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Factors affecting adoption intensity of climate change adaptation practices: A case of smallholder rice producers in Chitwan, Nepal

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This study examines how smallholder rice producers' adoption intensity for climate change adaptation practices (i.e., improved varieties, irrigation practices, direct seeded rice, integrated pest management, and adjustment in crop calendar) is influenced by access to Extension services, training, weather-related information, and membership in farmer groups or cooperatives (referred to as "institutional resources"). We use survey data collected from 359 smallholder rice producers in the Chitwan district of Nepal in 2019. The results indicate that: (1) access to institutional resources significantly enhance the likelihood of adoption of more climate change adaptation practices; (2) high intensity climate change adaptation practice measured by the adoption of three, four, and five practices significantly increases with access to institutional resources; (3) intensity of adoption of climate change adaptation practices is reduced with greater adaptation alternatives available to rice producers; and (4) lack of information and technical knowledge are the most important reasons for non-adoption of climate change adaptation practices by smallholder rice producers. The results are valuable for policy makers and planners to prioritize training opportunities and allocate scarce resources to enhance climate change adaptation and improve sustainability of rice production practices.

KEYWORDS

climate change, small land holders, adaptation, non-adoption, Nepal, intensity

Introduction

Climate change is one of the greatest challenges of the 21st century, threatening human nutrition, health, and development. Climate extremes continue to adversely affect agricultural productivity and food security in many regions around the world (IPCC, 2019). Smallholder producers in developing countries rely heavily on subsistence agriculture and their livelihoods are particularly vulnerable to climate change (Wheeler and Von Braun, 2013; Bandara and Cai, 2014; Harvey et al., 2014; Sarker et al., 2014). The impacts of climate change on agriculture vary substantially and are dependent on risk mitigation measures that improve the resilience of systems and promote sustainable development (Smit and Wandel, 2006; Morton, 2007; Aryal et al., 2020).

As the benefits of climate change adaptation to farmers have been well established (Teklewold et al., 2013; Aryal et al., 2020), a branch of literature has emerged on methods to encourage smallholder producers to adopt climate change adaptation practices in developing countries (Morton, 2007; Kurukulasuriya and Rosenthal, 2013). The literature using case studies find that: (1) understanding producer behavior is important to design effective climate change adaptation practices and improve overall sustainability of agricultural production (Feola et al., 2015); (2) climate risk perception and psychological elements influence smallholder producers' adaptation behavior (Azadi et al., 2019); and (3) access to institutional resources such as Extension services, skill enhancement training, location specific adaptation options, climate and weather information, membership in co-operatives in addition to education, support services and lines of credits have a positive effect on producer attitudes toward climate change adaptation (Bryan et al., 2009; Deressa et al., 2009; Gbetibouo, 2009; Tazeze et al., 2012; Piya et al., 2013; Mulwa et al., 2017; Zamasiya et al., 2017; Aryal et al., 2018; Khanal et al., 2018).

The different level of role of the access to institutional resources on climate change adaptation is a key takeaway from the existing literature as the information has clear implications for smallholder producers in developing countries. Despite the contributions of many studies on climate change adaptations in developing countries, a major gap in literature is that most of the studies have only examined the effect of the access to institutional resources with a single climate change adaptation practice at a time. Adjusting planting dates to coincide with monsoon onset, use of drought tolerant varieties and late harvest to mitigate impacts of monsoon are a few ways in which smallholder rice producers adapt to climate change. In practice, a producer in each crop season has the choice of adopting multiple climate change adaptation practices at the same time. For example, climate change adaptation practices include planting drought-tolerant, short-duration, disease-resistant varieties (referred to as "improved varieties"), practicing soil and water conservation measures, adjusting planting dates due to delayed monsoon, adopting enhanced irrigation practices, and diversifying crops (Deressa et al., 2009; Gbetibouo, 2009; Tazeze et al., 2012; Tilahun and Bedemo, 2014; Gadédjisso-Tossou, 2015; Thinda et al., 2020;). Despite this practical consideration, studies addressing multiple dimensions of climate change adaptation are absent from the literature.

The objective of this research is to determine the role of the access to institutional resources on smallholder rice producer decision-making to adopt multiple climate change adaptation practices. As a case study, we develop an empirical model to estimate the effect of access to institutional resources on adoption intensity of multiple climate change adaptation practices by rice farmers in Chitwan, Nepal (see Figure 1). We focus on how access to four types of institutional resources (i.e., membership in farmers' group and cooperatives, Extension services, training related to farming practices, and weather-related information) affect adoption intensity of five of climate change adaptation practices [i.e., planting improved varieties, adopting enhanced irrigation practices, direct seeded rice (DSR), integrated pest management (IPM), and adjusting planting due to monsoon].

Quantifying the effect of institutional resources on the intensity of climate change adaption enables a decision maker to prioritize farm practices. Understanding the effects on climate change adoption can help streamline resource allocation for institutional resources. Under this premise, if, for example, improving accessibility to one institutional resource is superior to another in increasing the adoption intensity of multiple climate change adaptation practices, financial incentives can improve adoptability of practices.

Materials and methods

Study area

Chitwan district of central Nepal was deliberately chosen as a case study because it is a prominent rice-producing district (Figure 1) with smallholder producers experiencing the adverse impacts of climate change on their farming practices (Gurung and Bhandari, 2009). The average farm size is 0.46 hectares (1.13 acres) in Chitwan district. Specifically, climate change adversely impacted rice farming in the plains (*terai* region) of Nepal in terms of acreage, production, and yield (Gumma et al., 2011; Karna, 2014; Khanal et al., 2018). According to Karna (2014), if the day-time maximum temperature surpasses 29.9°C, rice yields start to decline. Gumma et al. (2011) in their study found that variability in the rainfall pattern resulted in 13% reduction in rice acreage in 2006.

Agriculture constitutes one-third of Nepal's gross domestic product and rice is the most cultivated crop of the country (>50% of total cultivated area) (MoAD, 2015; MOF, 2018). In Nepal, only 18% of total cultivable land is under irrigation throughout the year, and nearly 46% of land under cultivation is primarily dependent on monsoon (natural rainfall) for irrigation, potentially leading to high vulnerability to climate change (Ministry of Energy, Water Resources, and Irrigation, 2018; MOF, 2018). Furthermore, the country's rice yield is <4 metric tons/hectare, much lower than the rice yield of other major rice-producing countries (7–8 tons/hectare) (FAO, 2020; National Planning Commission, 2020).

The study area may experience temperature fluctuations and greater variability in precipitation patterns in the future. McSweeney et al. (2010) projects Nepal's temperature to increase

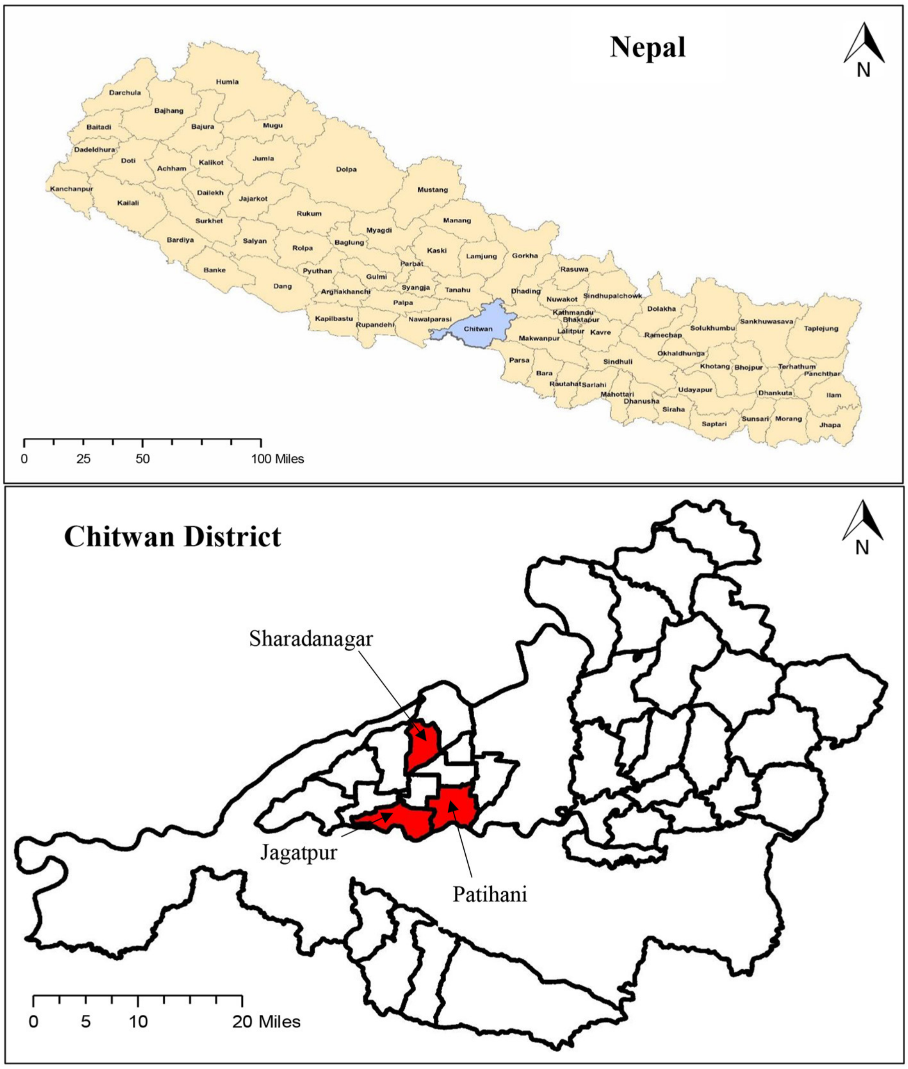

FIGURE 1
Map of Nepal showing Chitwan district and three villages in Chitwan district.

by 1.8^0C by 2030 and 2.8^0C by 2060, and the FAO (2014) projects more intense rainfall events during the rainy season but an overall rainfall decline in the range of 20 mm to 100 mm by 2050. Long-term variation in climatic parameters (primarily rainfall and temperature) and frequent occurrence of extreme weather events such as droughts and floods affect soil-water-plant relationships and results in reduced crop yields (Karna, 2014). Rainfall variability, longer periods of drought, late onset of monsoon, and increasing temperatures have increased the vulnerability of the monsoon-dependent rice production system in Nepal (Karna, 2014; MOF, 2014). Spatial and temporal distribution of rainfall has a noteworthy influence on rice acreage in Nepal. Between 2013 and 2014, rainfall variability adversely affected more than 50,000 hectares of rice and about 127,000 hectares of agricultural land was affected by natural disasters from 2017 to 2018 (MOF, 2014, 2018). Under projected climate change scenarios, rice yields may decline further unless considerable mitigation efforts target address adverse climate change impacts.

Survey design

Out of the seven administrative units in Chitwan district, the largest administrative unit–*Bharatpur* was deliberately selected. In consultation with the district agricultural Extension office (Chhetri, 2019; Agricultural Knowledge Center, Chitwan), we implemented the survey in three villages where rice is primarily cultivated–*Patihani*, *Jagatpur and Sharadanagar* (Figure 1). Survey data were collected using a random sampling technique at the household level within the three villages. To collect relevant information on climate change adaptation and rice production, we conducted on-site surveys by interviewing farming households at their respective households, farms, and local gathering spots in the three villages in June 2019. Sample size was determined following Krejcie and Morgan (1970) sample size determination:

$$\text{Sample size} = \frac{\chi^2 NP\ (1-P)}{d^2\ (N-1) + \chi^2 P\,(1-P)} \tag{1}$$

Where,

χ^2 = Chi-square tabulated value at desired confidence level (95%),
N = Total population size (number of households),
P = Population proportion (assumed to be 0.5),
d = Degree of accuracy expressed as a proportion (0.05).

Following Krejcie and Morgan (1970) a sample of 352 out of a total of 4,090 farming households (N) was determined to be representative to produce parameter estimates at a 95% confidence interval. Out of 383 farming households contacted, 359 (or 94%) agreed to participate in the survey while 24 (or 6.3%) declined to participate in the survey. We trained four enumerators (undergraduate students at Agriculture and Forestry University in Chitwan) to complete the questionnaire with adults in the farming households, and each respondent read a consent statement following Institutional Review Board guidelines about participant involvement, privacy protection and ensuring confidentiality of responses. Upon receiving consent that the participant understood the information and agreed to participate, enumerators asked questions in a face-to-face interaction that lasted approximately 15 min. Within the village, households were selected randomly to participate in the survey. The survey was composed of the following five sections: (1) farm household characteristics; (2) producer perceptions of climate change and variability; (3) adaptation to climate change; (4) producer risk attitudes; and (5) usage status of institutional resources (see Supplementary material for the survey).

We examined five climate change adaptation practices: use of varieties, irrigation, DSR, IPM, and planting adjustment based on a recent National Adaptation Program of Action (NAPA) report (MoE, 2010). NAPA was implemented by the government of Nepal in 2010 to reduce the impacts of climate change. Since agriculture is one of the prioritized sectors in NAPA, many adaptation practices in the agricultural sector such as selection of drought-tolerant and short-duration varieties, investment in improved irrigation, use of local plant extract and bio-pesticides for pest management were detailed in the program (MoE, 2010). Numerous studies indicated that selection of crop varieties, investment in water harvesting and improved irrigation practices, adjustment of crop planting dates, integrated pest management, and crop diversification are important adaptation practices to adapt to climate change and variability (Manandhar et al., 2011; Biggs et al., 2013; Piya et al., 2013). A study by Khanal et al. (2018) reported the use of varieties, improved irrigation, direct seeded rice, fertilizer management, and adjustment of timing of farm operations are all major adaptation practices adopted by rice producers in Nepal.

Institutional resources

The four institutional resources play a vital role in adaptation to climate change in rice production, and imparting skills among small-holder rice producers to enhance adaptation at the local level as described below:

- Membership in Farmer's Cooperatives or Groups: Producers who are members of cooperatives or groups are better equipped in learning from each other in adapting to climate change. The purpose of a cooperative is to help producers share best farm management practices, obtain needed farm products and services, improve income opportunities, reduce input costs, and manage risk (Aza, 2021). A cooperative also provides a supportive network for producers to discuss challenges and learn from each other in adopting climate change adaptation techniques.
- Extension: Extension agents conduct farm visits and host producers in their offices to answer queries on agricultural problems and challenges. Specifically, Extension agents provide technical expertise and provide information to producers on topics including improved farm management practices, climate change adaptation techniques, newer technologies, and plant protection measures (Regmi et al., 2022). By organizing field days, agricultural fairs, farm visits Extension agents disseminate technical information to motivate producers to adopt improved farming practices. Producers are more likely to contact Extension agents and vice versa if the district office is not very distant and easily accessible. A typical timeframe for a farm visit or an Extension office visit is one day (Singh, 1997).
- Training: Government and non-governmental agencies provide trainings on climate change adaptation to help producers identify, adapt, and mitigate the negative impacts on production practices and profitability (Regmi et al., 2022). The purpose of the trainings is to use latest technology and practices, efficient use of local resources and best management practices. Producers are encouraged to attend these 2–3-day trainings, in-service workshops, or field demonstrations at a central location. At times, trainers provide producers a scholarship or stipend to compensate for their time away from farm and encourage participation in these trainings (Singh, 1997).

TABLE 1 Producers' perceptions of climate change in Chitwan district in the past 10 years (2009–2018).

Climate change perceptions	% of respondents who perceived climate change in the past 10 years (2009–2018)
Weather unpredictability	99.6%
Hailstorms	97.8%
High summer temperature	86.9%
Late onset of monsoon rain	86.2%
Intensity of rainfall	80.8%
Overall change in climate patterns	76.6%
Dry spells	71.4%
High winter temperature	61.9%
Floods	29.1%

Source: Regmi, 2020.

- Information: A mass-contact method to quickly disseminate timely information to producers is through factsheets, publications, brochures, booklets, progress reports, Television/radio agricultural progress, weather forecasts, extreme weather events and weather advisories (Regmi et al., 2022). Access to print and digital media are dependent on the literacy of producers and ability to access programs through print, Television, radio, or internet. Many Extension publications are typically available for producers to access at Extension offices (Singh, 1997).

Producers' perceptions of climate change and variability

In the survey, information about producers perceptions were gathered on local weather patterns over the past 10 years. Specifically, we collected data on changes in temperatures, rainfall, dry periods, floods, hailstorms, unpredictability of weather, groundwater table and onset as well as retreat of monsoon. Climate change is a long-term phenomenon and researchers use long-term time series analysis of climatic variables, such as temperature and precipitation, however, we used producers' perceptions within past 10 years periods. Producers respond to survey questions based on their memory of the recent past and we chose 10 years period as a reference timeframe in this study. Table 1 presents the percentage of respondents who perceived climate change in the past 10 years from 2009 to 2018 (Regmi, 2020). If producers perceived changes in weather patterns, the probability of adopting climate change adaptation practices are high (Nhemachena and Hassan, 2007; Nhemachena et al., 2014; Khanal et al., 2018).

Empirical model

Theoretically, farmers' adoption intensity of climate change adaptation practices is higher if farmers' utility gained from cumulative effects of five practices is greater than non-adoption. Following Teklewold et al. (2013), we specify the total number of climate change adaptation practices to represent the adoption intensity and hypothesize that access to four types of institutional resources positively influence the farmers' adoption intensity. The number of practices adopted i.e., the adoption intensity may serve as a count variable with an assumption of equal probability of occurrence (Wollni et al., 2010). However, the likelihood of adopting the first practice may differ from adopting additional practices since experienced producers are more exposed to technical information (Teklewold et al., 2013). Therefore, the number of adaptation practices adopted serves as an ordinal variable instead of a count variable. The ordered probit model presented in equations 2–4 as following:

$$Y^*_i = X'_i\beta + \varepsilon_i \quad \text{for } j = 1, .., M \text{ practices} \tag{2}$$

we define

$$Y_i = j \text{ if } \alpha_{j-1} < Y^*_i \leq \alpha_j \tag{3}$$

Then,

$$P\left(Y_i = j|X\right) = 1 - \phi\left(\alpha_{j-1} - X'_i\beta\right) \tag{4}$$

where $Y*_i$ represents a latent variable (utility of adoption of producer i $(i = 1, \ldots\ldots, N)$) indicating adoption of j number of adaptation practices adopted $\left(j = 1, \ldots\ldots, M\right), X'_i$ is a vector of explanatory variables, β is a vector of parameters to be estimated, α_j are threshold parameters (cutoffs), ε_i is an unobservable error term (normally distributed; zero mean and unitary variance), and P represents probability and ϕ is the standard normal cumulative distribution function (cdf). The regression parameters, β, and threshold parameters (cutoffs), α_j, are estimated through maximum likelihood estimation. We use *oprobit* command in STATA 16 to estimate the ordered probit model (StataCorp, 2019). The coefficients from ordered probit estimation indicate how each institutional resource enhances intensity of adoption. Thus, we estimate marginal effects to quantify how each explanatory variables affect intensity of adoption. The marginal effect of change in X' on the likelihood of having j^{th} category is:

$$\frac{\partial P(Y_i = j)}{\partial X_i} = [\phi\left(\alpha_{j-1} - X'_i\beta\right) - \phi\left(\alpha_j - X'_i\beta\right)]\beta \tag{5}$$

We use the post-estimation command, *mfx* after fitting ordered probit model in Stata 16 to estimate marginal effects.

We hypothesize that access to four institutional resources (i.e., membership, Extension, training, and information) positively influence the producer's decision to adopt climate change adaptation practices. Following Deressa et al. (2009), we hypothesize that access to Extension, and information influence the adoption of climate change adaptation practices. Following Piya et al. (2013), our hypothesis is that membership, training, and information affect the adoption of multiple climate change adaption practices. Likewise, Zamasiya et al. (2017) indicate that access to Extension, information, and membership to social groups enhance the adoption of climate change practices among smallholder producers.

The control variables as a part of X'_i include farmers' and farm characteristics that may influence farmers' decisions to adopt multiple adaptation practices. Farmers' household characteristics such as gender of the household head, household size, years of farming experience, and education level are potential key determinants of adoption (Ali and Erenstein, 2017; Mulwa et al., 2017). We hypothesize that gender of farmers' head of household influences the decision to adopt. Following Deressa et al. (2009), we hypothesize that greater educational attainment of the household head implies better access to information on improved farming practices, and, thus, greater likelihood of adaptation to climate change. A dependency ratio, which is the total number of dependent family members divided by the total number of economically active members in the household, serves as a proxy for household labor availability. A family with a lower dependency ratio has greater availability of labor to adopt additional labor-intensive farming practices (Deressa et al., 2009). We include years of farming of household head to hypothesize that producers with many years of farming experience are more likely to adopt multiple adaptation practices (Deressa et al., 2009). We hypothesize that households whose members have migrated (for employment abroad) can influence the adoption decision in either way (positive and negative). As noted by Hassan and Nhemachena (2008), Nhemachena et al. (2014), Ali and Erenstein (2017), and Mulwa et al. (2017) we hypothesize that household income has a positive effect on adoption as higher income provides opportunities to improve farming practices. We hypothesize that producers are more likely to adopt climate change adaptation practices if they perceived changes in local weather patterns.

Following Nhemachena et al. (2014) and Mulwa et al. (2017) we include farm characteristics such as size and number of parcels as additional factors influencing the adoption of multiple climate change adaptation practices.

Empirical results and discussion

Data discussion

We present summary statistics from the data used for the empirical model in Table 2. More than three-fourths of producers (77%) perceived changes in local weather patterns in Chitwan over the past 10 years. Our data indicate that almost a quarter of producers did not adopt any climate change adaptation practice (23%). Among the five climate change adaptation practices, majority of producers adjusted their crop calendar (73%), adopted improved varieties (65%), and invested in irrigation practices (61%), while less than a quarter of producers adopted IPM practices (22%) and DSR practices (16%) in the past 3 years. More than half of producers (54%) had access to local agricultural Extension services and weather-related information through television, radio, mobile phone applications, text messages, or publications in the past year. About 44% of producers participated in climate change adaptation training programs, and more than two thirds of producers (68%) were members of agricultural groups or cooperatives in the past 3 years.

The farmers' demographic characteristics indicate that 20% of heads of farmers' households were female, and the ratio of dependent family members to economically active family members that are working age (16–60 years old) was 0.49. Nearly half (45%) of producers had at least one household member who migrated to another country for employment in the past year. The average education of heads of farmers' households was 7.9 years, the average farming experience of producers was 26.0 years, and average annual household income was equivalent to $2,091 (USD). The rice farm characteristics show that the average number of plots under rice cultivation was 1.65 and average rice cultivated area for each farm was 0.46 hectares (1.137 acres). Over three-fourths of the rice producers (78%) sold rice in their local marketplace in the past year.

Results from empirical model

We report parameter estimates and marginal effects of the ordered probit model in Table 3. The likelihood ratio chi-squared statistic for the ordered probit model is 324.56, the log-likelihood value is −434.87 and highly significant (Prob $> \chi^2 = 0.000$), indicating that the variables sufficiently explain the ordered probit model and goodness of fit measure of the model with the data. Multicollinearity was assessed by calculating conditional index values for each explanatory variable of the ordered probit model (Belsley, 1991). Multicollinearity can be a concern in regression models with many variables as in the ordered probit model. A condition index value is used to detect multicollinearity (Belsley, 1991). An informal rule of thumb suggests that the condition index value above 30 indicates multicollinearity. The condition index value of our model is 9.48, and thus there is no evidence of multicollinearity among the variables.

The coefficients of the ordered probit model can be interpreted only in terms of their signs, and the magnitudes of the effects of the variables are shown in their marginal effects where all the other covariates are held at the means. Our results indicate that if producers perceive variability in

TABLE 2 Variable descriptions and summary statistics ($n = 359$).

Variable	Description	Mean	Standard deviation	Expected sign
Climate change adaptation				
Variety	1 if adoption of drought tolerant and short-duration rice varieties; 0 otherwise	0.65	0.47	N/A
Irrigation	1 if producer invested in improved irrigation; 0 otherwise	0.61	0.48	N/A
DSR	1 if adoption of direct seeded rice; 0 otherwise	0.16	0.36	N/A
IPM	1 if adoption of integrated pest management; 0 otherwise	0.22	0.41	N/A
Adjustment	1 if adjusted crop planting date; 0 otherwise	0.73	0.44	N/A
Institutional resources				
Membership	1 if any household member is a member of a farmers group or cooperative; 0 otherwise	0.68	0.46	+
Extension	1 if producer contacted Extension agent in the past year; 0 otherwise	0.54	0.50	+
Training	1 if producer received agricultural training in the past year; 0 otherwise	0.44	0.48	+
Information	1 if producer received agricultural and weather information through TV/FM radio, phone applications, text messages, and publications; 0 otherwise	0.54	0.49	+
Demographics				
Gender	1 if head of the household is female; 0 otherwise	0.20	0.40	+/−
Dependency ratio	Ratio of number of dependent family members to number of economically active family members aged 16–60 years	0.49	0.65	-
Out-migration	1 if any of household member migrated to another country for employment; 0 otherwise	0.45	0.49	+/−
Education	Formal education years of producer	7.92	4.12	+
Farming years	Years of farming experience of producer	26.01	10.81	+
Income	Annual household Income (USD)	2,090.90	1,472.01	+
Climate change perception				
Climate	1 if perceived changes in local weather over the past 10 years; 0 otherwise	0.77	0.42	+
Farm characteristics				
Rice plots	Number of plots under rice cultivation	1.65	0.79	+
Rice sold	1 if sold rice in the market; 0 otherwise	0.78	0.41	+
Rice area	Hectares of rice area	0.46	0.30	+/−

local weather patterns, the likelihood of adopting more climate change adaptation practices increases. The marginal effects of the variable suggest that changing from unperceived to perceived variability in local weather patterns decreases the probability of not adopting, or adopting one, and two climate change adaptation practices by 17.8, 15.3, and 3.7%, respectively. In contrast, the same change increases the probability of adopting three, four, and five climate adaptation practices by 23.7, 9.9, and 3.2%, respectively.

Our results also indicate that if producers are a member of farmer groups or cooperatives and have access to Extension, training, and information services, their likelihood of adopting multiple climate change adaptation practices increases (see Figure 2). We analyzed and interpreted intensity of adoption as high intensity and low intensity. For example, low intensity includes adoption of one or two climate change adaptation practices and high intensity includes adoption of three or more climate change adaptation practices. Our analysis focuses on examining high intensity of adoption measured by the adoption of three, four, and five climate change adaptation practices. The positive effect of the membership in farmer groups or cooperatives is consistent with literature by Teklewold et al. (2013) and Aryal et al. (2018) who find that membership in farmer groups and cooperatives increases the likelihood of

TABLE 3 Parameter estimates and marginal effects from ordered probit model (Dependent variable: Climate adaptation intensity).

Explanatory variable	Coef.	St.Err	Marginal effect					
			Prob = (Y=0|X)	Prob = (Y=1|X)	Prob = (Y=2|X)	Prob = (Y=3|X)	Prob = (Y=4|X)	Prob = (Y=5|X)
Institutional resources								
Membership	0.410**	0.178	−0.059**	−0.072**	−0.028**	0.090**	0.051**	0.017**
Extension	0.595***	0.148	−0.080***	−0.103***	−0.044***	0.120***	0.078***	0.029***
Training	0.407***	0.144	−0.050***	−0.070***	−0.033**	0.077***	0.056***	0.021**
Information	0.509***	0.162	−0.068***	−0.088***	−0.038***	0.103***	0.067***	0.025**
Demographics								
Gender	−0.294*	0.150	0.042*	0.052*	0.020**	−0.066*	−0.036**	−0.012*
Dependency ratio	0.060	0.085	−0.007	−0.010	−0.004	0.012	0.008	0.003
Out-migration	−0.042	0.120	0.005	0.007	0.003	−0.008	−0.005	−0.002
Education	0.082***	0.021	−0.010***	−0.014***	−0.006***	0.016***	0.011***	0.004***
Farming years	0.001	0.005	−0.001	−0.001	−0.001	0.001	0.001	0.001
Income	0.001**	0.000	0.001**	−0.001**	−0.001**	0.001**	0.001**	0.001**
Climate change perception								
Climate	0.961***	0.186	−0.178***	−0.153***	−0.037***	0.237***	0.099***	0.032***
Farm characteristics								
Rice plots	0.111	0.086	−0.014	−0.019	−0.009	0.022	0.015	0.005
Rice sold	0.206	0.166	−0.028	−0.036	−0.015	0.045	0.026	0.009
Rice area	−0.269	0.213	0.034	0.047	0.022	−0.054	−0.036	−0.013

Log-likelihood ratio $\chi 2$ (24) = 324.56; Prob > $\chi 2$ = 0.000.
Number of observations = 359.
Log-likelihood = −434.87.
***, **, and * refers to significance at 1%, 5%, and 10 % levels, respectively.

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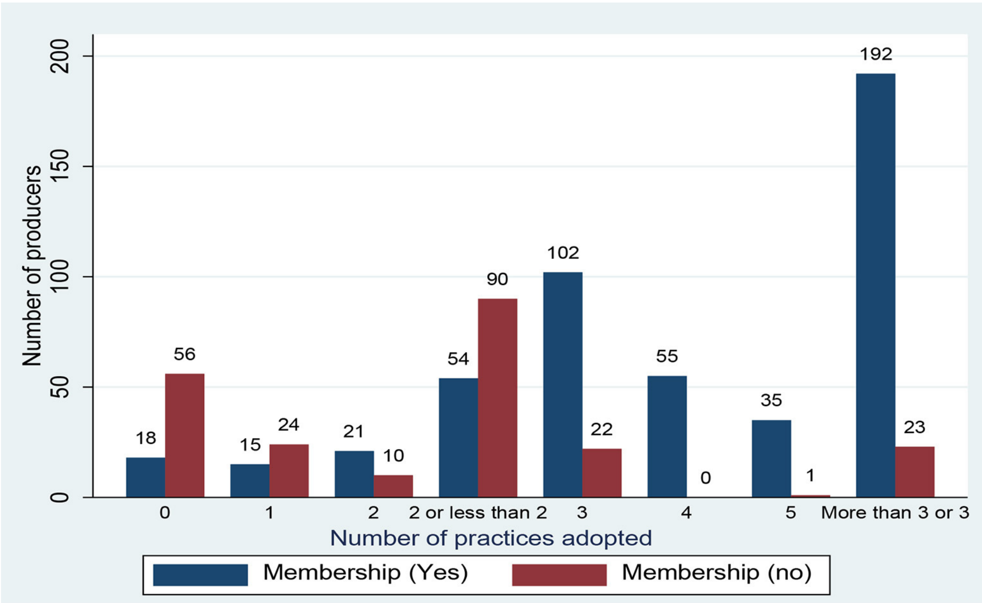

FIGURE 2
Intensity of adoption of climate change adaptation practices across membership status.

adopting climate change adaptation practices such as adopting stress-tolerant crop varieties, crop rotation, and tillage practices. The positive effect of the access to Extension service aligns well with previous studies (FAO, 2003; Etwire et al., 2013; Mulwa et al., 2017; Rickards et al., 2018; Atube et al., 2021) that find educational programs through Extension services help improving the capacity of smallholder producers to mitigate negative impacts of climate change. The positive effect of climate change adaption training implies that producers who attend such training programs are more likely to adapt to climate change by adopting improved crop varieties, adjusting farm calendar, following weather forecasts, and intercropping (Trinh et al., 2018). The positive effect of access to weather information supports previous findings (Mwalukasa, 2013; Upadhyay and Bijalwan, 2015; Islam and Nursey-Bray, 2017; Mulwa et al., 2017; Owusu et al., 2021) that access to climate-related information enhances the likelihood of climate adaptation practices.

The marginal effects of the four institutional resources show that, keeping other covariates at their means, changing from non-member to member of farmer groups or cooperatives and changing from not having to having access to Extension service, training program, and information decrease the likelihood of adopting zero, one, and two climate change adaptation practices. In contrast, the same changes under the same conditions increase the likelihood of adopting three, four, and five climate change adaptation practices. Out of the four institutional resources, access to Extension service has the highest absolute marginal effects across all six climate change adaptation practices. For example, changing from not having to having access to Extension service decreases the likelihood of adopting zero, one, and two climate change adaptation practices by 8.0, 10.3, and 4.4%, respectively. In contrast, the same change increases the likelihood of adopting three, four, and five climate change adaptation practices by 12.0, 7.8, and 2.9%, respectively. Overall, consistent with the findings of Aryal et al. (2018), the likely impact of each institutional factors reduces as the level of intensity increases. For example, access to Extension services enhances the likelihood of adopting three climate change adaptation practices by 12.0% whereas the likelihood of adopting five climate change adaptation practices increase by only 2.9%. These findings indicate that adoption of a greater number of adaptation practices reduced with the increasing availability of multiple adaptation practices.

It is noteworthy to identify that there are consistently negative marginal effects of the four institutional resources when producers do not adopt or up to two climate change adaptation practices (low intensity of adoption) while consistently positive marginal effects of the four institutional resources on three to five adaptation practices (high intensity of adoption). The reason behind this clear and consistent pattern is as follows: our data indicates that majority of producers who have a membership (78%), and have access to Extension service (82%), training program (84%), and information (84%) choose to adopt three or above climate change adaptation practices or high intensity adopters (see Table 4, Figure 2). In contrast, majority of producers who do not have a membership (80%) and do not have access to Extension service (66%), training program (59%), and information (69%) choose not to adopt

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TABLE 4 Intensity of adoption (number of practices) based on producer's access to extension, training, and information (institutional resources).

Intensity of adoption (number of practices)	Producer's access to:					
	Extension		Training		Information	
	Yes	No	Yes	No	Yes	No
0	6	68	0	74	0	74
1	14	25	10	29	13	26
2	15	16	15	16	18	13
Less than or equal to 2 (low intensity)	35	109	25	119	31	113
3	85	39	69	55	81	43
4	44	11	39	16	51	4
5	31	5	25	11	33	3
More than or equal to 3 (high intensity)	160	55	133	82	165	50

or adopt up to two climate adaptation practices or low intensity adopters.

The parameter estimates and their marginal effects of the control variables are also presented in Table 3. Results reveal that male-headed households are more likely to adopt at least three climate change adaptation practices (high intensity of adoption) compared with households headed by female. Results also show that farmers with higher levels of education and income are less likely to adopt less than two climate change adaptation practices (low intensity of adoption) and more likely to adopt at least three climate change adaptation practices (high intensity of adoption). In contrast, farm characteristics such as number of rice plots, whether harvested rice is sold in market, and rice acreage are not significant factors in the decision to adopt climate change adaptation practices.

We found that 23.4% of producers did not adopt any climate change adaptation practices. We analyzed the potential reasons for smallholder producers not adopting climate change adaptation practices (see Table 5). Results indicate that lack of relevant information and inadequate technical knowledge are two prominent reasons for not adopting improved varieties, DSR, IPM, and adjustment in crop calendar, while affordability is the main reason farmers to not adopt irrigation practices. Overall, we find that for four out of five adaptation practices (except improved irrigation), lack of information and lack of technical knowledge are the most important reasons for not adopting climate change adaptation practices. These findings suggest that improved education and providing technical training along with financial support to producers may improve adoption of climate change adaptation practices.

Conclusions

This study evaluated the influence of agricultural Extension services, agricultural training, and information on weather and improved farming practices, and membership in producer groups/cooperatives on adoption intensity of climate change adaptation practices. As a case study, we collected smallholder rice producer data in 2019 through household surveys in Chitwan, Nepal. We used an ordered probit model estimation to examine how institutional resources influence adoption intensity of practices.

Smallholder rice producers face many adverse impacts resulting from climate change. Along with reduced yields, the most serious challenges faced by smallholder rice producers in Chitwan include greater incidence of disease, pests, and weeds, delays in rice transplantation, and reduced availability of irrigation water. Smallholder producers adopted several practices to reduce the negative impacts of climate change and variability on rice production. Results indicate that 76.6% of rice producers adopted at least one adaptation practice. Lack of information and technical knowledge on adaptation practices and insufficient financial resources are main reasons for non-adoption of adaptation practices.

The findings indicate that: (1) access to institutional resources significantly enhanced the likelihood of adopting multiple climate change adaptation practices; (2) the adoption of three, four, and five climate change adaptation practices (high intensity of adoption) significantly increased with access to institutional resources; (3) intensity of adoption of climate change adaptation practices reduced with more adaptation alternatives available to smallholder rice producers; and (4) lack of information and technical knowledge are the most important reasons for non-adoption of climate change adaptation practices by smallholder rice producers.

The findings of this study are valuable for policymakers and local agencies to prioritize resource allocation to enhance intensity of climate change adaptation among smallholder rice producers. The results from this study are limited to the intensity of adoption of climate change adaptation practices and have no bearing on the effectiveness or the impact of

TABLE 5 Reasons for non-adoption of climate change adaptation practices (%).

Reasons for non-adoption	Varieties	Irrigation	DSR	IPM	Crop calendar adjustment
Lack of information	41.1	7.4	41.0	47.3	32.8
Unable to afford	15.2	59.6	2.1	4.5	11.4
Lack of technical knowledge	34.2	12.1	38	43.9	34.8
Requires more effort/not profitable	0.9	3.3	5.1	2.4	2.7
Not applicable	4.4	17.3	13.5	1.7	17.0
Unavailable	4.2	0.3	0.4	0.2	0

the practices. For example, holding other factors at mean, access to Extension services enhanced the likelihood of adopting three, four, and five climate change adaptation practices (high intensity of adoption) by 12.0, 7.8, and 2.9%, respectively, which is higher than the impacts of access to agricultural training services, access to weather information, and membership in producer co-operatives or farmer's groups. Local governments can enhance intensity of adoption by prioritizing resources to Extension services first, followed by access to weather-related information, training support, and membership in producer groups/cooperatives.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Review Board, University of Tennessee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

HR led the primary data collection, analyzed the data, conceptualized the model, and contributed to manuscript preparation. SU conceptualized the study, contributed to survey development, data analysis, and contributed to manuscript preparation. S-HC and CC assisted with survey development, data analysis, model estimation, and contributed to manuscript preparation. JM contributed to data analysis and manuscript preparation. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.1016404/full#supplementary-material

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