi et al. (2022) carried out a study in Chitwan, including the rice seed pocket area (Patihani), to determine the factors affecting the adoption of climate change adaptation strategies by the rice-producing farmers. They reported that the perception of rice seed growers in Chitwan is consistent with the actual trend of change in temperature and rainfall upon triangulation. They reported that 76.6% of rice growers in Chitwan experienced variation in climatic patterns during the last 10 years. They further reported that 87% and 62% of respondents perceived increased summer and winter temperatures, respectively, which is similar to the findings of our study. Furthermore, Regmi et al. (2022) also reported that 75% of respondents perceived intense rainfall and late monsoons, which is similar to the high intensity of rainfall perceived by the rice seed growers in our study. The respondents might have perceived decreased frequency of rainfall due to the irregular pattern of precipitation, spatial precipitation in peak periods, and delay in the onset and withdrawal of the monsoon over the years in Chitwan district (Devkota et al., 2019; Chaudhary et al., 2021).

4.2. Adaptation strategies against climate change in rice seed production

The variability of climatic parameters disturbs agriculture operations in regular cropping calendars due to weather extremes associated with biotic and abiotic stresses in crops (Paudel et al., 2014). To adapt to the changing climate, seed growers have started to alter their practices for preserving their yield (Regmi et al., 2022). For instance, the practice of late sowing by the majority of seed growers in our study could be to escape the period of heavy precipitation at the time of harvest (Fatima et al., 2020). Khanal and Kattel (2017), in their study in Chitwan district, Nepal, reported the major adaptation strategies to be; varietal selection (61%), alternate wetting and drying (59%) and cropping calendar change (43%), which are similar to our findings. Similarly, a study by Devkota et al. (2018a) in Chitwan reported that changes in rice varieties and variations in time of sowing were the major climate change adaptation strategies followed by rice farmers.

Similarly, a study by Khanal and Wilson (2019) in six different districts of Nepal, including Chitwan district, reported that change in crop varieties (76%), change in time of planting (21.8%), improved water management (15.64%), and nutrient management (71%), were the major adaptation strategies adopted by the rice farmers. Similarly, Upendram et al. (2023) also reported adjustment in the timing of agriculture operations (73%), resistant varieties (65%), and irrigation management (61%), as a means of adaptation against the changing climate in Chitwan district, Nepal. Regmi et al. (2022) carried out a study in the three major villages of Chitwan, including the rice seed pocket area (Patihani), in which they reported changes in variety of rice and improved water management as the major climate change adaptation strategies being adopted by the rice growers in the district. Khanal et al. (2019) studied rice farmers' autonomous adaptations to changing climates in Tanahu, Nepal. They reported that adjustments in time of sowing, selection of varieties, improved irrigation, and fertilizer management were the key adaptation strategies adopted by most of the rice growers in the district. A scoping review using meta-analysis of 202 literatures in the past thirty years by Acevedo et al. (2020) in developing and under-developed countries also reported that resistant varieties have been chosen as the major adaptation strategies against changing climates by rice growers.

The climate change adaptation strategies adopted by rice seed growers in our study have been identified as major adaptation strategies by different studies in the same study area. However, the importance of these strategies in the face of climate change needs to be understood by farmers, climate activists, and other concerned stakeholders. The role of these adaptation strategies in helping farmers cope with the changing climate is crucial.

The selection of recommended varieties as per the domain has been a key concern for rice growers in Nepal (Gauchan et al., 2014). With a changing climate, the selection of appropriate varieties is crucial (Hussain et al., 2020). For example, in flood and wetland areas, the Sub-1 variety can be grown, and in drought areas, the Sukkha series can be grown to cope with the changing climate (Mandal and Singh, 2020). Similarly, the cropping pattern can be changed to adapt to changing climates (Aryal et al., 2020). One of the major changes in cropping patterns is the timing of planting and harvesting. Early sowing or late sowing can help to escape the high temperature, unprecedented climatic hazards, and diseases and pests (Mutandwa et al., 2019; Aryal et al., 2020).

The improved water management practices of the farmers are also an adaptation strategy to cope with the changing climate (Srivastav et al., 2021). It particularly refers to the alternate wetting and drying of the rice field. It involves intentionally drying the field periodically between irrigations, allowing the soil to partially dry out before flooding again (Langensiepen et al., 2020). AWD reduces water usage in rice fields by 15–30% compared to continuous flooding (Kumar and Rajitha, 2019). With changing climates and increasing water scarcity in many regions, this technique helps optimize water resources and promote sustainable agriculture (Ishfaq et al., 2020). Furthermore, AWD promotes intermittent flooding, creating aerobic conditions that reduce methane emissions (Anapalli et al., 2023). This also contributes to mitigating climate change impacts.

Nutrient management in rice, specifically through the balanced application of fertilizers and manure, can play a crucial role in adapting to climate change (Hussain et al., 2020). Climate change can influence soil nutrient availability and affect nutrient uptake by rice plants (Elbasiouny et al., 2022). By implementing balanced nutrient management practices, farmers can optimize nutrient use efficiency. This involves providing the right amount and ratio of nutrients based on the crop's requirements, reducing nutrient losses, and minimizing environmental impacts (Wang et al., 2021). Enhanced nutrient use efficiency ensures that the available nutrients are effectively utilized by rice plants, contributing to better growth, yield, and overall resilience. Climate change is closely linked to the increased emission of greenhouse gases, such as Nitrous Oxide (N_2O) and Methane (CH_4) (Sonwani and Saxena, 2022). Nutrient management practices that involve the balanced application of fertilizers and manure can help mitigate these emissions (Sapkota et al., 2021). A balanced application of fertilizers based on soil testing and crop needs minimizes over-fertilization. Additionally, the incorporation of organic manure enhances soil health and promotes beneficial microbial activity, reducing the production of Methane in flooded rice fields (Zhou et al., 2023).

Conservation agriculture, specifically green manuring (residue management), can play a significant role in adapting rice fields to climate change (Hussain et al., 2020; Prayoga et al., 2020). Residue management refers to the practice of retaining and effectively utilizing crop residues, such as straw and stubble, in the field (Shinde et al., 2022). The practice helps conserve soil moisture by acting as a protective layer on the soil surface. The crop residues reduce evaporation and improve water infiltration, allowing the soil to retain moisture for longer periods (Sarkar et al., 2020). This enhances the water-holding capacity of the soil, reducing the vulnerability of rice crops to drought stress and ensuring more efficient water use (Sarkar et al., 2020). Residue management contributes to carbon sequestration by promoting the accumulation of organic matter in the soil (Wang et al., 2019). Crop residues are rich in carbon, and when they decompose, the carbon is incorporated into the soil, enhancing soil organic carbon content (Ansari et al., 2022). Increased soil organic carbon not only helps mitigate climate change by storing carbon dioxide but also improves soil fertility, structure, and nutrient cycling (Elbasiouny et al., 2022).

4.3. Determinants of the adoption of climate change adaptation strategies adopted by rice seed growers in Chitwan

In diverse studies, different socio-demographic and institutional factors like age, education level, experience, contact with extension agents, training, geographical location have been found to be linked either positively or negatively with adoption. Khanal and Kattel (2017) studied the farmers' perceptions, adaptation strategies, and determinants of the adoption of adaptation strategies in Chitwan district, Nepal, in 2017. They used a seemingly unrelated regression model and reported that the age of the household and education level were the key determinants of the adaptation strategies. Similarly, Khanal et al. (2018) also studied the factors affecting the adoption of climate change adaptation strategies in the Terai and Hill regions of Nepal. They reported that the age of the respondents, family size, and contact with extension agents had a significant and positive relationship with the adoption of strategies, which is similar to the findings of our study. A study by Devkota et al. (2018a) also reported that the age of the respondent, education status, experience in production, institutional involvement, training, and contact with extension agents are all associated with the adoption of strategies in rice farming. Similarly, Khanal and Wilson (2019) reported that education status and extension agent visits are significantly and positively associated with the adoption of climate change adaptation strategies among rice farmers in Chitwan. However, they reported that age and institutional involvement didn't have a significant relationship with adoption, which contrasts with our findings. A study by Regmi et al. (2022) in Chitwan reported that years of formal education, training, and contact with extension agents were significantly and positively associated with the adoption of different climate change adaptation measures, which concurs with the findings of our study in the same study area. Khanal et al. (2019) studied rice farmers' autonomous adaptations to changing climates in the Tanahu district of Nepal. They reported that the age of the respondent and family size influence farmers' adoption. Similarly, a recent study by Upendram et al. (2023) in the Chitwan district of Nepal reported that the membership of respondents, contact with extension agents, training received by farmers, and education are significant determinants of the adoption of different strategies. From their findings, they made suggestions to the local government on the enhancement of the adoption of the strategies by focusing on and targeting socio-economic and institutional variables like visits to the extension agent, training and membership in farmers' groups or cooperatives.

The socio-economic, demographic, and institutional factors affecting the adoption of adaptation strategies have been reported in multiple literatures around the globe as well. Marie et al. (2020) used multinomial logistic and binary logistic regression to identify the factors affecting the adoption of adaptation strategies in Ethiopia. They revealed that age, gender and family size are important determinants of adoption. Thinda et al. (2020) studied the adoption of climate change strategies by farmers in South Africa. The authors also reported that different socioeconomic factors determined the adoption: age, experience and extension services. Similarly, Ojo and Baiyegunhi (2020) used a multivariate Probit model to identify significant determinants of the adoption of such strategies in Nigeria. They reported that socio-economic, institutional and locational variables significantly determine adoption. A scoping review using meta-analysis of 202 literatures in the past thirty years by Acevedo et al. (2020) in developing countries showed that age, extension services, education level and other socio-economic status of farmers affect the adoption of climate change adaptation strategies.

In this study, the negative association of the location of respondents with the probability of adoption of climate change adaptation measures implies a decreasing probability of adoption of climate change adaptation measures upon moving to Bharatpur. Various literature have mentioned that adaptation strategies might be dependent on geographical location, the nature of climatic variability, and indigenous knowledge and skills observed in the community (Maharjan et al., 2011; Abid et al., 2015; Saguye, 2016). Bharatpur is particularly urban, making it challenging to implement certain adaptation strategies that require larger land areas, like crop diversification and crop rotation (Rai et al., 2020). Furthermore, the occupation of respondents was found to be significantly associated with the locations, as observed in Table 4. The farmers in Bharatpur thus might have been more interested in secondary occupations like business, marketing, service, etc., as 25.6% of respondents had primary occupations other than agriculture, thereby making them reluctant towards the impacts of climate change and adaptation strategies. The Madi Municipality, on the other hand, is known for the better availability of resources like water, which enables them to implement climate change adaptation strategies like improved water management with ease. This finding from our study leaves an opportunity to further assess the reasons associated with the reluctance of farmers in Bharatpur to adopt climate change adaptation strategies.

In case of the education level of the respondent household, it has been observed that with increased years of formal education, there are better chances of gaining knowledge on climate change and various adaptation strategies (Mihiretu et al., 2019). Similarly, Evangelista et al. (2013) reported that educated farmers were more likely to adapt to a changing climate based on their preferences. This might be the reason for the positive linkage between the years of formal education and the adoption of strategies.

Likewise, farmers with more experience are probable to adopt different strategies, as they are expected to have sound knowledge and ideas regarding trends in climatic parameters over time (Urgessa, 2013). Furthermore, contact with extension agents by rice seed growers can be helpful to gain necessary information related to climate change (Adeagbo et al., 2021). Upon contact with the extension agent, farmers learn about the associated risk of climate change in their farming practices, ultimately diversifying their decision regarding adaptation (Amdu et al., 2013). Zakaria et al. (2020) also reported that visits to extension agents can increase tendency of farmers to adopt the climate change adaptation strategies. Similarly, participation in training can encourage farmers to adopt new climate change adaptation measures. Juana et al. (2013) asserted that training could also be important to make the farmers aware, teach them different adaptation strategies, and ultimately encourage them to apply the diverse strategies to adapt to the changing climate scenarios.

4.4. Policy recommendations

The significant determinants of climate change adaptation from our study can be a great asset to policymakers and planners, specifically climate change activists. Focusing on the significant determinants and deliberate targeting of these variables in programs, plans, and activities can encourage the adoption of climate change adaptation strategies. Based on the findings of our study, it can be suggested to provide formal education, enhance experience, increase the contact of seed growers with extension agents, and provide training to the rice-seed growers in Chitwan so as to increase the likelihood of the adoption of strategies against climate change. Furthermore, the program and plan shall be implemented in such a way that the seed growers of Madi Municipality will be encouraged and the seed growers of Bharatpur will be motivated to adopt the adaptation strategies. The findings from this study can be useful for rice seed growers in similar agro-ecozones around the globe.

5. Conclusion

Our study aimed to determine the perception of rice seed growers towards climate change and identify major adaptation strategies against climate change as well as their determinants. From the findings of our study, we can draw three major conclusions: (i) the majority of rice seed growers in Chitwan have perceived change in climatic parameters (increased temperature and decreased frequency of rainfall), which to some extent is in par with the actual trend of climatic parameters; (ii) the major adaptation strategies prioritized and identified in Chitwan were resistant variety, green manuring, planting time alteration, improved water management and nutrient management; and (iii) the years of formal education, experience, contact with extension agent and training were found to increase the likelihood of adopting climate change adaptation strategies, while farmers in Madi were more likely to adopt such strategies. It can be suggested to the local and provincial governments, policy practitioners and concerned stakeholders to design programs, plans and activities to increase years of formal education, increase the experience of seed growers, increase contact with extension agents and receival of training to increase the likelihood of adapting climate change adaptation strategies. The farmers of Madi shall be further encouraged, while those of Bharatpur shall be motivated to adopt such strategies through effective awareness.

Ethics statement

The study was performed in full accordance with the Agriculture and Forestry University. The study ensured that the respondents were well informed in writing about all the aspects of the study. A written consent was hence obtained from the participants regarding their consent to participate, and further use of data.

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Data availability statement

The data that has been used is confidential and cannot be made available due to the privacy issues of data obtained from seed companies, seed groups and other seed producers in the district.

CRediT authorship contribution statement

Rabin Thapa: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Shiva Chandra Dhakal:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Rabin Thapa reports financial support was provided by Government of Bagmati Province, Ministry of Agriculture and Livestock Development. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.farsys.2024.100095.

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