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RESEARCH ARTICLE

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Building resilience to climate change: Examining the impact of agro-ecological zones and social groups on sustainable development

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Abstract

Nepal is one of the most vulnerable countries to climate change, which is negatively affecting agricultural production and food security. However, the role of agro-ecological zones and social groups in climate change adaptation (CCA) and its impact on smallholder farmers in Nepal remains unexplored. To fill this gap, this study aimed to identify the effect of agro-ecological zones and social groups on smallholder farmers' adaptation to climate change using the multivariate probit model. Multistage sampling was used to collect data from 400 households in three agro-ecological zones of Nepal. These zones were highland (mountainous region), midland (hilly region) and lowland (terai/plain region). The results of our study showed that farmers in the Mountain region are more likely to adopt off-farm activities and temporary migration as a CCA strategy than those in the Terai/plain agro-ecological zone. In the Terai/Plain, farmers mainly adopt small-scale irrigation and agroforestry. In terms of social groups, the Brahmin group was more likely to adopt new crop varieties and small-scale irrigation than the Sudra group. The Sudra farmers preferred temporary migration and off-farm activities more than the Brahmins. Our study shows that policies to promote the adoption of CCA strategies need to take into account location and social group differences in order to improve the adaptive capacity of the most vulnerable farmers. Mountain and Sudra farmers need support to adapt to climate change and sustain agriculture.

KEYWORDS

agro-ecological zones, climate change, multivariate probit model, social groups, sustainable development

1 | INTRODUCTION

Nepal is one of the countries highly exposed to climate-related hazards due to its fragile topography, climate-sensitive subsistence livelihoods and low adaptive capacity of farmers (Government of Nepal, 2021; Piya et al., 2013; Shrestha & Aryal, 2011). It was also ranked as the fourth most climate-vulnerable country in the world by Maplecroft's Climate Change Vulnerability Index in 2011 (Eckstein et al., 2019). Continued temperature rise, rainfall variability and extreme events such as droughts and floods are increasing at a higher rate in Nepal than in other countries (Olesen & Bindi, 2002; World Bank, 2021). A report by the Asian Development Bank estimates that climate change will reduce Nepal's GDP by 2.2 per cent per year by 2050 (ADB, 2021). Nepal's GDP is predominantly dependent on agriculture, with agriculture contributing 25.8% to the national economy (Government of Nepal, 2021). Climate-related shocks have severely affected the productivity of the agricultural sector and the livelihoods of smallholder farmers (Ahmed et al., 2014; Aryal, Sapkota, Khurana, et al., 2020; Aryal, Sapkota, Rahut, et al., 2020; Ryghaug, 2011). A variety of adaptation strategies, such as crop diversification, new crop varieties, agroforestry and off-farm activities, help reduce vulnerability to climate shocks (Beltrán-Tolosa et al., 2020; IPCC, 2012; Mahmood et al., 2020). Climate change adaptation (CCA) strategies are effective when they are site- and context-specific (Diwakar & Lacroix, 2021; Makate et al., 2019; Mogomotsi et al., 2020; Tenali & McManus, 2022).

Agricultural systems in Nepal vary according to agro-ecological zones (AEZs) (Liliane & Charles, 2020). The country has three representative agro-ecological zones, namely Mountain, Hill and Terai/Plain, which are characterised by different altitudes, climates and agricultural production systems (World Bank, 2017). The consequences of climate change, such as reduced yields, are a more pressing issue in the Mountain region than in the Hill and Terai/Plain regions (FAO, 2015; Ginbo, 2022; Nepal Academy of Science and Technology, 2018; World Bank, 2021). Mountainous farmers are biophysically limited to a maximum of two cropping seasons per year, while Terai/Plain farmers have three (Poudyal et al., 2021). Farming systems in the mountain of Nepal are more based on cattle and yak (livestock) production, and farmers there have less diversified sources of income than those in the plains. Mountain farmers also have less access to human, financial and physical capital (Choden et al., 2020; Poudyal et al., 2021). Smallholder farmers in the mountain region have fewer options for CCA strategies than their counterparts in the hill and terai/plain regions due to lower adaptive capacity (Choden et al., 2020; Poudyal et al., 2021).

Adaptive capacity also differs among social groups (Adger et al., 2003; Asante et al., 2021; Aslany & Brincat, 2021; IPCC, 2012; Smit & Wandel, 2006). In Nepal, there are four social groups: Brahmin, Kshatriya, Vaishya, and Sudra. The allocation of farm work and land resources in the communities of Nepal is based on these social groups. The contribution of Brahmins in designing strategies to reduce the impact of climate shocks is comparatively higher than the other groups (Nagoda & Nightingalea, 2017). Similarly, a few Sudra farmers could also have higher levels of adaptability. However, the Sudra households usually cultivate land owned by the Brahmins and receive a negotiated share of the harvested crops. Although most Sudra farmers are disadvantaged, some Brahmin farmers may face challenges due to their lower economic status. Sudra farmers are usually tenant farmers and depend on daily labor for their livelihoods. These sources of income are highly volatile in the face of climate change and increasing disasters. In some cases, Sudra farmers are marginalised from decision-making on agricultural production, including the adoption of new technologies such as the purchase of machinery for sharing within the community (Poudel et al., 2021; Ravera et al., 2016). The government provides farming equipment, improved seed varieties and other benefits to the farming groups in the local communities, which are supposed to be distributed equally. However, the Sudra groups have less control over them or are given the last chance to use them (Bapuji & Chrispal, 2020). Because of this inequality, unequal distribution of resources and access to information and institutions, Sudra farmers have less adaptive capacity. They are more vulnerable to climate change (Nagoda & Nightingalea, 2017).

Previous studies have suggested CCA strategies and factors influencing their adoption in different countries such as in Nepal by Tiwari et al. (2014), Bhatta and Aggarwal (2016); Uprety et al. (2017), in Pakistan by Mahmood et al. (2019), in Ghana by Antwi-Agyei et al. (2021), in Bangladesh by Alauddin and Sarker (2014), and in India by Jha and Gupta (2021). However, to our knowledge, no research has been conducted to assess the impact of agro-ecological zones and social groups on farmers' CCA strategies. To fill this gap, this study examines the impact of agro-ecological zones and social groups on smallholder farmers' CCA strategies in Nepal. The study identifies location- and social group-based CCA strategies at the household level in Nepal and suggests comparable solutions for other countries with similar characteristics. It will also promote the adoption of CCA, leading to improved rural livelihoods, increased crop productivity and a systematic shift towards sustainable development. The study aims to accomplish the following objectives:

a. To identify agro-ecological zones' impact in adopting CCA strategies among smallholder farmers in Nepal.
b. To identify the impact of the social groups in adopting CCA strategies among smallholder farmers in Nepal.

To date, the action theory of adaptation and the framework of intersectionality have been used separately. This study contributes to theory building by combining the action theory of adaptation and the framework of intersectionality. Understanding how AEZs and social groups influence the adoption of CCA strategies will help policy makers, donors and extension agents to prioritise the most vulnerable household farmers and increase their capacity to adapt to climate change.

2 | CONCEPTUAL FRAMEWORK: ACTION THEORY OF ADAPTATION AND CONCEPT OF INTERSECTIONALITY

As a theoretical background for this study, we integrated an action theory of adaptation by Eisenack and Stecker (2011) with the concept of intersectionality. An action theory of adaptation proposes a way of thinking about adaptation that emphasises the interconnectedness of complex activities that address the social consequences of climate change and considers multiple actors in different roles (Eisenack & Stecker, 2011). Exposure units are climate shocks resulting from temperature and precipitation variability (Figure 1) that negatively affect agricultural production and the livelihoods of farm households. In our context, smallholder farmers (operators) are exposed to and respond

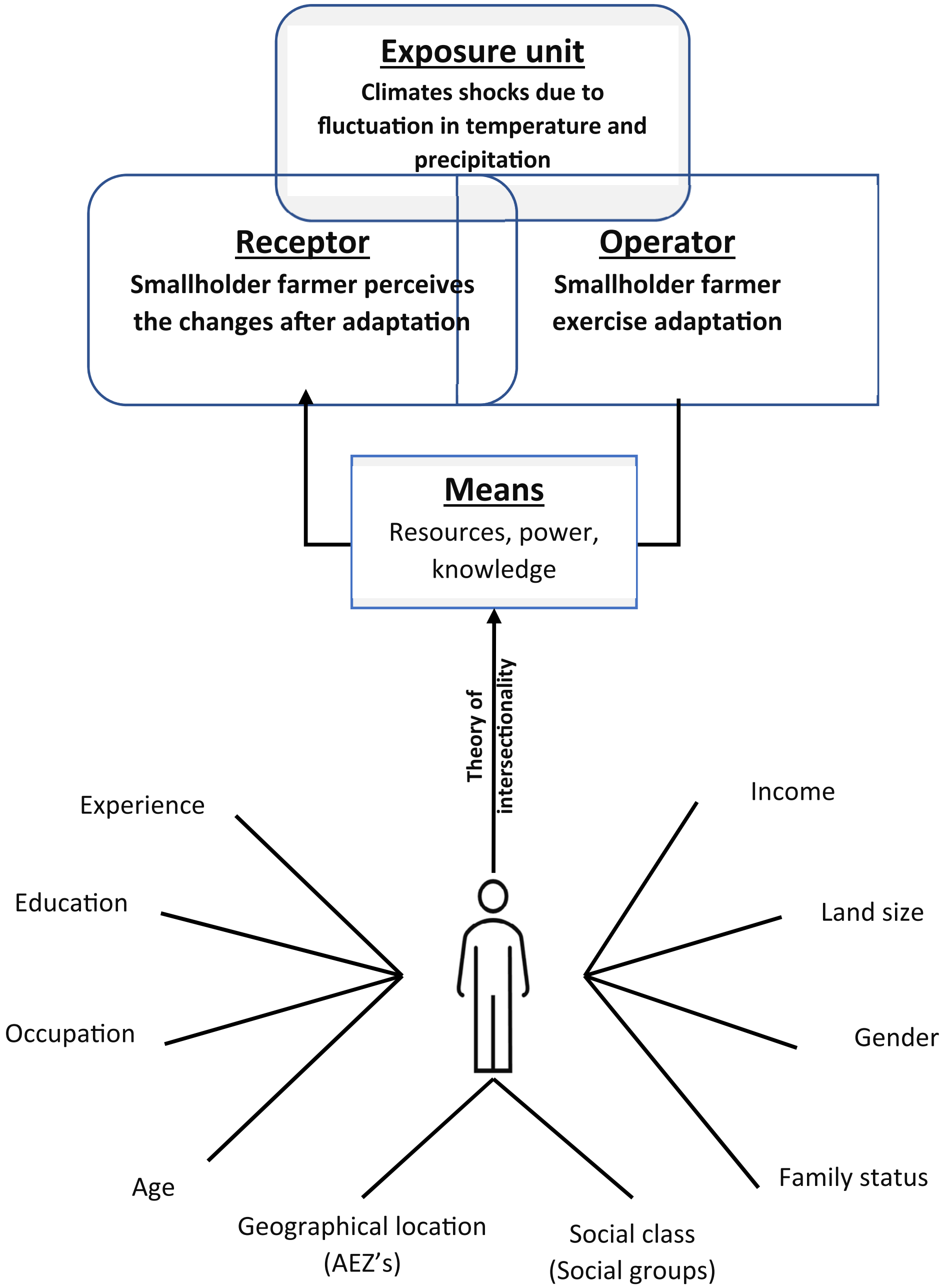

FIGURE 1 Concepts of an action theory of adaptation and framework of intersectionality. Author's formulation based on (Eisenack & Stecker, 2011); (Crenshaw, 1991)

to climate shocks. As smallholders experience the benefits of adaptation, such as improved food security and livelihoods, they are the receptors. The actor needs resources, knowledge and power to implement the adaptation strategies. Resources, knowledge and power depend on the characteristics of individuals and households (Eisenack et al., 2012). The characteristics of individuals and households are examined through the lens of intersectionality.

Crenshaw's (1991) framework of intersectionality looks at different forms of inequality in society. It also helps to understand the combination of different forms of inequality that are complex to address. Intersectional theory argues that individuals and households can be disadvantaged by different forms of inequality. In our context, the concept of intersectionality aims to raise awareness of social inequalities in terms of adaptive capacity to climate change and to strengthen the capacity of mountain and Sudra farmers. An intersectional lens supports addressing the vulnerability of these disadvantaged (mountain farmers) and discriminated (Sudra farmers) households in society.

Previous literature by Onta and Resurreccion (2011), Amran et al. (2011), Ravera et al. (2016), Lawson et al. (2020), Azong and Kelso (2021) and IPCC (2022), reported that smallholder farmers' adaptation capacity relies on geographical and social characteristics. Crenshaw's (1991) intersectionality approach addresses the interconnectedness of CCA strategies with geographical and social conditions (Collins & Bilge, 2020). Inequalities based on agro-ecological zones are geographically embedded. In contrast, social groups in Nepal's agriculture-dependent communities are socio-economically embedded.

Along with agro-ecological zones and social groups, various other intersecting factors such as age, education, off-farm occupation, income,

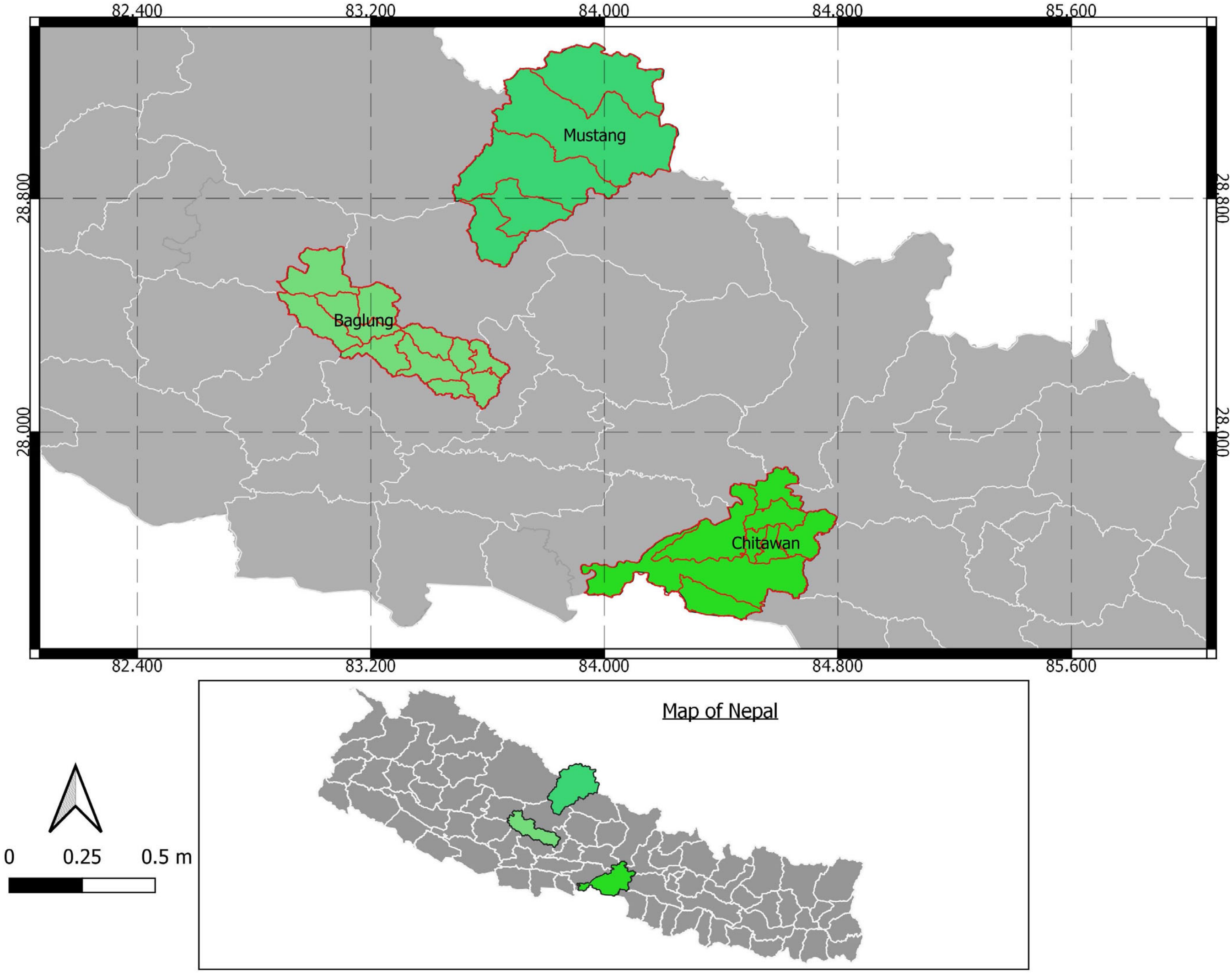

FIGURE 2 Study area map.

landholding, land size, access to market, access to irrigation, access to credit, and access to information also influence farmers' ability to adopt CCA strategies (Azong & Kelso, 2021; Kaijser & Kronsell, 2014; Lawson et al., 2020; Onta & Resurreccion, 2011; Ravera et al., 2016).

Previous studies have used the action theory of adaptation and the theory of intersectionality separately (Eisenack et al., 2012; Griese et al., 2021; Jordanoska, 2018; Maia et al., 2022; McArdle, 2021; Sharma et al., 2022). In this study, we bring these theories together to better understand the complexity of CCA drivers. The action theory of adaptation focuses on climate change and operators' adaptation strategies, and the theory of intersectionality focuses on social and geographical drivers.

3 | METHODOLOGY

3.1 | Study area

Nepal has three representative agro-ecological zones that run from east to west and are characterised by different altitudes, climates and agricultural production systems. The highland (mountainous region) ranges from 2500 to 8848 m, the midland (hilly region) from 610 to 2500 m, and the lowland (terai region) from 67 to 610 m above sea level. This research was conducted in these three agro-ecological zones, that is, Mustang district from the mountain region (latitude 28°N and longitude 84°E), Baglung district from the hill region (latitude 27°N and longitude 84°E) and Chitwan district (latitude 29°N and longitude 84°E) from the Terai or plain region(Figure 2). The study area was selected on the basis of the altitude of different AEZs and the representation of different social groups.

While in some parts of the study area there may have a higher proportion of Sudra farmers at higher altitudes, it is important to note that social groups are not restricted to specific locations and can be found throughout the study area. The population of smallholder farmers is higher in the mountain region than in the hill and terai regions. Subsistence farming and crop-livestock integration are the main characteristics of agriculture in the study area (Rijal et al., 2022). Farmers in the study area practice different adaptation strategies to cope with climate shocks.

3.2 | Sampling technique

A multistage sampling technique was used to select the respondents. In the first stage, three districts, Mustang district from the mountainous region, Baglung district from the hilly region and Chitwan district from the erai/plain region, were purposively selected to include respondents from all three AEZs. In the second stage, we also used a purposive sampling technique to select one rural municipality (the lowest administrative unit within the government structure in Nepal) in each district to include respondents from different altitudes. The villages of three rural municipalities, Thasang, Gharapojung and Baragaun Muktikshetra, were selected from Mustang district, and Bhuskat, Hila and Tara (Tarakhola Municipality) from Baglung district. Similarly, three villages, Lanku, Ratnanagar and Sharadpur, were selected from Chitwan district. Finally, snowball sampling was used to select 180 smallholder farmers from the Hill region, 150 from the Hill region and 70 from the Terai region. The snowball sampling technique helps to access hidden populations while being cost and time efficient (Dudovskiy, 2018). The selected sample represents approximately 7–10 percent of the total population of smallholder farmer households in each rural municipality. A total of 400 farmers were selected. Due to the low response rate and population of smallholder farmers, different respondents were interviewed in each region.

3.3 | Data collection

Primary data were collected from households in the three agro-ecological zones using a structured questionnaire survey. A structured questionnaire was developed based on the conceptual background presented in section 2. Recent studies such as those by Khanal et al. (2018), Trinh et al. (2018), Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020), Karki et al. (2020), Muench et al. (2021), Antwi-Agyei et al. (2021), Jha and Gupta (2021) and Tesfaye and Nayak (2022) helped to further improve the questionnaires. In addition, the survey content was adapted based on a focus group discussion with a local farmers' group. We conducted a pilot test by randomly selecting 28 respondents (12 from the mountain region, 10 from the hill region and 6 from the terai/plain region) from the study region to check the clarity of the questionnaire. The comprehensive questionnaire was divided into four categories: socio-demographic characteristics, access to credit and market, climate change awareness, and climate change vulnerability and adaptation strategies. Data were collected from March 2021 to July 2021 using a multistage sampling technique. First, the mayor and secretary of the village in each study area were contacted to obtain permission to collect data. Village staff made the initial contact with smallholder households and, in some cases, the secretary and mayor. In addition to the lead author, 15 (5 in the mountain region, 5 in the hill region and 5 in the terai/plain region) well-trained enumerators were employed to assist in conducting the interviews with the smallholders. All questionnaires were administered on paper and were based solely on face-to-face interviews with farmers. The questionnaire was developed in English and translated into Nepali prior to fieldwork.

3.4 | Analytical tools

3.4.1 | Multivariate Probit model

A multivariate probit (MVP) model was used to capture smallholder farmers' decision to adopt multiple CCA strategies. The MVP model was used because farmers rely on adopting multiple CCA strategies rather than relying on one option to reduce the impacts of climate change. Previous literature suggests that the multivariate probit (MVP) model is the most appropriate option when the responses of the dependent variables are interdependent and correlated (Abid et al., 2019; Aryal, Sapkota, Khurana, et al., 2020; Aryal, Sapkota, Rahut, et al., 2020; Trinh et al., 2018). The correlation between the different multiple adaptation options is the main source of the correlation between the error terms (Aryal, Sapkota, Khurana, et al., 2020; Aryal, Sapkota, Rahut, et al., 2020; Trinh et al., 2018). However, the multivariate probit model eliminates these correlations (Gebregziabher et al., 2016; Trinh et al., 2018). In addition, the MVP model allows a flexible correlation structure for the unobservable variables (Aryal, Sapkota, Khurana, et al., 2020; Aryal, Sapkota, Rahut, et al., 2020; Trinh et al., 2018).

The formula of the multivariate probit model for observation i and equation m is as follows (Cappellari & Jenkins, 2003; Tesfaye & Nayak, 2022; Trinh et al., 2018):

$$Y_{\mathrm{im}} = 1 \text{ if } Y_{\mathrm{im}}{}^{*} > 0 \text{ and } 0 \text{ otherwise } (i = 1, 2, \ldots, N;\ m = 1, 2, \ldots, M).$$

$$Y_{\mathrm{im}}{}^{*} = X_{\mathrm{im}}{}^{*}\beta_{\mathrm{m}} + \varepsilon_{\mathrm{im}}.$$

where, N is number of observations, M is number of options, X_{im} is matrix of explanatory variable, β_{m} is matrix of parameters, and $\varepsilon_{\mathrm{im}}$ is matrix of error terms.

Simulated Maximum Likelihood (SML) using the Geweke-Hajivassiliou-Keane (GHK) simulator developed by Cappellari and Jenkins (2003) was used to estimate the MVP model. The SML estimator is consistent as the number of observations and draws tends to infinity. STATA 14.2 software is used to analyse the data, which is appropriate for this dataset. A correlation test is performed to avoid multicollinearity between different explanatory variables. However, certain variables were initially measured in the category and transformed into a dummy. Because the variable type is initially category, the following variables were omitted from the model and used as a reference group. These are non-formal education as part of education, earning less than 150,000 Nepalese rupees as part of income, Terai region from agro-ecological region and Sudra from social groups.

3.4.2 | Selection of variables

Dependent variables

The CCA strategies were initially identified based on the previous literature. The pilot test in each study area further clarified the appropriateness of the CCA strategies. Initially, farmers were offered a choice of 14 main adaptation strategies from which they were instructed to select

TABLE 1 Descriptive statistics of variables used in regression.

Variables	Description	Mean	Standard deviation
Dependent variables			
Off-farm activities	Dummy = 1 if household implemented off-farm activities as an adaptation measure, 0 otherwise	0.53	0.50
New crop varieties	Dummy = 1 if household implemented new crop varieties as an adaptation measure, 0 otherwise	0.41	0.49
Early-matured varieties	Dummy = 1 if household implemented early-matured varieties as an adaptation measure, 0 otherwise	0.43	0.50
Small-scale irrigation system	Dummy = 1 if household implemented small scale irrigation system as an adaptation measure, 0 otherwise	0.46	0.50
Agroforestry	Dummy = 1 if household implemented agroforestry as an adaptation measure, 0 otherwise	0.31	0.46
Temporary migration	Dummy = 1 if household implemented temporary migration as an adaptation measure, 0 otherwise	0.62	0.49
Independent variables			
Gender	Dummy = 1 if the household head is male, 0 otherwise	0.72	0.45
Age	Continuous, household age in years	50.32	13.99
Education	Dummy = 1 if education level is "primary" 0 otherwise	0.36	0.48
	Dummy = 1 if education level is "higher secondary" 0 otherwise	0.27	0.44
	Dummy = 1 if education level is "graduate" 0 otherwise	0.03	0.16
Household size	Continuous, number of the family members in the household	5.80	2.88
Farm experience	Continuous, farming experience of HH in years	23.78	14.29
Land size	Continuous, total land owned by the household	13.16	17.86
Access to informal credit	Dummy = 1 if the household accessed informal credit, 0 otherwise	0.12	0.32
Farm income	Dummy = 1 if household earns more than 150,000 Rs from the farm, 0 otherwise	0.07	0.26
Awareness of CC	Dummy = 1 if HH is aware of climate change, 0 otherwise	0.92	0.27
Temperature rise	Dummy = 1 if farmers perceived temperature rise, 0 otherwise	0.84	0.36
Erratic rainfall	Dummy = 1 if farmers perceived an increase in erratic rainfall, 0 otherwise	0.58	0.49
Access to information via internet	Dummy = 1 if farmers have access to climate change information via. the internet, 0 otherwise	0.62	0.49
Access to information via farmers' group	Dummy = 1 if farmers have access to climate change information via farmer's group, 0 otherwise	0.42	0.49
Variable of interest			
Agroecological zone (Altitude)	Dummy = 1 if agroecology zone is Mountain "highland", 0 otherwise	0.46	0.50
	Dummy = 1 if agroecology zone is Hill "midland", 0 otherwise	0.38	0.48
Social groups	Dummy = 1 if social group is "Brahmin" 0 otherwise	0.24	0.43
	Dummy = 1 if social group is "Kshatriya" 0 otherwise	0.01	0.11
	Dummy = 1 if social group is "Vaisya" 0 otherwise	0.61	0.49

Note: Ropani = A unit of the area measured in Nepal, 1 Ropani = 0.051 hectare. NPR = Nepalese rupee (Currency of Nepal), 1$ = 120NPR as of May 2021.

their main strategy. Of the 14 adaptation strategies, six were significant. These were off-farm activities, new crop varieties, early-matured varieties, small-scale irrigation systems, agroforestry, and temporary migration, which were used as dependent variables (Table 1).

Explanatory variables

The selection of explanatory variables included in this study is based on the theoretical framework and a review of existing literature. Previous literature suggests that socio-demographic characteristics such as gender, age, education, social class, ethnic group, household size and farm experience positively affect farmers' adaptation choices (Aryal, Sapkota, Khurana, et al., 2020; Aryal, Sapkota, Rahut, et al., 2020; Tesfaye & Nayak, 2022; Trinh et al., 2018). Furthermore, the literature suggests that farm characteristics such as land size and institutional factors such as access to farmer groups significantly affect farmers' adaptive capacity and adaptation choices (Abid et al., 2019; Piya et al., 2013). Access to information through the internet and farmer groups are other important factors reported by previous researchers (Ullah et al., 2021; Ullah et al., 2022b; Vaughan et al., 2019). Several researchers have noted that experiences of climate change, such as temperature increases and erratic rainfall, also significantly influence farmers' adaptation choices (Tesfaye & Nayak, 2022; Trinh et al., 2018). Previous research has also shown that agro-ecological zones significantly influence the choice of CCA strategies (Aniah et al., 2019; Karki et al., 2020). Therefore, we include these climate change experience variables in our model.

Variables of interest

There is a lack of knowledge about how different agro-ecological zones and social groups influence the adoption of adaptation strategies. Nepal provides a perfect opportunity to study this, as it is located at different altitudes, resulting in different farming systems, and the society is divided into social groups. Mustang district represents mountainous regions, Baglung district represents hilly and mid-altitude regions, and Chitwan represents terai/plain and low altitude regions. Similarly, the social groups included in this research have a hierarchy of Brahmin, followed by Kshatriya, Vaisya and Sudra.

4 | RESULTS

4.1 | Sample description

The results of our descriptive statistics are presented in Table 1. Approximately 72% of households were male headed. The average age of the household head was 50.31 years. In terms of education, 36% of the farmers had primary education, 27% had secondary education and 3% had postgraduate education. The average farming experience of the respondents was 23.8 years. The average household size was 5.80 members, while the average size of land owned by smallholder farmers was 13.16 ropani (1 ropani = 0.051 ha). About 12% of the farming households had access to informal credit for agriculture. About 7% of the households earn more than 150,000 Nepalese Rupees (Rs), equivalent to $1250 ($1 = Rs.120 as of May 2021) per year from their farm. Most farmers were aware of climate change (i.e., 92%), while 84% and 58% perceived an increase in temperature and erratic rainfall, respectively, in the last 10–15 years. About 62.0% and 42 percent of smallholder farmers reported having access to weather information through the Internet and farmers' groups, respectively. About 46% of the farming households belong to the mountain AEZs and 38% to the hill AEZs. In the study area, 24% of the farmers are Brahmins, while 1.25% and 60.5% are Kshatriyas and Vaisyas, respectively.

4.2 | Adaptation strategies

In Table 2, adaptation strategies are presented based on the agro-ecological zones of Nepal. The majority of farmers in the Mountain region use agroforestry (76.23%), followed by small-scale irrigation (53.01%) and temporary migration (48.39%). Farmers in the Hilly region prefer adopting early-matured varieties (59.06%), followed by temporary migration (37.9%) and off-farm activities (37.14%). Correspondingly, 64.2% of farmers in the Terai region adopted new crop varieties, followed by small-scale irrigation (14.8%) and temporary migration (13.7%).

Table 3 below presents adaptation strategies based on the social groups. Among the six adaptation strategies, the Brahmin farmers, were highly adopting early-matured varieties and temporary migration by 57.29% each, followed by new crop varieties (56.25%) and off-farm activities (48.96%). Among the Kshatriya farmers, temporary migration (60%) was highly adopted and followed by new crop varieties (40%) and early-matured varieties (20%). The majority of farmers in the Vaisya group also used temporary migration (61.57%) and followed by small-scale irrigation (52.48%) and off-farm activities (51.65%). The Sudra farmers adopted highly temporary migration (71.93%) and followed by off-farm activities (66.67%) and early-matured varieties (33.33%).

4.3 | Determinants of farmers' adoption of adaptation strategies to climate change

The results of the MVP model are shown in Table 4. Our results show that the model fits the data well (Table 5). The adaptation strategies implemented are not mutually exclusive; the adoption of one CCA strategy does not mean that other strategies could not be adopted. To better understand which CCA strategies are often used in combination, we looked at the correlation matrix obtained from the MVP model (Table 5). A positive coefficient indicates complementarity between the two practices, meaning that the adoption of one practice is related to the other. A negative correlation coefficient indicates that the two practices are substitutes or compete for the same scarce resources. The chi-squared test of the model is statistically significant (Wald $\chi 2$ (126) = 390.13, p = .000), confirming that the explanatory variables taken together are significant in explaining the variation in farmers' adoption of the six adaptation options in the study regions. The likelihood ratio test rejects the hypothesis that the adaptation options considered are independent ($Chi^2(15) = 129.758$, $p < .000$), indicating that the multivariate regression generates more reliable information than separate univariate regressions. The results show that demographic, socio-economic, biophysical, institutional and climate change risk factors are significant determinants of CCA measures.

Results from the MVP model show that the gender of the household head has a significant and positive effect on the adoption of new crop varieties as an adaptation strategy. Male-headed farmers are more likely to adopt these CCA strategies than female-headed farmers. The model results showed that education is a significant factor in the adoption of CCA measures. This variable had a positive and significant impact on the use of off-farm activities and agroforestry. The decision to adopt agroforestry is significant for farmers with

TABLE 2 Farmers' adaptation strategies based on the agro-ecological zone ($N = 400$).

Variables		Adopters (in percentage)		
		Mountain region	Hilly region	Terai region
Adaptation strategies	Off-farm activities	51.43	37.14	11.4
	New crop varieties	8.64	27.16	64.2
	Early-matured varieties	30.99	59.06	9.94
	Small-scale irrigation system	53.01	32.24	14.8
	Agroforestry	76.23	10.66	13.1
	Temporary migration	48.39	37.9	13.7

TABLE 3 Farmers' adaptation strategies based on the social groups ($N = 400$).

Variables		Adopters (in percentage)			
		Brahmin	Kshatriya	Vaisya	Sudra
Adaptation strategies	Off-farm activities	48.96	0.00	51.65	66.67
	New crop varieties	56.25	40.00	37.19	28.07
	Early-matured varieties	57.29	20.00	39.67	33.33
	Small-scale irrigation system	39.58	0.00	52.48	31.58
	Agroforestry	14.58	0.00	38.43	26.32
	Temporary migration	57.29	60.00	61.57	71.93

higher secondary and tertiary education, while the adoption of off-farm activities was significant for all farmers with education (primary, higher secondary and tertiary) (Table 4). The farming experience of the head of the household has a significant and negative effect on the likelihood of temporary migration as an adaptation measure. Land size also has a significant and negative effect on the adoption of small-scale irrigation (Table 4). Unexpectedly, access to informal credit, such as borrowing from friends and relatives, is significantly and negatively associated with the likelihood of adopting early-matured varieties, agroforestry and temporary migration. Farm income significantly affects the adoption of agroforestry and temporary migration. Farmers earning more than 150,000 Nepalese rupees per year are more likely to adopt agroforestry and less likely to adopt temporary migration.

We found that the adoption of adaptation strategies is influenced by awareness of climate change. Farmers who are aware of climate change use off-farm activities, new crop varieties and agroforestry. Farmers' perceptions of rising temperatures and erratic rainfall also affect the adoption of adaptation strategies. The perception of rising temperatures has a significant but negative effect on the use of agroforestry. The perception of erratic rainfall has a significant and positive effect on the use of off-farm activities and early-matured varieties. Access to climate-related information significantly influences the implementation of adaptation strategies. Farmers with internet access are less likely to adopt new crop varieties and more likely to adopt small-scale irrigation. Similarly, farmers involved in local farmer groups and receiving climate change information through farmer groups significantly influence the adoption of off-farm activities, new crop varieties, early-matured varieties, small-scale irrigation and agroforestry, but not temporary migration.

5 | DISCUSSION

5.1 | CCA strategies in different agro-ecological zones

Our study revealed that (Table 2), farmers in three agro-ecological zones have adopted different adaptation strategies due to different farming systems and climatic conditions in each zone. The majority of farmers in the mountainous region have adopted agroforestry (Table 2) as a CCA strategy, which is consistent with previous studies by Ullah et al. (2022a) and Ullah et al. (2023), who reported that most farmers in mountainous regions have adopted agroforestry as a CCA strategy. Agroforestry is a system that integrates crop production with trees. Adopting agroforestry reduces the risks of climate change and increases the adaptive capacity of farmers (Ullah et al., 2022a). Farmers in the hilly region prefer to adopt early-matured varieties as a CCA strategy. This is also consistent with the previous studies by Manandhar et al. (2011) who reported that farmers in the hilly regions prefer adopting early-matured and less water demanding varieties as a CCA strategy. Accordingly, most of the respondents in the terai region adopted new crop varieties as a CCA strategy. Our results are in line with the previous findings of Karki et al. (2020) who found similar results from the study region as they reported that most farmers in the terai region adopted new crop varieties as a CCA strategy.

Results from our MVP model showed that different agro-ecological zones in Nepal influence farmers' adoption of different CCA strategies. A farmer in the mountain agro-ecological zone (Mustang district) is less likely to adopt small-scale irrigation and agroforestry practices than a farmer in the Terai region. The adoption of small-scale irrigation and agroforestry may be affected by the low

TABLE 4 Multivariate probit regression results.

Variables	Off-farm activities	New crop varieties	Early-matured varieties	Small scale irrigation system	Agroforestry	Temporary migration
Gender	−0.026(0.155)	0.302(0.166)*	−0.187(0.157)	0.065(0.158)	−0.088(0.176)	0.089(0.152)
Age	−0.003(0.008)	−0.004(0.008)	0.008(0.008)	0.011(0.008)	0.002(0.008)	0.008(0.007)
Primary education	0.303(0.173)*	0.027(0.188)	0.122(0.18)	0.236(0.177)	0.051(0.202)	0.217(0.172)
Higher secondary education	0.646(0.209)***	−0.256(0.226)	−0.185(0.214)	0.068(0.21)	0.48(0.23)**	0.107(0.205)
Graduate education	0.753(0.438)*	0.243(0.484)	0.024(0.441)	−0.091(0.452)	1.164(0.502)**	0.516(0.453)
Household size	0.027(0.026)	−0.008(0.029)	−0.028(0.027)	−0.003(0.027)	0.028(0.031)	0.027(0.025)
Farm experience	0.006(0.008)	−0.008(0.008)	−0.004(0.008)	−0.004(0.008)	0(0.008)	−0.016(0.007)**
Land size	−0.005(0.004)	0.006(0.005)	0.002(0.005)	−0.014(0.005)***	−0.001(0.006)	0.001(0.005)
Access to informal credit	0.175(0.216)	0.062(0.226)	−0.438(0.233)*	−0.107(0.228)	−0.575(0.298)*	0.607(0.229)***
Farm income	−0.232(0.257)	0.147(0.276)	0.38(0.259)	0.102(0.264)	0.666(0.283)**	−0.428(0.256)*
Awareness of CC	0.669(0.276)**	0.916(0.307)***	0.359(0.266)	−0.084(0.266)	0.576(0.316)*	0.177(0.248)
Temperature rise	0.103(0.193)	−0.094(0.208)	−0.124(0.201)	−0.081(0.2)	−0.444(0.219)**	0.013(0.189)
Erratic rainfall	0.23(0.138)*	0.095(0.149)	0.333(0.141)**	−0.202(0.14)	−0.199(0.155)	−0.013(0.136)
Access to information via internet	−0.075(0.154)	−0.335(0.165)**	0.079(0.157)	0.717(0.159)***	−0.051(0.179)	0.236(0.154)
Access to information via farmers group	−0.354(0.145)**	0.31(0.154)**	0.283(0.147)*	0.351(0.146)**	0.373(0.161)**	0.012(0.144)
Variable of interest						
Agro-ecological zone “Mountain”	2.026(0.766)***	−0.008(0.814)	0.444(0.804)	−1.869(0.828)**	−1.898(0.864)**	3.172(0.796)***
Agro-ecological zone “Hilly”	1.455(0.572)**	1.107(0.606)*	1.421(0.6)**	−1.313(0.618)**	−2.503(0.662)***	2.31(0.592)***
Social groups “Brahmin”	−0.257(0.276)	0.769(0.303)**	0.573(0.282)**	0.511(0.281)*	−0.136(0.33)	−0.194(0.27)
Social groups “Kshatriya”	−5.211(129.017)	0.759(0.588)	−0.163(0.655)	−4.554(145.143)	−4.531(165.162)	−0.117(0.632)
Social groups “Vaisya”	−0.422(0.22)*	0.248(0.231)	0.11(0.213)	0.415(0.221)*	0.221(0.231)	−0.225(0.219)

rainfall in the study area (Khadka, 2018). The average annual rainfall in the area is around 260 mm, which is one of the lowest in the country, limiting the availability of water for irrigation (Khadka, 2018). Previous findings from Nepal have reported similar results as by Paudel et al. (2022) and Kattel and Nepal (2022) found that a farmer in mountainous agro-ecological zone is less likely to adopt agroforestry and irrigation system. They suggested that the non-adoption of agroforestry may be due to limited knowledge about the practices and their proper implementation. Similarly, farmers from the hill agro-ecological zone are more likely to adopt off-farm activities and temporary migration than those from the terai/plain agro-ecological zone (Table 4). Compared to the terai/plain agro-ecological zone, the agricultural production in the mountainous agro-ecological zone often does not provide sufficient livelihood to the farmers (disadvantaged farmers in terms of intersectionality theory), which pushes these farmers to engage in off-farm activities and temporary migration to overcome the problems they face due to low productivity and climate change (Ullah et al., 2021). This is similar to the previous findings of Ullah et al. (2021) who reported that instead of adopting CCA practices such as agroforestry and irrigation, they migrate to other regions for off-farm activities.

Our results showed that farmers in the hilly AEZ were less likely to adopt small-scale irrigation and agroforestry practices than those in the terai AEZ. This is consistent with previous findings by Deressa et al. (2009) and Piya et al. (2013), who reported that farmers in the hilly AEZ usually did not adopt such practices or adopted them on a limited scale. Several studies in different countries, such as in Ethiopia by Tesfaye and Nayak (2022); in Pakistan by Abid et al. (2019), in coastal Bangladesh by Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020), and in Andean-Amazonian foothill households in Colombia and Peru by Beltrán-Tolosa et al. (2022), have reported that farmers' CCA strategies vary across agro-ecological zones.

Farmers in the mountainous and hilly regions of Nepal grow mainly traditional food crops such as millet, buckwheat, indigenous beans, barley, rice, potatoes and vegetables. Agriculture is mainly rain-fed, with a few exceptions such as micro-irrigation systems fed by springs and snowmelt. There are now a variety of climate change impacts, including positive and negative effects on rainfall, temperature, snowfall and snowmelt patterns. Households are adapting to the changing climate by adjusting agricultural practices, integrating livestock with agriculture, and taking up off-farm income-generating activities (Merrey et al., 2018).

Our results confirm that AEZs are one of the key determinants of smallholders' choice of appropriate CCA. Therefore, policies to support the diffusion of different adaptation strategies need to be locally

TABLE 5 Correlation of error terms of selected climate adaptation measures.

Correlation	Coefficient (standard error)	*p*-value
ρ21	0.1(0.088)	0.258
ρ31	0.092(0.085)	0.283
ρ41	0.082(0.082)	0.319
ρ51	0.164(0.091)*	0.072
ρ61	0.436(0.072)***	0.000
ρ32	0.652(0.062)***	0.000
ρ42	0.155(0.085)*	0.068
ρ52	0.105(0.096)	0.276
ρ62	0.18(0.085)**	0.035
ρ43	0.222(0.081)***	0.006
ρ53	0.205(0.088)**	0.02
ρ63	0.159(0.084)*	0.058
ρ54	0.35(0.086)***	0.000
ρ64	−0.095(0.084)	0.26
ρ65	0.143(0.089)	0.108
ρ43	0.22(0.081)***	0.006
ρ53	0.203(0.088)**	0.021
ρ63	0.158(0.084)*	0.06
ρ54	0.349(0.085)***	0.000
ρ64	−0.098(0.084)	0.245
ρ65	0.143(0.089)	0.109
Log-likelihood	−1269.0041	-
Wald chi2(126)	390.13	-
Prob > chi2	0.0000	-
Number of observations	400	-

Note: Likelihood ratio test of H0 ρ21 = ρ31 = ρ41 = ρ51 = ρ61 = ρ32 = ρ42 = ρ52 = ρ62 = ρ43 = ρ53 = ρ63 = ρ54 = ρ64 = ρ65 = 0; chi2(15) = 129.758; Prob > chi2 = 0.0000. ***, **, and * significant at 1%, 5%, and 10% levels, respectively. ρ1 = Off-farm activities; ρ2 = New crop varieties; ρ3 = Early-matured varieties; ρ4 = Small scale irrigation system; ρ5 = Agroforestry; ρ6 = Temporary migration.

specific. Farmers in mountainous or hilly agro-ecological zones (AEZs) face several challenges, including adverse climatic conditions, limited opportunities for income diversification and limited access to financial resources. As a result, they face greater difficulties in adapting to climate change, as predicted and explained by intersectionality theory. Similar studies, particularly in Nepal, such as by Poudel and Kotani (2013), Merrey et al. (2018), Thapa and Hussain (2021), also reported that CCA strategies in Nepalese agriculture should be tailored based on the AEZs.

5.2 | CCA strategies among different social groups

Our study found (Table 3) that most farmers in the Brahmin group adopted different CCA strategies compared to the Sudra farmers. These findings are similar to other findings in the CCA literature. For example, studies by Deressa et al. (2009) and Tesfaye and Nayak (2022) in Ethiopia, Makuvaro et al. (2018) in Zimbabwe, and Trinh et al. (2018) in Vietnam showed that social systems influence the adoption of new crop varieties, and that small-scale irrigation systems, agroforestry, and early planting and early-matured varieties are important adaptation strategies. Studies by Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020) in coastal Bangladesh and Kundu and Mondal (2022) in the Lower Gangetic Plain of India found that seeking off-farm activities and temporary migration were highly used CCA strategies among vulnerable social groups.

Our results from the MVP model also show that social group significantly influences the adoption of different CCA strategies. Respondents from the Brahmin group are more likely to adopt new crop varieties, early-matured varieties and small-scale irrigation than farmers from the Sudra group. In addition, farmers reported that the social system in Nepal is historically linked to the governance system, in which the Brahmins have long controlled the majority of official positions of power and privilege. As the dominant privileged caste group has dominated these institutions in Nepal, policies have been created to favor the Brahmins rather than the Sudra groups. Farmers from the Kshatriya social group were unlikely to adopt any adaptation measures. This may be because they were mostly dependent on agriculture for their livelihoods. We also found a significant influence of Vaisya farmers on the adoption of different CCA strategies. Our results suggest that Vaisya farmers are less likely to adopt off-farm activities and more likely to adopt small-scale irrigation than Sudra farmers. Since Vaisya farmers were initially employed to work on farms, whether owned or rented, they may be less likely to adopt off-farm activities. This is because they have fewer opportunities to engage in non-farm activities. Households in the Vaisya group are more likely to engage in flat farming, where access to irrigation water is easier, compared to Sudra farmers, who mostly engage in terrace farming (Pariyar et al., 2018).

It was also reported by (World Bank, 2011) that the Sudra group has been marginalised and denied access to crucial governmental structures and institutions, affecting farmers' adoption of CCA strategies. Therefore, caste-based discrimination is most likely to be enforced and experienced harshly by Sudra farmers in their local community. Our findings are consistent with the intersectionality theory. That means Sudra farmers were more vulnerable to climate change because of their lower CCA capacity and the need to deal with multiple problems simultaneously. A similar study conducted by Coulier and Wilderspin (2016) reported that ethnic minority groups and a study by Pariyar et al. (2018) reported that Sudra farmers in Nepal were highly affected by climate change and had less capacity to implement CCA measures.

5.3 | Impact of other drivers on adoption of CCA strategies

Our study shows that gender is an important factor in influencing the adoption of new crop varieties. It also means that male-headed households are more likely to adopt new crop varieties as a CCA measure than female-headed households. This may be because women have limited access to information and other resources due to traditional social constraints or because they contribute more to household activities than to agricultural activities. This finding is consistent with previous studies by Deressa et al. (2009), Trinh et al. (2018), and Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020), which reported that male-headed households were more likely to adopt new crop varieties as a CCA strategy.

Our study suggests that formal education has a significant and positive impact on the adoption of off-farm activities and agroforestry. This may be because the adoption of off-farm activities and agroforestry requires specific training and knowledge, which is insignificant without education. Our findings are consistent with previous studies from Ethiopia by Deressa et al. (2009), in Bangladesh by Alam et al. (2016), Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020), and in Nepal by Khanal et al. (2018). These studies reported that education plays a positive role in the adoption of off-farm activities and agroforestry.

The farming experience of household heads was another significant and negative variable influencing the adoption of temporary migration as a CCA strategy. More years of farming experience is often associated with older age. Older farmers tend not to shift their livelihoods from on-farm to off-farm activities, which has a negative impact on temporary migration (Rigg et al., 2020). For different adaptation strategies such as agroforestry, small-scale irrigation, soil and water conservation, findings by Trinh et al. (2018), Abid et al. (2019), Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020) and Tesfaye and Nayak (2022) reported that households with more years of farming experience were more likely to adopt these adaptation strategies.

Our results show that farm size has a significant negative impact on farmers' adoption of small-scale irrigation practices. This means that farmers with large landholdings are less likely to adopt small-scale irrigation. This may be because farmers from the study area are highly dependent on rain-fed agriculture and the cost of adopting an irrigation system is higher for the large land size. This finding is similar to a previous studies in Nepal by Piya et al. (2013) and in Pakistan by Abid et al. (2019), who reported that adoption of small-scale irrigation is negatively affected by land size.

In our study, access to informal credit has a significant and negative impact on farmers' adoption of early-maturedvarieties and agroforestry as a CCA strategy. Farmers with access to informal credit are less likely to adopt early-maturedvarieties and agroforestry practices. This may be because farmers who borrow small amounts of money from relatives, neighbours or local moneylenders are struggling to meet their subsistence needs rather than productive agricultural investments. The poor farmers who do not adopt CCA strategies usually borrow money from informal credit sources. Moreover, our study found that access to informal credit increases the likelihood of adopting temporary migration as a CCA strategy. This statement is also supported by several studies, such as Timsina (2015) and Bhattarai (2020), which examined the process of borrowing money from banks in Nepal. Conceivably, this is the reason why temporary migration was positively influenced by access to informal credit. Studies such as Piya et al. (2013), Trinh et al. (2018), Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020) and Tesfaye and Nayak (2022) also reported that access to informal credit had a significant and negative impact on the adoption of early-maturedvarieties and agroforestry as CCA strategies.

The results of our MVP model show that farm income has a significant and positive impact on the adoption of agroforestry practices. This means that the higher the farm income, the higher the probability of adopting agroforestry as a CCA strategy. This result is consistent with the study by Ojo and Baiyegunhi (2020) and Tesfaye and Nayak (2022) who reported that farm income increases the probability of adopting CCA strategies including agroforestry. In addition, our results showed that the higher the farm income, the lower the likelihood of temporary migration, suggesting that farmers with lower farm income are forced to migrate to secure their livelihoods. This finding is consistent with a study by Deressa et al. (2009) and Sam et al. (2020). Their studies reported that farm income increases the financial capacity to produce different crops to maintain and improve their farm productivity from climate change losses.

Farmers' awareness of climate change (such as droughts, floods and landslides) has a significant impact on the adoption of CCA strategies. In our study, awareness of climate change positively influenced off-farm activities, new crop varieties and agroforestry. This suggests that farmers who are aware of climate change are more likely to adopt off-farm activities, new crop varieties and agroforestry as a CCA strategy. Our findings are consistent with the previous studies in the central region of Vietnam by Trinh et al. (2018), in Bangladesh by Aryal, Sapkota, Khurana, et al. (2020), Aryal, Sapkota, Rahut, et al. (2020) and in Ethiopia by Tesfaye and Nayak (2022). These studies reported that awareness increases the adoption of off-farm activities, new crop varieties and agroforestry.

We found that farmers' perceptions of temperature rise significantly and negatively influenced the adoption of agroforestry. Similarly, our results showed that farmers' perceptions of the increase in erratic rainfall significantly and positively influenced the adoption of off-farm activities and early-matured varieties. This suggests that household heads who were aware of the rise in temperature did not adopt agroforestry, whereas those farmers who perceived erratic rainfall realised the greater need to adopt off-farm activities and early-matured varieties. Since agroforestry in Nepal is mainly apple based, an increase in temperature will affect apple production and reduce agroforestry adoption. Similarly, farmers who perceived an increase in erratic rainfall (in the last 10–15 years) go for off-farm activities and adopt early-matured varieties. The probable reason for engaging in off-farm activities due to erratic rainfall could be that farmers do not want to take the risk of adopting new crop varieties. However, planting early-matured varieties helps to reduce harvest and post-harvest losses due to erratic rainfall, so the likelihood of adopting early-matured varieties increases with the perception of erratic rainfall in the study area. This finding is also supported by Lawson et al. (2020), Azong and Kelso (2021) and Tesfaye and Nayak (2022) who indicated that the perception of climate indicators such as temperature rise and erratic rainfall increases the likelihood of adopting early-matured varieties and agroforestry.

We found that farmers' access to information via the internet had a significant and negative effect on the adoption of new crop varieties, whereas it had a significant and positive effect on the adoption of small irrigation systems. This means that new crop varieties were less likely to be adopted by farmers with access to the internet, whereas small irrigation systems were more likely to be adopted. The probable reason for this could be that farmers are less likely to search for information on new crop varieties on the Internet. This is because new crop varieties depend on local biophysical conditions, whereas farmers often search for information on different irrigation systems (Sedeek et al., 2019). As irrigation systems are relatively easy to search for, accurate information is easily accessible on the internet (Zinkernagel et al., 2020).

Access to information through farmer groups has had a significant and positive impact on the adoption of new crop varieties, early-matured varieties, small-scale irrigation and agroforestry. However, it had a negative effect on the adoption of off-farm activities. The significant and positive effect of access to information through farmer groups on the adoption of new crop varieties, early-matured varieties, small-scale irrigation systems and agroforestry suggests that information from local groups appears to be valuable to farmers. In addition, the information shared by the farmer groups only covers climate change and farming practices, not off-farm activities. Many studies have found similar results that access to climate change information through the internet and farmer groups increases the likelihood of farmers adopting early-matured varieties, small-scale irrigation and agroforestry (Deressa et al., 2009; Lawson et al., 2020; Piya et al., 2013; Ravera et al., 2016; Tesfaye & Nayak, 2022).

6 | CONCLUSION AND RECOMMENDATIONS FOR POLICY IMPLICATIONS

The study uses a multivariate probit regression model to examine the influence of agro-ecological zones (AEZs) and social groups on the adoption of CCA strategies at the household level in Nepal. The results of this study indicate that 53%, 41%, 43%, 46%, 31% and 62% of the surveyed households have adopted six key CCA strategies, namely off-farm activities, new crop varieties, early-maturedcrops, small-scale irrigation, agroforestry and temporary migration, respectively.

The research validates that agro-ecological zones determine farmers' adaptation strategies. The most preferred CCA strategies among mountain farmers were off-farm activities and temporary migration. Hill region farmers preferred the use of off-farm activities, early-matured varieties, new crop varieties and temporary migration. Farmers in the Terai region preferred the use of small-scale irrigation and agroforestry.

Social group is an important determinant of the decision to adopt off-farm activities, new crop varieties, early-matured varieties and small-scale irrigation as adaptation options. The preferred CCA strategies of Brahmin farmers were new crop varieties, early-matured varieties and small-scale irrigation. While the preferred CCA strategies of Sudra farmers were off-farm activities and temporary migration.

Access to climate change information through farmer groups is another important factor in the decision to adopt all strategies except temporary migration. In addition, access to informal credit, such as borrowing from friends and relatives, also determines farm households' decision to adopt early-maturedvarieties, agroforestry and temporary migration as adaptation strategies. This result suggests that farmers with better access to information and finance have a higher adaptive capacity. The results are consistent with the action theory of adaptation and the intersectionality framework, which predict lower adaptive capacity of farming households in the disadvantaged geographical location and disadvantaged social groups.

The results show that both off-farm activities and temporary migration are strategies used by disadvantaged farmers (Mountain and Sudra group farmers). Therefore, in order to empower disadvantaged farmers and support them to stay in agriculture, policies need to support the dissemination of updated CCA information to all farmers, including to farmers leaving in remote rough terrains and those belonging to vulnerable social groups. The study recommends that in case the government want to prevent/reduce migration and keep agricultural production, consideration be given to providing subsidies to Mountain and Sudra farmers to help them cope with climate shocks and to support them in maintaining their farming activities. Similarly, access to credit is an important factor influencing the choice of adaptation strategies. Therefore, easy access to credit (perhaps microfinance credit) needs to be made available to farmers, especially disadvantaged farmers (Mountain and Sudra farmers), which will allow them to increase their adaptive capacity. Furthermore, educating, and sensitising farmers to adopt multiple combinations of strategies rather than relying on a single adaptation option will diversify the livelihoods of disadvantaged farmers and motivate them to stay in agriculture.

7 | LIMITATIONS OF THE STUDY

This study has certain limitations that need to be acknowledged, particularly in relation to the collection of qualitative data due to the COVID-19 pandemic. Travel restrictions and physical distance measures hindered in-depth interviews, which are valuable for understanding the nuances of CCA at the local level. Including qualitative data collection could have strengthened the findings by providing a comprehensive perspective on the challenges and dynamics of adaptation strategies. Future research should consider conducting additional qualitative research to enhance understanding beyond the pandemic period.

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