Heliyon 8 (2022) e09695

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

What affects farmers in choosing better agroforestry practice as a strategy of climate change adaptation? An experience from the mid-hills of Nepal

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HIGHLIGHTS

- Modification of the traditional agroforestry practice to optimize household benefits.
- Out of total farmers experiencing climatic effects, only some of them were adopting adaptation strategies.
- Multiple factors affect farmers in adopting climate change adaptation strategies.
- Multiple factors affect farmers for selecting the better agroforestry practice.
- Additional education programs are required to promote the agroforestry practice.

ARTICLE INFO

Keywords:
Income
Climatic effects
Traditional practice
Improved practice
Education
Combat

ABSTRACT

Determinants for choosing climate change adaptation strategies and selecting improved agroforestry practices have rarely been explored, while numerous studies have been conducted on climate change and agroforestry. This paper discusses; local understanding of climate change, climatic impacts, and factors that affect farmers' choices of adaptation strategies, and agroforestry practices. We focused on three districts located in the mid-hills of Nepal, where farmers were adopting agroforestry practices in two forms; traditional and improved practices. We followed three techniques of social survey; household survey (n = 420), focus group discussions (n = 6), and key informant interviews (n = 24). Almost all farmers of the study areas were experiencing climatic challenges, but only 59.29% of them accepted that the challenges are induced by climate change and, likewise, 55.24% have adopted climate change adaptation measures. Diversifying crop production, shifting farming practices, changing occupation, and emigration were local adaptation strategies. Livelihood improvement, income generation, and food production were the primary motives for adopting agroforestry practices in the study area. Agroforestry as an adaptation measure to climate change was considered secondary by most farmers. Statistical analysis using a logit model revealed that age, education, and habit of growing commercial species significantly influenced farmers adopting climate change adaptation strategies. Likewise, age, education, gender, habit of growing commercial species, and income from tree products significantly influenced the choice of improved agroforestry practices as a better option. Though agroforestry was widely considered a strategy to combat climate change, only some farmers accepted it due to their awareness level. Therefore, education programs such as training, farmer field schools, door-to-door visits, etc., should be intensified to sensitize farmers about climate change and encourage them to adopt improved agroforestry practices. The findings of the study could reinforce local, national, and international allied agencies to design operative actions in the days to come.

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https://doi.org/10.1016/j.heliyon.2022.e09695
Received 15 September 2021; Received in revised form 23 March 2022; Accepted 5 June 2022

1. Introduction

Climate change caused by anthropogenic intervention oscillates temperature and precipitation, intensifies floods and droughts, and induces unexpected consequences, and, therefore, has been increasingly receiving local, national, and global attention (IPCC 2007; Agwu et al., 2018; Bonnot et al., 2018). Unpredictable and intense weather conditions induced by climate change are a serious threat to the agricultural sector, especially in food production, food security, and productivity loss (Lasco et al., 2014; Agwu et al., 2018). Climate change severely impacts the rural livelihood of developing countries due to the availability of limited resources to fight against severe storms and extreme weather patterns (Bryan et al., 2013; Reppin et al., 2020). Furthermore, the negative impact of climate change on food production accelerates the burden of a large population to survive under extreme vulnerability (IPCC 2014; Wang et al., 2019). Continuous declination of water resources to irrigate agricultural land due to climate change (Aryal et al., 2019) and the projection of an increasing consumption rate by 2050 (Boretti and Rosa 2019) indicate a more dire situation in the agricultural sector in the coming years (IPCC 2012). Similarly, accelerating land-use change characterised by deforestation and forest degradation (Hosonuma et al., 2012; Ahmad et al., 2018) demands crucial strategies to link the agriculture and forestry sectors to combat climate change. Rural communities dependent on subsistence farming practices are highly vulnerable even with minimal effect of climate change due to having limited coping strategies (FAO 2010). Although it is well recognized that farmers are facing a host of challenges due to climate change, the issues of farmers' understanding and perceptions towards climate change and linkages to agricultural production, are poorly understood and need depth study.

Similarly, being more vulnerable to climate change, smallholder farmers are under pressure to find alternatives to increase income and farm productivity (Roka 2017; Aryal et al., 2019; Chhogyel et al., 2020). Efforts are being made by several stakeholders to enable farmers to survive under adverse climatic impacts (Wheeler and Von Braun 2013). Farmers are often independently adopting different strategies at the grassroots level instead of following adaptation measures recommended by authorities (Semenza et al., 2008; Bryan et al., 2009; Simane et al., 2016). Several scholars have claimed that farmers are adopting agroforestry practices as a climate change adaptation strategy to make themselves more resilient and reduce the vulnerability of agricultural production (Palsaniya and Ghosh 2016; Gnonlonfoun et al., 2019). But agroforestry has been practiced from long ago as a traditional farming practice, even before climate change emerged as a critical issue in the agriculture sector. While the impacts of climate change on agricultural production and livelihoods exists as a serious challenge, it becomes crucial to understand, how farmers perceive climate change, whether they link climate change with the agroforestry practices adopted, and if so, what factors influence them to adopt improved agroforestry practices.

Climate change also negatively affects the yield and growth of crops and agroforestry species (Fischer et al., 2002; Agwu et al., 2018), so farmers adopt different forms of agroforestry practices (Paudel et al., 2021). Over the past few decades, some farmers have been modifying traditional agroforestry practices to optimize benefits, however, some farmers are continuing traditional ones (Paudel et al., 2019). Several factors affect farmers in selecting practices, and most only accept the practice as an adaptation strategy, when it appears to help in minimizing climatic effects (Deressa et al., 2009; Foguesatto and Machado, 2021). Though modification to agroforestry practice is regarded as a climate change adaptation strategy by many stakeholders, what factors motivate farmers to modify them need to be explicitly known. The effective adoption of agroforestry practices to respond to climate change impacts requires in-depth understanding of agroforestry components and human dimensions (Deressa et al., 2009; Coulibaly et al., 2017). Adaption strategies depend on the understanding and adaptive behavior of local communities (Simane et al., 2016; Asrat and Simane, 2018), therefore, assessment of farmers' perceptions of climatic effects is an important step for designing adaptation strategies (Mase et al., 2017). This study was conceptualized to appraise farmers understating of climate change, factors that influence farmers to adopt agroforestry practices, and determinants for choosing appropriate practices. The findings of the study provide key insights into the reasoning behind adoption of agroforestry practices and could assist concerned stakeholders in promoting improved agroforestry practices for climate change adaptation and mitigation.

2. Conceptual framework

Farmers are adopting agroforestry in two forms, i.e., traditional and improved agroforestry practices in the study areas. As previously mentioned, we have conceptualized a framework (Figure 1), which shows how two different agroforestry practices contribute to (a) household income (b) climate adaptation and strengthen farmers in building climatic resilience. Multiple factors influence these parameters, and ultimately motivate farmers' decisions to select an agroforestry practice as better practice for their upliftment. Based on this premise, we designed this study to explore the determinants for the adoption of improved agroforestry practices at the study sites.

3. Methods and materials

3.1. Study area

We consulted academicians, researchers, model farmers, and government officials connecting with the forestry and agriculture sectors, and listed 10 districts situated in the mid-hills of the Nepal adopting agroforestry practices. We organized a preliminary survey in these 10 districts and broadly classified existing agroforestry practices into traditional and improved practices as prescribed by Paudel et al. (2019). The traditional practice reflects those agroforestry practices where farmers raise native woody perennial species (fodder species such as *Ficus species*) along with agricultural crops to satisfy household subsistence. Whereas, in the improved agroforestry practice, farmers grow commercial species (fruit species; *Citrus species, Coffee*) intensively along with other woody perennial species (Such as fodder species; *Ficus species*) and agricultural crops to generate income annually by selling products such as oranges, coffee, vegetables, etc. Three villages (Figure 2); Chhang, Nirmal Pokhari, and Karen Danda from the respective districts of Tanahun, Kaski, and Syangja, were selected as study sites through a participatory approach. These sites are situated in the subtropical climatic zone, nationally known as the mid-hills region in Nepal (CBS 2011), where farmers have been adopting both agroforestry practices for more than 10 years.

3.2. Data collection

This study followed three types of social survey designs; structured questionnaire survey (household survey), focus group discussions, and key informant interviews. To finalize the questionnaire designed for the households (HHs) survey, pretesting was done among 12 randomly selected HHs. We consulted 24 key informants (government officers, lead farmers, and representatives of agricultural co-operatives) to identify traditional and improved practitioners and select HHs for the study. Among the selected 3 villages, the smallest village consists of only 70 HHs adopting the improved practice, therefore, we fixed 70 HHs as the benchmark sample size for each practice at each site (Figure 3). Altogether 420 HHs (210 HHs from each practice or 140 from each district/village) were interviewed to assess the socioeconomic condition of the respondents and their understating of climate change. Furthermore, we interviewed them to find reasons behind adopting agroforestry practices, and whether these reasons have any relation to climate change or not. We gave discrete choice questions for acquiring information related to the respondents' willingness to adapt to climate change and choosing improved agroforestry practices. Moreover, six focus group discussions

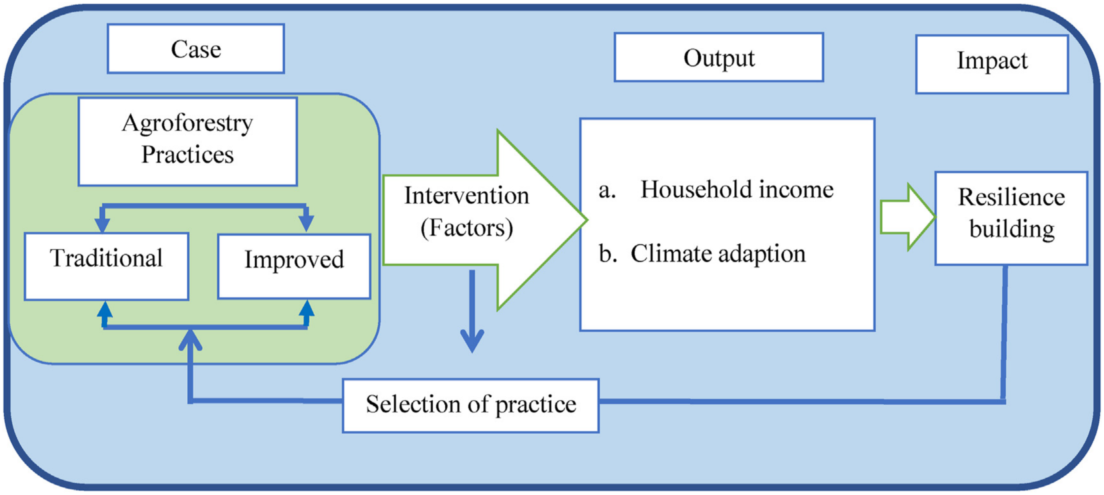

Figure 1. Conceptual framework of the study.

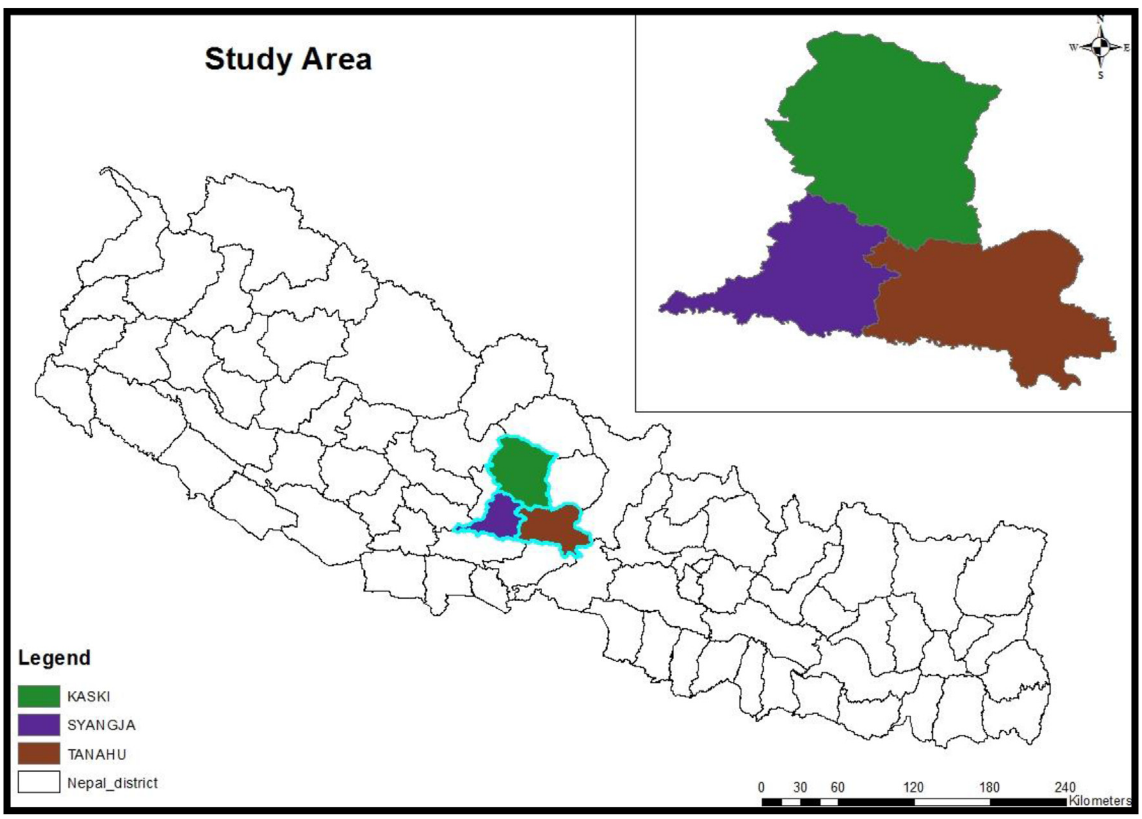

Figure 2. Study area showing three districts of mid-hills of Nepal.

were organized with each type of practitioner to crosscheck the information obtained from the HHs survey. The consent was obtained from all participants involved in the study.

3.3. Data analysis

Regression analysis was done to analyze the factors that influenced farmers to adopt agroforestry as a means of climate change adaptation and opting for improved agroforestry practice (continue the traditional or convert to improved practice). The correlation between dependent and independent variables was tested through different probability models, where the dependent variable is a dummy, namely, the linear probability model (LPM), probit model, and logit model. LPM showed uniformity of error term and had the risk of getting a probability function of 0 and 1, or it predicted beyond a range of 0 and 1. Moreover, the R^2 in LPM is irrelevant for interpretation when the regression line was a poor fit and it is not logically suited in the case of binary responsive variables (Halcoussis 2005; Verbeek 2008). Whereas, the logit model ensures that the estimated likelihood increases and only falls within the range of 0–1 (Uddin et al., 2014). Because of observational data, the logit model seemed more appropriate compared to the probit model in our case. Therefore, we followed the logit model to find out factors that affect

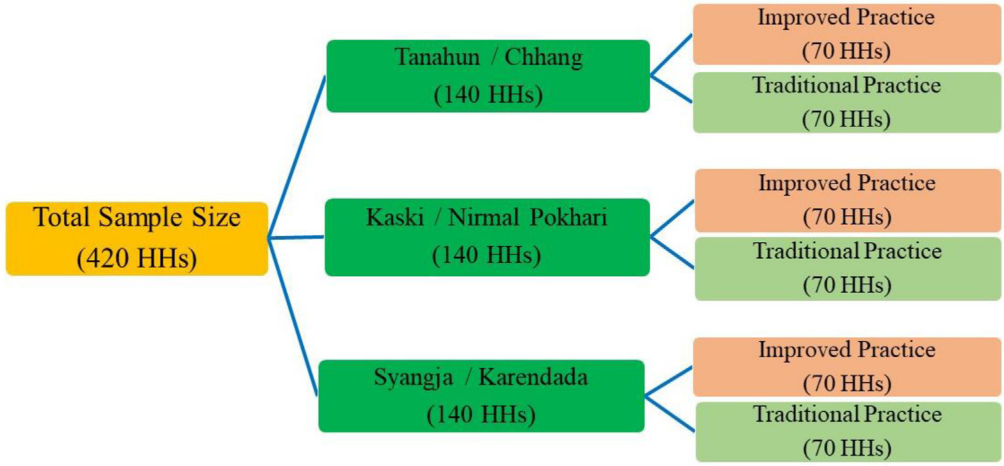

Figure 3. Sample size with respect to district, village and agroforestry practices.

farmers' response to climate change and choosing between traditional and improved agroforestry practices. According to Hosmer et al. (2013), the following logistic distribution function was used (eq1) in this study:

$$P_i = E(Y = 1/X_i) = 1/(1+e^{-(B0+BiXi)}) \tag{1}$$

For simplicity, Eq. (1) can be expressed as (eq2):

$$P_i = 1(1/(1+e^{-Zi}) \tag{2}$$

Where, P_i is the probability of perception of farmers being observed climate change phenomenon for the i^{th} respondent household (ranged from 0-1) and Z_i is a function of *N* explanatory variables (X_i) denoted as (eq3):

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n + \mu_i \tag{3}$$

Where, β_0 is an intercept, β_1, β_2 *and* β_n are the estimated parameters of all explanatory variables $X_1 - X_n$ (age, sex, education, household size, income from trees, landholding size, commercial species plantation, and knowledge about climate change) and μ_i is the error term.

The explanatory variables were used to explain the variability in the dependent variables (Table 1). Before running the model, the correlation between the explanatory variables was checked using the contingency coefficient test. Furthermore, the co-linearity among explanatory variables was cross-checked with the variance inflation factor (VIF), and the variable having the multicollinearity effect was discarded.

4. Results

4.1. Farmers' socioeconomic characteristics

The farmers' socioeconomic characteristics; gender, age, household size, occupation, landholding size, and educational level of respondents, were collected during the HHs survey. Of the 420 respondents, 44.29% were male and 55.71% were female. The age of respondents ranged from 18 to 85 years (51 years on average) and 21.43% of them were illiterate. Though agriculture was the main source of livelihood in the study area, some respondents had other occupations along with agriculture. Specifically, there were 67% farmers, 8% businessmen, 13% jobholders, 6%

Table 1. Variables and their description with mean and standard deviation.

Variables	Description	Mean	SD
Decision to adapt strategies for climate change	Whether or not respondents decided to adapt climate change strategies. Binary variable: 1 if a respondent decided to adapt to climate change strategies, and 0 otherwise	0.552	0.497
Improved or traditional practices adoption	Binary variable: 1 if a respondent adapted improved practices, and 0 otherwise	0.500	0.500
Age	Respondent age in years (continuous variable)	50.65	14.71
Gender	Respondent's sex: Binary variable 0 if male and 1 for female	0.557	0.497
Education	Literacy level of the respondent. Binary variable: 1 if a respondent is literate, and 0 otherwise	0.785	0.410
Household size	Number of members in a household (continuous variable)	5.802	2.441
Income from trees/fruits	Income derived by trees and fruit trees. Binary variable: 1 if the respondent derived income from trees or fruit trees, and 0 otherwise	0.471	0.499
Total used land area (Landholding size)	Private property area owned by respondent in *ropani*[a] (continuous variable)	12.396	11.778
Commercial species plantation	On-farm commercialized product planted by household member. Binary variable: 1 if respondent planted commercial plant in their farm, and 0 if not	0.845	0.362
Knowledge about climate change	Knowledge and awareness about climate change. Binary variables (1: Yes, 0: No)	0.592	0.491

[a] 1*ropani* = 0.0509 ha.

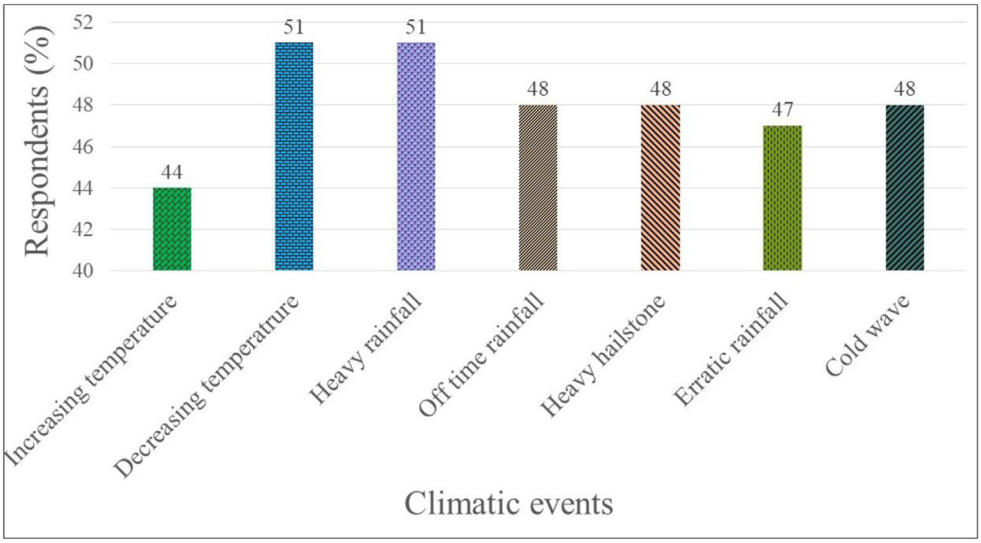

Figure 4. Farmers' response to climatic events in the study area.

Table 2. Responses towards agroforestry practices.

Statements (agroforestry practice for)	Ranking (weighted)	Response			
		Agree	Neutral	Disagree	Mean*
Enhancing household income	2nd (2.62)	372 (89)	30 (7)	18 (4)	2.84
Coping strategies of climate change	4th (3.44)	320 (76)	89 (21)	11 (3)	2.74
Ensuring food sufficiency	3rd (2.95)	336 (80)	76 (18)	8 (2)	2.78
Increasing commercial farming	5th (3.62)	310 (74)	49 (12)	61 (15)	2.59
Improving livelihood condition (overall)	1st (2.36)	373 (89)	43 (10)	4 (1)	2.88

[*] Weighted mean score is obtained from the scale (Disagree = 1, neutral = 2, agree = 3), figures in parenthesis indicates weighted mean score (1- first, …, 5-last) in case of ranking, and percent of total respondents in case of response.

retired, 2 % students, and 3% housewives. More than half (52%) of the HHs had more than 4 members. Individual landholding size varied from 0.5 to 54 *ropani*[a] (12.39 *ropani* on average), where about one-third (30.23%) HHs had less than 5 *ropani* of land.

4.2. Farmers' response toward climatic events

Farmers reported experiencing severe climatic events; unpredicted rainfall, oscillation in temperature, drought, flood, landslide, and violent winds in recent years (Figure 4). Though most of the respondents experienced multiple climatic events, 91% of the total respondents had experienced at least one form of such events. However, only 59.29% of respondents were aware of climate change and also believed that climate change was responsible for these climatic events. More males (53%) were found to be aware of climate change compared to females (47%). 51% of respondents agreed that climate change was accountable for decreasing temperature and heavy rainfall, whereas 48% believed climate change was the cause of untimely rainfall, heavy hailstone, and cold waves.

4.3. Farmers' response toward agroforestry practice

Agroforestry practices contributed to HHs in multiple ways in the study sites. Through the key informant interviews, we assessed 5 statements that expressed reasons behind adopting of agroforestry practices. We placed the weightages 1, 2, and 3 for disagree, neutral, and agree, respectively. The weighted mean score of farmers' responses reflected that agroforestry practices contributed to livelihood improvement overall (2.88), followed by income generation (2.84), food supply (2.78), coping with climate change consequences (2.74), and commercial farming (2.59) (Table 2). Similarly, farmers were encouraged to rank these 5 statements (1-first, ..., 5-last) to know the main motive of adopting agroforestry practice. According to the weighted mean scores, farmers were adopting agroforestry practices to improve their livelihood and generate more income. Coping with climatic effects was the fourth motive of the farmers for adopting agroforestry practices. Nevertheless, they realized that agroforestry practice contributed to climate change mitigation and adaptation while reducing their vulnerability to climatic impacts. Similarly, farmers also believed that commercial farming could be made possible through agroforestry practices. So, farmers have been attracted to improved agroforestry practices.

4.4. Locally adopted strategies for climate change adaptation

Agriculture, the main occupation in the study area, was affected by climatic impacts. Due to low production from the existing farming practices and various problems induced by climate change, farmers were adopting different strategies to overcome these problems. However, some farmers did not perceive these problems as the effect of climate change. Out of the total respondents, 91% experienced climatic events, while only 55.24% of them were adopting different strategies to reduce climate change impacts (Table 3). Farmers were adopting numerous activities in the study area as coping strategies. About 55% of farmers were diversifying crops to increase the overall production by introducing new crop species instead of continuing the same species. Some 52% have shifted farming practices from agricultural crops production to fruit tree

[a] 1*ropani* = 0.0509 ha.

Table 3. Strategies for coping climatic effects.

Adaptation strategies	Frequency
Shifting farming practice	218 (52)
Integrating crop and livestock	198 (47)
Diversification crop production	231 (55)
Improving irrigation practice	208 (50)
Adopting new farming technique	204 (49)
Shifting occupation	150 (36)
Emigration	116 (28)

Figures in parenthesis indicates percent of total respondents in case of response.

species cultivation. Likewise, about 50% were improving irrigation practices. Similarly, 49% of farmers have adopted new farming techniques, e.g., plastic tunnel-based farming, out-of-seasonal vegetable production, etc. Some farmers have focused on livestock rearing along with crop production (47%). On the other hand, 36% of farmers were engaged in other occupations as well, for income augmentation, such as daily wage labour. Whereas, 28% were emigrating to city areas and other countries for securing jobs.

4.5. Determinants of climate change adaptive strategies

Despite experiencing the impacts of climate change, some farmers were not knowingly adopting climate change adaptation strategies (Table 3). Other socioeconomic factors were influencing them in adopting climate change adaptation strategies. We used a binary logistic model to assess the relationship between the socioeconomic characteristics of the respondents and their decision to adopt climate change strategies (Table 4). Education, and the habit of growing commercial species significantly affected farmers adoption of adaptation strategies ($p < 0.01$), whereas, age also influenced them to some extent ($p < 0.1$). This indicated that older and educated farmers growing commercial species were able to define the climate change adaptation strategies adopted.

In the study areas, we observed that some farmers were continuing traditional agroforestry practices, whereas others were attracted to improved agroforestry practices. The socio-economic characteristics and agroforestry services might have influenced farmers in choosing the type of agroforestry practice (Table 5). The logistic regression revealed that the explanatory variables; education and habit of growing commercial species were positively significant ($p < 0.01$) in selecting the improved practices. Farmers of older age groups, females, and generating income from tree products, were more likely to adopt improved agroforestry practices ($p < 0.1$). Household size had a positive association and landholding size had a negative association with choosing the improved practice. The growing population has increased family separation and land fragmentation which ultimately reduced the landholding size of HHs and caused greater vulnerability to climatic events. Thus, they were more likely to adopt improved agroforestry practices to enhance livelihoods and reduce the negative effects of climate change. Furthermore, respondents who were aware of climate change and its effects had a positive tendency to adopt improved agroforestry practices.

Table 4. Determinants in deciding strategies for climate change adaptation.

Variables	Coefficient	Standard error	Marginal Effects
Age	0.0157313*	0.0084621	0.0039103
Gender (Female)	0.3088174	0.2386835	0.0767077
Education	2.513978***	0.336702	0.5270625
Household size	-0.0341452	0.0491919	-0.0084873
Income from tree product	0.3465658	0.2503193	0.0858669
Landholding size	-0.0028111	0.0102101	-0.0006987
Growing commercial species	1.126949***	0.3427728	0.2709695
Knowledge about climate change	0.2938762	0.236702	0.0730551
Constant	3.849637***	0.6606861	
Observations	420		
Log likelihood	-234.25182		
Prob > χ^2	0.0000		
Hosmer-Lemeshow Test	13.05		

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5. Determinants in choosing agroforestry practice.

Variables	Coefficient	Standard error	Marginal Effects
Age	0.0185341*	0.0087099	0.0046001
Gender (Female)	0.4821054*	0.2443313	0.1187968
Education	2.758873***	0.3872083	0.5156739
Household size	0.0230008	0.0505742	0.0057087
Income from tree product	0.4213188*	0.250515	0.1042949
Landholding size	-0.0012636	0.0103679	-0.0003136
Growing commercial species	1.731276***	0.4058963	0.36106
Knowledge about climate change	0.2294601	0.2425555	0.0567813
Constant	5.461288***	0.7510654	
Observations	420		
Log likelihood	-225.54478		
Prob > chi2	0.0000		
R squared	0.2253		
Hosmer-Lemeshow Test	4.30		

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

4.6. Participation in education programs

Farmers, adopting both agroforestry practices, have been participating in different educational programs related to agroforestry and climate change. Out of the 420 respondents, 196 respondents had participated in training and awareness programs; among them 147 had joined in agriculture/agroforestry, and 39 had participated in integrated (climate change with agroforestry) programs (Table 6). Out of 210 respondents of each practice, 155 (73.8%) improved practitioners had participated in training, whereas, only 41 (19.5%) traditional practitioners participated in the training. Gender-wise, females appeared dominant in participating trainings and educational programs. 50.6% (17 traditional and 102 improved practitioners) female and 41.6% (24 traditional and 53 improved practitioners) males have participated in training and educational programs. From field observations (Table 6) it was noted that educational programs had encouraged farmers to adopt improved agroforestry practices.

5. Discussion

5.1. Farmers' perception to climate change and adaptation strategies

Farmers' knowledge of climate change and its impacts play an important role in implementing adaptation strategies (Deressa et al., 2009; Ado et al., 2019) and reducing the vulnerability to climatic risks. Most (91%) of the farmers experienced changes in climatic events, which resonates with the finding of several other studies (Fosu-Mensah et al., 2012; Mustapha et al., 2012; Muzamhindo et al., 2015; Fadina and Barjolle 2018; Ado et al., 2019), where they have also reported that most of the respondents experienced changes in climatic patterns and severe weather events. This offers clear evidence that challenges due to climate change exists in the agriculture sector throughout the world. Other studies also reported that men have a better understanding of the climatic effects compared to women (Ajayi 2014; Ado et al., 2019), which is consistent with our findings. Besides participating in educational programs, males frequently joined in village-level meetings and had high

Table 6. Farmers' participation education program.

Agroforestry Practice	Gender (Respondent)	Farmers' participation in training/programs			
		Agriculture/Agroforestry	Agroforestry/Climate change	Total participation	Total (Practice wise)
Traditional	Male (102)	19	5	24	41
	Female (108)	16	1	17	
Improved	Male (83)	39	14	53	155
	Female (127)	83	19	102	
	Total (420)	157	39	196	196

exposure to various sources of information, so their understanding of climatic effects seemed better than that of females.

Unpredictable rainfall, temperature, and wind patterns are among the consequences of climate change (IPCC 2007) that resonate with the situation at our study sites. Oscillation in temperature, irregularity in rainfall patterns, floods, landslides, and violent wind were the most frequently experienced climate events in the study areas, which were also reported by other scholars (Adhikari et al., 2007; Mustapha et al., 2012; Assoumana et al., 2016; Lasco et al., 2016; Ado et al., 2019). Changes in climatic events negatively affect agricultural production and local livelihood; our study sites were not beyond this conjecture, where resource (food, water, etc.) scarcity was recorded as a major problem induced by climatic change. Farmers were changing their agricultural practices, attracted to agroforestry practices, and adopting improved practices to overcome climatic impacts. A similar situation was reported in other African and Asian countries (Lasco et al., 2016; Fadina and Barjolle 2018; Ado et al., 2019). Though 91% of total respondents experienced changes in climatic events, only 59.29% of them accepted events were induced by climate change, and 55.24% had initiated adaptation strategies to counter climate change in our study area. Fadina and Barjolle (2018) reported that 90.8% of respondents had experienced change in climatic events, where only 85% of them were applying adaptation strategies. Similarly, Fosu-Mensah et al., (2012) found only a few farmers had developed adaptation strategies. These differences might be due to the intensity of climatic effects, awareness level, and number of educational programs or government and NGO support related to climate change launched in the sites. The farmers reportedly affected by climate change were adopting the multiple coping strategies. The adopted strategies included crop diversification, changing farming practices, integrating crop and livestock rearing, improving irrigation practice, adopting new techniques (eg., agroforestry), shifting occupation, and emigration. Scholars; Sutcliffe et al. (2016), Assoumana et al. (2016), and Ado et al. (2019) have reported similar situations as in our study, however, the number of farmers adopting these strategies varied with other studies. Though farmers have adopted multiple strategies to cope with climate change and scarcity, their effectiveness needs to be further studied to strengthen resilience and enhance livelihoods in the face of ever-intensifying climate impacts.

Factors such as age, education, and growing commercial species influenced farmers significantly in deciding to adopt specific adaptation strategies. Our finding was consistent with previous studies (Tazeze et al., 2012; Chalchisa 2016; Lasco et al., 2016; Fadina and Barjolle 2018) which concluded that educational programs sensitized the farmers about climate change and encouraged them to initiate adaptation strategies. Income from trees and commercial farming seemed to contribute positively to cope with climate change impacts, so farmers need to be encouraged to grow more commercial tree species. In our case, farmers with large householding sizes and small landholding sizes were more interested in adaptation strategies, which was contrary to the findings of Chalchisa (2016). Having no option besides growing more crops within limited land resources, and due to the possibility of adopting agroforestry with minimal financial investment, small-scale farmers are attracted to agroforestry practice in our case. Therefore, this study suggests that concerned stakeholders should prioritize small-scale farmers when designing agroforestry and climate change-related programs. Socioeconomic factors should be taken into consideration while formulating climate change adaptation strategies and promoting agroforestry practices in the mid-hills of Nepal.

5.2. Determinants for choosing improved agroforestry practices as an adaptation strategy

Traditional (home garden, fodder trees with agricultural crops) and the improved (commercial fruit orchards, coffee plantation, and fodder trees with agriculture crops) practices are existing agroforestry practices in the study sites (Paudel et al., 2019, 2021). Although two thoughts persist in the region, namely, continue the traditional practice or initiate improved agroforestry practices, farmers were also continuing the traditional practice for basic requirements (Regmi 2003; Kiptot and Franzel 2012; Paudel et al., 2019, 2021). However, some farmers were modifying their traditional practice into improved practices. Farmers' decisions in selecting appropriate adaptation techniques often rely on anticipated benefit or risk avoidance (Gebreeyesus 2017). Multiple factors, such as age, sex, education/knowledge, the nature of farming practices, played roles in realizing the necessity of adopting climate change adaptation strategies in our case. Older and educated farmers growing commercial species were significantly able to define adaptation strategies to climate change. Our finding is in line of Kiptot and Franzel (2012), Coulibaly et al. (2017), Simane et al. (2016), Asrat and Simane (2018), Gebrehiwot et al., (2018), and Foguesatto and Machado (2021), that limited knowledge and technologies were the main reasons for hindering adoption of agroforestry practices and preventing farmers from acknowledging climate change and understanding agroforestry practices as a strategy for climate change adaptation and mitigation. Our findings matched with Deressa et al. (2009), who reported that age, social capital, and knowledge about climate change have significant effects on farmers' perceptions of climate change. Though agriculture is the main occupation in Nepal (CBS 2011), very few youths showed interest in agriculture. Based on the circumstances at our study sites, we agree with Kiptot and Franzel (2012), and Maharjan et al. (2012) that educational programs such as training, and extension activities appear to be necessary to spark the interest of young farmers towards an agricultural occupation.

Though the improved practice was more beneficial (Teklehaimanot 2004), its promotion depends on farmers' knowledge and interest, and available extension services (Kiptot and Franzel 2012). Similar to this finding, we found that older, educated, female farmers growing commercial species, and generating income from tree products significantly chose the improved agroforestry as a better practice. Additionally, Deressa et al. (2009) also claimed that education level, gender, age, access to extension, and social capital influence farmers in choosing the practices.

We do agree that females, previously known as assistants of males in agriculture (Halbrendt et al., 2014; Gebrehiwot et al., 2018), became key actors due to male out-migration (Maharjan et al., 2012; Devkota and Pyakuryal 2017), and fulfilled labour shortage required for the improved practices (Maharjan et al., 2012; Halbrendt et al., 2014; Paudel et al., 2019). Our finding also resonates with Buyinza and Wambede (2008) that women were significantly involving in agroforestry, while being contrary to Phiri et al. (2004) and Keil et al. (2005) who found women not to be significantly involved in agroforestry practices in Africa. The results (Table 6) showed that educational programs have enabled a large number of females to adopt the improved practices. Kumar and Nair (2004) had also similar observation that women were forward in understanding agroforestry and household requirements.

Financial constraints and limited knowledge of methods were the main barriers to adopt agroforestry (Deressa et al., 2009). The positive association with household size and negative association with landholding size in selecting improved practices indicate that smallholder farmers with large householding sizes should be prioritized while designing agroforestry and climate change adaptation programs. However, large landholders having small household size also need further empowerment to scale up agroforestry practice. Crop diversification appeared supportive to farmers in reducing uncertainties in agriculture and overcoming the negative impacts of climate change. Growing multiple crops would have positive effects on people's health and nutrition (Pandit et al., 2014; Asayehegn et al., 2017; Karki et al., 2018). Being more sensitive to family health and nutritional food production, females preferred the improved practice. Similarly, the high potential of sustaining yields is another reason to attract farmers for adopting improved agroforestry practice (Regmi 2003; Lin 2011; Makate et al., 2016). Besides these, agronomically stable and resilient through the improved agroforestry practices also lead farmers to continuously modify the traditional practice. Finally, our study recommends that young male farmers, who were continuing the traditional agroforestry practice, should be sensitized to the benefits of adopting the improved practices.

5.3. Other factors that promote agroforestry practice in Nepal

Though agroforestry is a traditionally adopted farming practice in Nepal, several institutions have been attempting to scale up agroforestry practice throughout the country with some modifications. However, agroforestry has received less attention though it is potential for improving livelihoods and building climate change resilience. Farm Forestry Project launched at the Institute of Agriculture and Animal Science (IAAS), Chitwan, and in the Institute of Forestry, Hetauda, with the financial support of International Development Research Centre (IDRC), Canada in the mid-eighties (1985) was the first important event in the history of agroforestry in Nepal. Afterward, continuous scientific contributions; Amatya and Newman (1993), Pandit et al. (2013), Balla et al. (2014), Amatya et al. (2018), Cedamon et al. (2019), Khadka et al. (2021), etc., have further scaled up agroforestry practices in Nepal by highlighting its contribution to the local economy, livelihood, food security, and satisfying HHs requirements. Recently, the Government of Nepal has also paid attention to strengthening agroforestry practices throughout the country. The Fourteenth Plan (2013/14 -2015/16) has targeted individuals and communities for identifying, harvesting, and commercializing important agroforestry species (NPC 2013). Legal amendment to simplify the commercialization of some woody species (*Dalbergia sissoo, Tectona grandis, Toona ciliata, Eucalyptus species, Mangifera indica*, etc.) grown on private land has created an enabling environment for scaling up agroforestry practices (GoN, 2015). Moreover, the Forest policy (2015) and Forestry Sector Strategy (2016) have recognized the role of private forests and emphasized forest entrepreneurship and agroforestry practices (GoN, 2015, 2016). Participatory action research, integration of woody species (*Neolamarckia cadamba*) with NTFPs, carried out by the Department of Forest Research and Survey (DFRS) has reinforced scientific study in agroforestry sectors. Increasingly, the involvement of stakeholders has strengthened agroforestry-based action research and contributed to the local livelihood, food security, and formulation of agroforestry policy (NPC 2013). The increasing role of national and international institutions working on forestry, agricultural, NTFPs, environment, etc., is also supportive in promoting agroforestry practices as means of local livelihood and combat climate change. In cooperation with IUCN, the Kathmandu-based Food and Agriculture Organization of the United Nations (FAO) is implementing pilot programs in Kaski and Parbat districts to formulate improved agroforestry policy for the country. Similarly, the Government of Nepal and the Australian Centre for International Agricultural Research (ACIAR) implemented a five-year action research project in 2013 to enhance livelihood and food security through agroforestry and community forestry program. Besides these institutions, individuals, formal and informal groups, community-based organizations, and cooperatives are involved at the grassroots level in the promotion of agroforestry practices. Finally, many farmers are continuously adopting agroforestry practice without perceiving it as an effective adaptation strategy for climate change adaptation. So, we agree with Simane et al. (2016) and Semenza et al. (2008) that the concerned stakeholders need to pay attention to additional interventions to promote agroforestry at the grassroots level. Autonomous strategies adopted by local farmers can contribute more at the grassroots level than adaptation measures designed for larger area from a higher level (Semenza et al., 2008; Bryan et al., 2009; Simane et al., 2016) so these local autonomous strategies need to be further strengthened (Semenza et al., 2008; Simane et al., 2016).

6. Conclusions

Most of the farmers have been experiencing changes in climatic patterns, however, only a few of them attributed these changes to climatic effects, and thus, few farmers adopted climate change adaptation strategies. Diversification of crop production, shifting farming practice, improvement in irrigation practice, adoption of new techniques, integration of crop and livestock farming, shifting occupation, and emigration were the major activities adopted by farmers as means of climate change adaptation. Income generation and securing livelihoods were the primary motives for adopting agroforestry practices in the study area. However, some farmers also realize agroforestry practices as coping strategies for climate change. Age, education, and the habit of growing commercial species significantly affected farmers in adopting climate change adaptation strategies; whereas, age, education, gender, and habit of growing commercial species and generating income from tree products influenced farmers choice of improved agroforestry as a better practice compared to the traditional practice. Though agroforestry is an important strategy for climate change adaptation, many farmers are not still considering it due to limited knowledge about climate change and its impact on their livelihood and agricultural. Therefore, educational programs linking agroforestry with climate change such as; door-to-door visits, farmer group schools, field training, and technological input to increase production, need to be further strengthened to sensitize farmers to enable them to choose effective agroforestry practices for climate change adaptation and mitigation.

Declarations

Author contribution statement

Deepa Paudel: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Krishna Raj Tiwari & Bishal K Sitaula: Conceived and designed the experiments.

Nani Raut & Roshan Man Bajracharya: Conceived and designed the experiments; Wrote the paper.

Suman Bhattarai & Shivaraj Thapa: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Funding statement

This work was supported by NORHED SUNREM Himalaya Project for South Asia.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

We were thankful to all the farmers involved in this study. We would like to acknowledge Bishnu Prasad Devkota, Abdesh Singh, Bijendra Basnyat, Prabin Poudel, Pawan Karki, Sistata Bagale, Sara Ranabhat, Ram Thapa, and Resham Karki for their support during field work.

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