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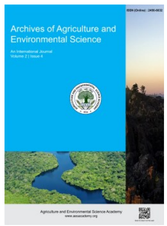

ORIGINAL RESEARCH ARTICLE

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Farmer's perception and adaptation strategies to climate change on potato farming in Narayan Municipality of Dailekh district, Nepal

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ABSTRACT

This study was aimed to assess farmer's perceptions of climate change and their adaptations in potato farming in Dailekh District, Nepal. A total of 97 randomly selected respondents were selected for the study. Primary data was collected through focus group discussions, direct observation, semi-structured questionnaires while secondary data was collected through review of relevant literature. The data was analyzed using descriptive statistics, time series regression, Logit, and Seemingly Unrelated Regression model (SUR). By analyzing the farmer perception of climate change, 75.26% of the respondent experience climate change. In contrast to 84.5% farmer perceived increased temperature, 94.85% believed decrease rainfall duration with increase in rainfall intensity. The key variables determining the climate change perception of farmer were: socio-economic variables (education, farming experience, and family size) and bio-physical variables (increase in drought, change in insect pests and diseases and lack of irrigation). Based on the study, 58.76% of the farmers adopted climate adaptations. Farmers primarily adapted to climate change through changing potato variety (61.86%), adjusting planting/harvesting time (64%), changing planting method (71.13%), pest's management, irrigation, fertilizers, and crop rotation. Logistic regression revealed higher education and attainment of training increased adaptation by 9% and 18.54%, respectively. A link was found between farmers' perception of climate change and the implementation of some adaptation options. Thus, socioeconomic and biophysical variables have a significant association with adaptation, as well as investment in education, extension training, and access to credit, and can be considered to increase climate change adaptation to improve farmers' well-being.

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INTRODUCTION

Potato is one of the major staple foods in Nepal and is grown in all agro-ecological zones extending from the southern plain of Terai to the northern highlands. It can be grown from the altitude of 100 MASL to 4000 MASL. People residing above the altitude of about 2000 masl use potatoes as the only staple food, as the environmental conditions do not favor the production of other crops like cereals, legumes, etc. It is the sixth important crop in terms of area, third in terms of production, and second in terms of productivity in Nepal (AITC, 2019). In Nepal, 3,487,816 mt. of potatoes are produced annually in an area of 203,812 ha, while in Dailekh, 33,450 metric tons of potatoes are produced in an area of 1924 ha (MOALD, 2024). Nepal is a part of the Hindu Kush Himalaya (HKH) region, and the rate of warming in this region is significantly greater than the global average (Kulkarni *et al.*, 2013). The Climate Risk Index puts Nepal as the world's tenth most affected country, although it contributes the least to global GHG emissions, emitting only 0.10%. It is highly sensitive to climate change and natural disasters, with both extreme and slow-onset climate-related hazards. Nepal is highly vulnerable to climate change due to its rugged mountainous topography, extreme climatic conditions, frequent climatic hazards, and the low capacity of its poor populations to invest in adaptation strategies, political conflict, and governance challenges. These challenges extend to western Nepal, a region in which international donors and government have both stressed the need for irrigation development (Risal *et al.*, 2022).

Dailekh is located in a hilly region of Karnali Pradesh, where the majority of the people are marginalized and destitute. So, they are quite susceptible to the effects of climate change. As they have weaker capacity and fewer resources, they have less ability to adjust to the vulnerability of climate change. Besides that climate change has led to scarcity and irregular availability of water, without access to safe drinking water (Ayanlade *et al.*, 2022). Pests and diseases of lower ecosystems are also gradually shifting to the mid and high hills of Dailekh district (Timilsina *et al.*, 2019) which has massive impact on potato production. The purpose of this research is to better understand the impact of climate change on the potato sector and to identify vulnerable populations along with their adaptation strategies. Furthermore, it seeks scientific validation of findings to inform future research and policy recommendations for effective climate change adaptation in this crucial agricultural sector.

MATERIALS AND METHODS

The study was conducted in wards no 3, 4, 6, and 10 of Narayan municipality of Dailekh District of Nepal where, a total of 97 samples were selected by simple random sampling for the survey (Figure 1). Data were collected from both primary and secondary sources. Primary data were collected through semi-structured interviews with farmers, key informant interviews (KIIs), and focus group discussions (FGDs). Secondary data were collected from relevant publications, municipal records, reports from the Agricultural Development Office (ADO), National Agriculture Research Council (NARC), and the Ministry of Agriculture and Livestock Development (MoALD). Data analysis was done by using descriptive statistics, time series regression, Logit, and a seemingly unrelated regression model (SUR). Both qualitative and quantitative data, were analyzed using SPSS (Statistical Package for Social Science), Stata and Microsoft Excel. To assess the status of the perception and adaptation of improved practices, descriptive statistics such as frequency and percentage were calculated. Additionally, the extent of adoption was analyzed using the adoption index as formulated by Sengupta (1967) as:

$$\text{Adoption Quotient} = \frac{\text{Adoption Score of the Respondents}}{\text{Maximum Score a Respondent will get}} \text{x } 100$$

The logit model of regression analysis was used to examine the relationship between the various factors and the level of perception and adaptation as it is widely used model in assessing the factors affecting the perception and adaptation level (Jirel *et al.*, 2018). The dependent variable for this study was the farmer's adoption status of adopter and non-adopter to a value of 1 (if the farmer is adopter) and 0 (for non-adopters) and same process goes for perception. The independent variables with their values. If Yi be the binary response of a farmer and can take one of two possible values: Y= 1 if the farmer is the adopter and Y= 0 if non- adopter. The probability of the binary response is defined as follows:

If Yi = 1; P (Yi= 1) = Pi

Yi= 0; P (Yi= 0) = 1 – P

Where, Pi= E (Y= $\frac{1}{X}$)

Thus, the probability of adopting the technology then expressed as,

P (Yi= 1) = Pi= $\frac{1}{1+exp^{-z}}$

Where; Z = a+ SβiXi + e

The logit equation of the probability of adopting the recommended technology, P (Yi) (Gujrati, 2003), is shown below:

$$Li = \ln\frac{Pi}{1-Pi}\ \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ \ldots\ldots\ldots\ldots\ldots.. + \beta_i x_i$$

Where;

Yi = Adoption level (Dichotomous dependent variable with value 1 if adopter and 0 if non adopter),

Li= Logit, Pi/1-Pi = odd ratios,

$\ln$ = base of natural logarithm,

β_0 = intercept

e = Error Index

And $\beta_1, \beta_2, \beta_3, \ldots\ldots\ldots \beta_i$ are the slope against the independent variables $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_i$ respectively.

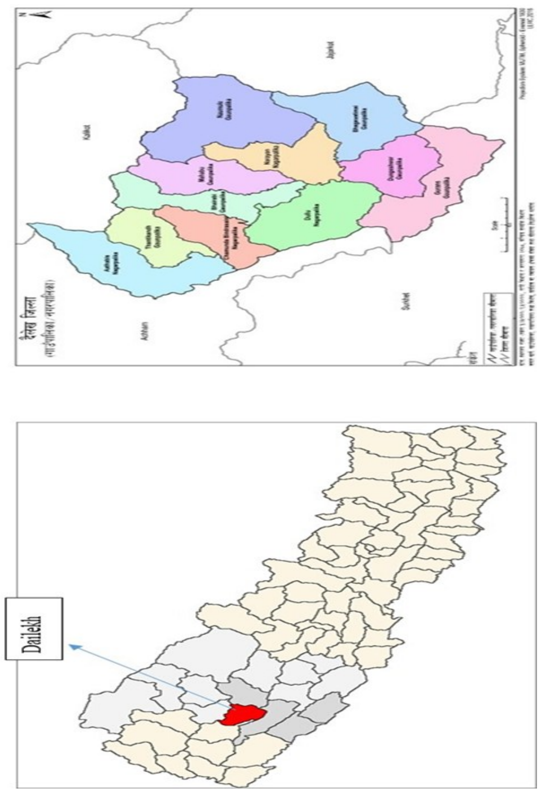

Figure 1. *Map showing study area at Dailekh district in Nepal.*

RESULTS AND DISCUSSION

Farmer's perception on experiencing climate change

During this study, household surveys was conducted within the Narayan municipality of Dailekh district of Nepal for knowing the farmer's perception on experiencing the climate change. All the farmer's responses were asked dichotomous (yes/no) responses questions about whether or not they had experienced changes to regional climate over the last 20 years. The farmers were questioned about their perceptions of a series of climate occurrences widely linked with the effects of global climate change in the Dailekh district of Nepal. For this, they could have responded that they had either perceived or not (yes/no), or had experienced increased, decreased, or no change in the occurrence of the events in the past 5-10 years. The majority of respondents (75.26%) said that they had perceived climate change knowingly or unknowingly, while 24.24% of the farmers had no concept or idea about it.

Farmer's perception of climate change

Based on the results from the household surveys conducted within the Narayan municipality of Dailekh, climate change indicators such as temperature, precipitation, drought, hailstorms, weed species, insect pests and diseases, changed in cropping area and yield, were identified. A significant majority (84.5%) of respondents reported an increase in temperature, while 15.5% did not perceive any change. 94.85% of the respondents believed that the duration of rainfall was decreasing, while only 5.15% reported no change. Among those who perceived a change, 59.79% reported an increase in rainfall intensity and 36.09% reported a decrease in its frequency (Table 1). These findings suggest a notable shift towards more intense rainfall events for a short period of time which is similar to Tamm *et al.* (2023). Another indicator of the impact of climate change was an increase in drought, which was frequently observed by farmers in the study area. Almost 85.5% of farmers said that the intensity and frequency of drought had increased in the past ten years, and 14.5% had no idea about it. Most of the farmers, i.e., 77.08% had no irrigation facility, and the remaining 22.92% of farmers had irrigation facilities for potato cultivation. A significant majority (85.5%) of respondents believed that hailstorm frequency had decreased, while only 14.5% perceived no change. This suggests a notable decline in hailstorm occurrences in the region. Most of the farmers, 85.5% perceived that climate change caused an increase in climate-induced disease (like potato late blight) and pests (like potato tuber moth) in potato farming, which impacted their farming directly and indirectly. Decreases in potato yield and cropping area were noticed by 73.2% and 55.7%, respectively, by the farmers. Most of the farmers thought their yield was continuously decreasing year after year. This suggests that a considerable number of farmers had reduced the land they allocated to potato cultivation, potentially due to various factors such as the effects of climate change, economic challenges, or shifting agricultural priorities. About 70.4% of farmers perceived a change in weed species. New weed species are arising in higher density, analogous to past years.

Table 1. Farmer's perception of climate change in Dailekh District, Nepal.

Change mention by farmers		No. of farmers	Percentage
Increase in temperature	Yes	82	84.5
	No	15	15.5
Change in rainfall			
Shorter duration of rainfall	Yes	92	94.85
	No	5	5.15
Increase in intensity of rainfall	Increased	58	59.79
	Decreased	35	36.09
	No change	4	4.12
Decrease in rainfall	Yes	85	87.6
	No	12	12.4
Increase in drought	Yes	83	85.5
	No	14	14.5
Decrease in hailstorms	Yes	83	85.5
	No	14	14.5
Change in climate induced insect, pest and diseases.	Yes	83	85.5
	No	14	14.5
Decrease in potato cropping area	Yes	54	55.7
	No	43	44.3
Decrease in potato yield	Yes	71	73.2
	No	26	26.8
Change in weed species	Yes	69	70.4
	No	28	29.6

Source: Field Survey, 2024.

Factors determining the farmer's perception of climate change

Interestingly, people had their own experiences with perceptions of climate change in the study area, which were determined by many factors. Based on different literature reviews and different responses of respondents, 14 different explanatory variables were selected to investigate the factors affecting the farmer's perception of climate change. The statistical description of these variables is done in Table 2. Perhaps the household characteristics (e.g., gender, education, farming experience of the farmer, family size involved in agriculture), biophysical and impact variables (changes in precipitation, increase in drought, increase in climate-induced insect pests and disease, lack of irrigation facilities for irrigation) were major determinants of variables observed by farmers in the study site. The independent variables were chosen based on the theoretical basis from literature, professional consultations, and experiences gathered by local farmers. Likewise, Mairura *et al.* (2021) used the same type of variable in their study of factors affecting the farmer's perception of climate change. Many climate change indicators had been reported by farmers of the study site. The logit regression was calculated to determine the relationship between and among the major indicators in the study area, as it was presented in Table 2. The logit regression result showed that the farmers' perceptions of climate change were determined by many factors in the study area. The factors include gender (p = 0.028), education (p = 0.014), farming experience (p = 0.015), and involvement in Ag (p = 0.087), which were recorded as having a positive and significant relationship with the farmer's perception of climate change in the study area. The significance of gender to farmer perception of climate change indicates that male farmers were more likely to perceive the climate change than female Similar to Liu *et al.* (2014) who show female farmers were more concerned with the impact of climate change. Similarly, Bessah *et al.* (2021) reported that climate change was perceived by both males and females, but males perceived it more than females.

Education was found to be positive and significant to farmer perceptions of climate change, implying that the probability of perception of climate change was greater for those who had higher educational attainment compared to less-educated or illiterate farmers. The findings of Chemeda *et al.* (2023) also showed a similar result in their study, which addressed education as an influencing factor of farmers perception of climate change and was also found in other studies conducted by other researchers. Farming experience is positively associated with the perception of climate change by farmers. Further, this line was similar to Ndambiri *et al.* (2013) who reported experienced farmers were more aware of changing temperatures, rainfall, and other disaster events. These experiences might be helpful to understand the prediction of future changes of these events and have been identified in other research. Family size was significant to perceptions of climate change. With the increasing size of the family, the probability of farmers' perception of climate change was also increasing, which was consistent with Ndambiri *et al.* (2013) results. Other variables like change in precipitation (p=0.052), increase in drought (p=0.009), change in climate-induced insect pest diseases (p=0.043), and lack of irrigation (p=0.009) were recorded as significant variables regarding the farmer's perception of climate change, as shown in Table 3. This was consistent with the findings of Rai *et al.* (2023) who found that the lack of irritation and change in precipitation affect the farmer's perception of climate change. An increase in drought was significant to perceptions of climate change. As droughts increase, a farmer may notice the effect of climate change and its impact on agriculture. Other variables were also crucial, but they were not statistically significant in the logit regression of this study.

Table 2. Determinant of farmer's perception of climate change in Dailekh District, Nepal (Source: Field Survey, 2024).

Explanatory variable	Coefficient	SE	Wald	Significance (p)
1. Socio-economic character				
Age	0.120	6.627	0.00	0.986
Gender	5.302**	2.420	4.80	0.028
Education	2.779**	1.130	6.04	0.014
Farming experience	2.682**	1.098	5.96	0.015
Training	8.330	13.379	0.39	0.534
Organization	3.203	2.134	2.25	0.133
Family size involved in Ag	2.341*	1.368	2.93	0.087
Summary Statistics				
N	97			
LR chi(8)	50.26***			
Prob > chi2	0.0000			
Log Likelihood	-29.14			
Pseudo R2	0.4631			
2. Bio- physical variable and impact variable				
Change in Temperature	-0.468	1.177	0.16	0.691
Change in precipitation	3.729*	1.917	3.78	0.052
Increase in drought	3.369***	1.384	6.91	0.009
Change in insect pest diseases	1.974**	0.977	4.08	0.043
Lack of irrigation	4.271***	1.629	6.87	0.009
Decrease in potato yield	1.092	0.908	1.44	0.229
Decrease in cropping area	0.577	0.870	0.44	0.507
Summary Statistics				
N	97			
LR chi(7)	61.05***			
Prob > chi2	0.000			
Log Likelihood	-23.75			
Pseudo R2	0.562			

Farmer's adaptation to climate change

Majority of respondents (58.76%) regards they had adopted various adaptation practices to cope with the impact of climate change knowingly or unknowingly, while 41.24% of the farmers had no concept about it.

Farmer's adaptation practices to climate change on potato production

The above study data present the relationship between changes in variables and adaptation to climate change. 60 out of 97 respondents (61.86%) reported that they changed the variety of potato, while 38.14% did not adapt any changes. In order to reduce the crop period and impact of climate change in later stages of the crop, most of the farmers had shifted to hybrid and improved varieties of potatoes. 37.11% of respondents believed changing the planting time helps to cope with climate change (Table 3). Farmers who had changed their planting time were more likely to be able to avoid the negative effect of climate change. Few farmers (27.84%) had adapted the climate change practices by changing their harvesting time, while 72.16% of farmers did not change their harvesting time to adopt other practices. A majority of respondents (71.13%) reported adopting the planting method, indicating its popularity among farmers in the region. This suggests that changing planting methods is a common adaptation where most of the farmer's sow potatoes in ridges rather than plain beds. Very few respondents (14.43% and 19.59%) reported adopting pest and irrigation management practices, respectively, to cope with the impact of climate change. A few respondents changed their irrigation management practices by constructing ponds and other irrigation channels. Karnali Province is also called organic Province (Sharma & Shrestha, 2023). More than 80% of the respondents had adopted weed and fertilizer management practices. Almost all farmers performed hand weeding and used FYM and compost manure with negligible use of complete NPK. Crop rotation is a more widely (64.95%) adopted adaptation practice in the study site, compared to mulching (9.28%). Only educated and commercial farmers were involved in mulching practices.

Factors affecting adaptation of climate change

A dependent variable Adaptation to climate change was regressed using a logit model upon the 10 independent variables, which showed that the variables ethnicity, education, farming experience, and training were found to be statistically significant (Table 4). These variables were the determinant factors for farmers' decisions to adapt or not to adapt climate-resilient practices. Education, extension, and training were found to be statistically highly significant. The study revealed that if the respondent had gotten the higher education, the probability of adaptation to climate change increased by 9.2% and was highly significant at the 1% level of significance. Similarly, access to training enhanced the adaptation practices by 18.5%, which was highly significant (p-value < 0.001), indicating training had a positive impact on the dependent variable. The higher the experience of the farmer in potato cultivation, the probability of adaptation of climate change practices was increased by 11.2% and was significant at the 10% level of significance. Ethnicity was significant at the 5% level (p-value 0.063), indicating that ethnicity had a negative impact on the adaptation to climate change. The dy/dx value of -0.372 suggests that a one-unit increase in ethnicity is associated with a 0.372 decrease in the log odds of the dependent variable. Gender, age, religion, source of income, heard climate change, and access to credit of the respondents were not statistically significant. The Pseudo-R2 value is 0.416, implying that the factors in the model had been able to explain a 41.6% probability of a decision to adapt or not to adapt the climate change practices, which is quite high. The log likelihood for the adaptation of climate change practices is -38.421, and the corresponding chi-square value stands at 54.63.

Seemingly Unrelated Regression (SUR) analysis

To quantify the impact of various explanatory factors affecting farmers' choice of adaptation methods, we used logistic regression models for all adaptation measures. The standard error of logistic regression told us about the degree of uncertainty in the accuracy of the dependent variable's projected values from independent variables (Table 4). The marginal effects explaining the effect of a unit change in explanatory variables on the dependent variable. Seven different strategies as models were used to access some explanatory variables that determined the different adaptation strategies adopted. Seemingly Unrelated Regression (SUR) analysis revealed that farming experience, training, access to credit, and membership in organizations were major positively significant explanatory variables in farmers' decisions for adaptation of different climate change combat strategies. Education was found to be positively significant for models 2, 5, 6, and 7 and was negatively significant for model 1, as shown in Table 4. In the following sub-sections, we describe the impact of various explanatory variables on the probabilities of adopting different adaptation measures in response to variability in climate.

Table 3. Farmers adaptation practices to climate change on potato production in Dailekh District, Nepal (Source: Field Survey, 2024).

S. No.	Adaptation	Frequency (percent)
1.	Change in variety	60(61.86)
2.	Change in planting time	36(37.11)
3.	Change in harvesting time	27(27.84)
4.	Change in planting method	69(71.13)
5.	Change in pest management	14(14.43)
6.	Irrigation management	19(19.59)
7.	Weed management	81(83.51)
8.	Fertilizer management	91(93.81)
9.	Crop rotation	63(64.95)
10.	Mulching	9(9.28)

Table 4. Logit regression analysis of variables.

Variable	Coefficient	Std. error	P(z)	dy/dx
Gender	0.341	0.558	0.541	0.052
Age	-0.209	1.281	0.870	-0.020
Religion	-1.172	1.714	0.494	-0.132
Ethnicity	-2.569*	1.384	0.063	-0.372*
Education	0.874***	0.327	0.008	0.092***
Source of income	-0.046	0.222	0.835	0.009
Farming experience	0.891**	0.403	0.027	0.112**
Heard CC#	0.686	0.606	0.258	0.119
Training	2.240***	0.674	0.001	0.185***
Access to credit	-0.083	0.648	0.898	0.154
Summary statistics				
N		97		
LR chi(10)		54.63***		
Prob > chi2		0.000		
Log Likelihood		-38.421		
Pseudo R2		0.416		

Source: Field Survey, 2024; Note: Signs*, ** and *** indicate Significant at 10%, 5% and 1% level respectively.

Education

Education was found to be negatively significant on the adoption decision to change the variety of potatoes. Whereas positively significant on decisions to adopt changes in planting time, irrigation management, fertilizer management, and crop rotation. Increase in years of school of household head by one year, the possibility of decreasing the changing of potato variety by 8%, whereas increasing the possibility of changing planting time, adopting irrigation management, fertilizer management, and crop rotation by 15.7%, 14.5%, 11.1%, and 7.2%, respectively. This finding can be supported by Maddison (2007), who reported educated farmers were more likely to respond by implementing at least one adaptation practice. The negative significance of the changing variety depicts that educated farmers had reduced the number of varieties, instead using less but selective and effective ones and even continued to grow local varieties to adapt to climate change.

Farming experience

The coefficient of years of experience in farming had a positive sign for changing variety as adaptation measures, indicating a positive relation between farming experience and the possibility of changing variety to adapt to climate change. Years of farming experience significantly increased the probability of changing crop varieties, as a 1% increase in years of experience increased the probability of changing the crop variety by 8.8%. According to Hue *et al.* (2023), more experienced farmers had more management skills and techniques and better judgment on adaptation to adverse conditions, changed the existing variety, and used the improved one as an adaptation to climate change. Correspondingly, Nhemachena & Hassan (2007) suggested experienced farmers were usually leaders and progressive farmers were rural communities, and these can be targeted in promoting adaptation management to other farmers who didn't have such experience and were not yet adapting to changing climatic conditions. It can be concluded that farmers with greater farming experience were likely to be more aware of past climate events and better judge how to adapt their farming to extreme weather events.

Training

The logistic regression shows a position and significant association between the extension training and changing planting time, harvesting time, and adopting crop rotation. If the family members were involved in extension training, the likelihood of changing planting time and harvesting time increases by 3.2% and 21.3%, respectively, whereas the likelihood of adopting crop rotation increases by 38.4%. This collaborates with the finding of Hue *et al.* (2023), who argue that greater access to extension services will be better able to obtain information on climate risk management information and techniques and climate-smart practices. Similarly, Kuponiyi *et al.* (2010) also reported a similar type of result, which revealed that the provision of extension facilities increases the probability of farmers practicing various adaptation strategies.

Access to credit

Access to farm credit had a positive and significant effect on changing crop variety and pest management as an adaptation to climate change. 1% increase in availability or access to credit, changing crop variety by 45.6%, and adopting pest management by 9.8%. This result was similar to Hue *et al.* (2023) who also found a positive link between loan access and climate change adaptation. It was because adaptation strategies require certain levels of financial adoption and poorer counterparts who had difficulty in credit access. Also, Nhemachena & Hassan (2007) reported that per capita income had a positive influence on farmers' decisions to take up adaptation measures.

Involvement in organization

The study shows that the farmer who had participated in a farmer association increased the probability of adopting an adaptation strategy, which implies that if the family member was involved in an organization, then the probability of changing variety would be increased by 15.4%. This may be due to farmers' groups sharing experience and ideas on how to increase yield and exchanging information about improved technology and resilience to climatic risk. In this, Boansi *et al.* (2017) also reported that membership in a group helps to adopt climate change risk management.

Link between farmer's perception of climate change and implementation of adaptation practices

The analysis of the connection between perception of climate change and adoption of adaptation options did not fully support our initial hypothesis that perception drives the adoption of adaptation options. On the one hand, the connection held true for those farmers who perceived the lack of irrigation, changing the variety as an adaptation strategy, but the perception of lack of irrigation was negatively significant with the change in variety. As the lack of irrigation on the farm increases, the adoption of changing varieties decreases; this is contrary to Amadou *et al.* (2022) who believed the change from traditional to modern cultivars was due to an increase in temperature and drought. This may be due to the adoption of other adaptation strategies, such as improving water management practices, and also due to the lack of availability of improved/stress-tolerant varieties. The perceived change, decreases in hailstorms, and lack of irrigation triggered farmers to change the planting time. A decrease in hailstorms is negatively significant with the adoption of an adaptation strategy, meaning that the farmers who perceived a decrease in hailstorms were more likely to take any adaptation decisions, like a change in planting time, because hailstorms provide moisture to the plant and help to combat the lack of irrigation and drought problems. Farmer's perception of lack of irrigation was one of a statistically significant explanatory variable that had a positive coefficient. The positive sign indicates that it had a positive influence on taking an adaptation strategy to climate change. Farmers who didn't have an irrigation source were more likely to change their planting time to adapt to climate change. The findings are in line with Guan *et al.* (2017) who reported that farmers change their planting time and water harvesting by increasing resilience to heat stress and lack of irrigation. Likewise, Sultan & Gaetani (2016) also mentioned changing sowing dates, density, and irrigation and fertilizer management to mitigate the adverse effects of climate change. Some of the perceived changes like the change in precipitation, were significant with the change in harvesting time. Shortening the days and increasing the intensity were connected with the adaptation of changing harvesting time. Change in precipitation significantly influenced farmers' perception of climate change, thereby leading to the adaptation of climate change practices by farmers, as suggested by Asrat & Simane (2018). Decrease in hailstorms and change in climate-induced insect pests and diseases was negatively significant with the harvesting time. Lack of irrigation was positively significant with the change in harvesting time. An increase in drought and change in climate-induced insect pest and disease was an important variable driving the adoption of crop rotation practice. Increase in drought is negatively significant with the adaptation of crop rotation. Similarly, farmers who adapt the crop rotation technique were more likely to experience an increase in drought. The change in climate-induced insects, pests, and diseases was positively significant with the adaptation to climate change that triggered the adaptation of the crop rotation. Some of the perceived changes, and notably the change in precipitation, were not connected to the implementation of any adaptation option. This is worrying, given the fact that the issue is real (Taylor *et al.*, 2017). Although not mentioned directly by farmers, irrigation management and crop rotation practices help to reduce the runoff and evaporation, and that helps to mitigate the changing pattern of irrigation, which was similar to Walker & Ogindo (2003), that the soil surface is shaded due to vegetation, resulting in evaporation from the lower soil surface. Similarly, the perceived changes in temperature were also not connected to the implementation of any adaptation options. Rising temperatures impact crop growth and yield through several processes. Rising temperature accelerates crop development and shortens crop cycle with lower crop yield; raising temperature and lack of irrigation caused change in planting time and change in variety.

Conclusion

Adaptation to climate change is a two-step process that requires farmers to first perceive climate change and then respond to those changes. The majority of the farmers have observed noticeable pattern in climatic patterns like increased temperature, altered rainfall patterns, and more frequent drought on potato farming. Those perceived changes have direct and indirect impacts on potato productivity, disease and pest prevalence, and cropping pattern. Based on these perception farmers used early maturing varieties, altered planting and harvesting time based on climatic variability and crop rotation as a major strategy to reduce the impact of climate change. On contrary factors like gender, education level, farming experience, and family size involved in agriculture were found to be positively and significantly associated with the farmer perception of climate change whereas age, extension training, and involvement in organizations did not show statistical significance in affecting perception rates. Furthermore, the study highlighted that changing the potato varieties, adjusting planting and harvesting time and implementation of crop rotation were widely adopted adaptation practices followed by farmers in response to climate change. Education, training, farming experience, ethnicity and access to credit were key factors affecting the adoption of adaptation practices. Access to training and education increased the probability of adopting the adaption measure suggest the importance of dissemination of knowledge through extension and capacity building. The link between perception and adaptation was found to be complex but in some cases perception of climate change influenced the adaptation process. The findings indicate that farmers are aware of climate change and its impact on potato farming and capable of adapting to some extent. But enhancing awareness through education, training and support through credit and increased access to resources can significantly improve the adaptive capacity to climate change. Efforts should be taken from both the local level and the central government level in developing and implementing climate resilient and sustainable potato production in this region.

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DECLARATIONS

Author contribution statement

Conceptualization: P.B. and D.K.; Methodology: P.B.; Software and validation: D.K., D.T., and N.K.; Formal analysis and investigation: P.B and D.K.; Resources: D.T; Data curation: P.B. and N.K.; Writing—original draft preparation: P.B.; Writing—review and editing: P.B.; Visualization: D.T. and N.K.; Project administration: D.T. and D.K. All authors have read and agreed to the published version of the manuscript.

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