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Climate Adaptation in Rain-fed Agriculture: Analyzing the Determinants of Supplemental Irrigation Practices in Nepal

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Abstract: Climate change has severely impacted the rain-fed agricultural production system which is dominant in Nepal. This situation demands implementable strategies like supplemental irrigation for mitigating adverse impacts. In spite of the importance of supplemental irrigation, it is not adopted on a wider scale. Hence, this paper aims to assess perceptions of climate change and identify factors that influence the adoption of supplemental irrigation practices. Climate change impact survey data for Province No. 1 (one of the seven provinces in Nepal) with a sample of 800 households were analyzed by using the probit regression model. The results showed that the majority of the farmers perceived increasing temperature and decreasing precipitation, resulting in climate-induced disasters such as drought. Similarly, only about 27% of the households have adopted supplemental irrigation practices. The significant factors influencing the adoption of supplemental irrigation practices were the household head's number of years of farming experience and education level, distance to motorable roads, operational size of landholding, membership in community-based organizations, and the perception of changes in summer temperature. Considering the empirical results, it is necessary to undertake research on sustainable practices and develop support measures for scaling up this practice as the adoption of this practice is very low in Province No. 1. The policy and strategy should also emphasize enhancing the capacity of farmers in technical and managerial aspects of supplemental irrigation practices, raising awareness about climate change and its impact, and strengthening community-based organizations for sharing and exchanging knowledge and skills. In addition, creating additional employment opportunities to enhance the income of the farmers for mitigating the capital constraint and increasing investment in infrastructures like roads for improving physical access thereby promoting adoption.

Keywords: Agriculture; Adaptation; Climate; Supplemental irrigation; Perceptions; Nepal

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1. Introduction

Agriculture is the main sector of the economy in terms of its contribution to the Gross Domestic Product (GDP) and providing employment to the economically active population. The indicators such as labor productivity, productivity gaps, trade and competitiveness, poverty and malnutrition, and infrastructure highlight that the Nepalese agricultural sector is in a low development stage. The production system in Nepal is mostly subsistence and cultivated under rain-fed conditions. Nepalese agriculture is characterized by low input use with low land (USD 1804/ha) and labor productivity (USD 794/person) [1]. The per capita GDP in Nepal was USD 708 in 2012/2013 which has reached USD 1381 in 2021/2022 [2].

In Nepal, the agricultural production system is heavily dependent on monsoon rain, hence more sensitive to climate change. The agricultural production and productivity of crops and commodities are affected by the time, duration, and intensity of precipitation and its pattern. The majority of the people earn their livelihood from the cultivation of crops such as paddy, maize, wheat, millet, and potato, and rearing different types of livestock, changes in the pattern of precipitation especially the monsoon rainfall highly aggravate the poverty and inequality in the country. Although there may be some short-run location-specific positive effects, these would be offset by the negative effects of rising temperatures and frequent occurrences of drought [3].

The diverse topography and social vulnerability have made Nepal prone to geological and climate-related disasters. Different climatic hazards have led to increased soil erosion, landslides, flash floods, and droughts in recent years across the country with increased intensity and impact on the lives and livelihoods of the people in Nepal [4]. Because of the occurrence of such extreme weather events between 2000 and 2019, Nepal is the 10th most vulnerable country with 0.82 fatalities per 10,000 inhabitants and 0.39% losses per unit GDP [5] despite Nepal's very lower share (0.06%) to global greenhouse gas (GHG) emission [6]. Combining political, geographic, and social factors, UNM (2020) estimated ND-GAIN Index and considered Nepal as vulnerable to climate change impacts with a rank of 126th position out of 181 countries with a low score of 41.7.

The long-term impact of climate change on agriculture and food security is inevitable, which will have disproportionately bigger impacts on women, Dalits, indigenous people, and other marginalized communities. About 90% of crop loss in Nepal can be attributed to weather-related events, increased temperature, and hazards such as irregular rainfall, droughts, and floods triggered by them. When crops, livestock, and fisheries are combined, climate change induced losses in production are equivalent to 10% to 30%. Among them, drought is the most critical hazard. Between 1971 and 2007 droughts accounted for 38.9% and floods for 23.2% of all losses caused by weather and climate-related events [7]. The increasing temperature negatively affects animals in terms of gaining weight, reproduction, breeding patterns, feed consumption, and conversion efficiency.

The agricultural sector suffers significantly in the years to come from climate change. It is estimated that South Asia would lose 1.8% of its annual GDP by 2050 while this would increase to 8.8% by 2100 if countries lack in implementing adaptation strategies. This figure for Nepal will be 9.9% by 2100. It is estimated that the direct cost of current climate variability and extreme events is equivalent to 1.5%-2% of the current GDP per year in Nepal. This amount would be approximately USD 270-360 million per year in 2013 prices. It would be much higher in years with extreme climatic events [8]. Agricultural production is anticipated to be impacted by changes in precipitation patterns, leading to significant annual yield fluctuation and increased production risks. In addition, croplands and yields are predicted to be negatively impacted by climate change if weather-related risks such as droughts and floods occur more frequently [9].

The contribution of irrigation is immense to increasing agricultural production. On average, irrigated agriculture is at least twofold as productive per unit of land in comparison to rain-fed agriculture, leading to more intensification and diversification of crops [10]. Irrigation is the most important variable affecting the growth of Agricultural Total Factor Productivity (ATFP) in Nepal. In the context of the high variability of rainfall in Nepal, assured irrigation water supply complements the potentiality of biological techniques such as variety thereby resulting in increased productivity. The irrigation ratio shows that with a one percent increase in irrigated area, the ATFP would increase by 1.38% [11]. The contribution of irrigation and variety alone would contribute respectively to 29% and 30% of total incremental yield while their interactions would contribute 41% to total incremental yield [12]. Under the rice-wheat cropping pattern, as we go up from improved variety-unirrigated to improved variety-irrigated farming, the incremental grain yield would be 41% in the case of paddy and 35% in the case of wheat in Nepal [11].

Although irrigation is an important production input for increasing agricultural production and productivity, it has not been available as per the need of the crops and is also not under the control of the farmers. Over 60% of the cultivated area still depends on monsoon and winter rain for crop cultivation in Nepal. Investments in the ponds and collecting rainwater for supplemental irrigation have been one of the coping strategies to mitigate the impacts of droughts and irregular rainfall in Nepal. Supplemental irrigation can be described as the addition of small amounts of water to mainly rain-fed crops during times when rainfall fails to deliver enough moisture for normal plant growth, in order to improve and stabilize yields [13]. It is a simple but highly effective technology that facilitates the farmers to plant and manage crops at the optimal time, without being dependent on erratic rainfall [14]. When a limited amount of water is utilized properly during the critical stages of crop growth, this may lead to crop growth and can result in a substantial increase in yield and water productivity. This strategy can be considered an efficient response to lessen the undesirable impact of soil moisture stress during dry spells on the yield of rain-fed crops.

The adoption of supplemental irrigation practices such as rainwater harvesting, collection of water in ponds, and use of non-conventional methods (drip and sprinkler irrigation) would help lessen the over-dependence on rainfall with proper planning and management [15]. However, the adoption of such practices is low in spite of their effectiveness and viability as a coping strategy to climate change, most importantly in the resource-constraint rain-fed environment. There could be several reasons for the slow and low adoption of such important practices for climate adaptation but are not well documented in the previous literature. Province No. 1 (one of the seven provinces in Nepal) in general and hilly and mountain districts in particular are experiencing mid-season dry spells and an increase in the incidence of drought, which is mainly because of climate variability and change. This creates high risks in agricultural production, which further worsens poverty and food insecurity in the province. In this context, this paper intends to assess climate change perceptions and identify factors that affect the adoption behavior of farmers toward supplemental irrigation practices.

2. Materials and Methods

2.1 Description of the Study Area

2.1.1 General Background

Province No. 1 has an area of 25905 square kilometers with an elevation from 60 m to 8848 m. Mt. Everest, the highest peak in the world lies in this province. This province has 14 districts covering mountains, hills, and Terai ecological region. Out of the total land area, 23% of the area is cultivated. The total agricultural (cultivable) land in this province is 783595 ha out of which surface irrigation is available in 284863 ha while groundwater irrigation is in 48155 ha with a total of 333018 ha irrigated. It reveals that 42.5% of the total cultivable area has received irrigation facilities [16]. However, the year-round irrigation water available is lower than this figure.

2.1.2 Climatic Information

There is a wide spatial and temporal variation in climatic variables across the province. It was observed that the precipitation (mm/day) in pre-monsoon is 3.38 mm, summer 12.05 mm, post-monsoon 1.63 mm, and winter 0.37 mm with an average of 5.26 mm [7]. As the monsoon starts from the eastern part of Nepal, Province No. 1 has the highest pre-monsoon rainfall. The winter precipitation in Nepal is influenced by westerlies, and consequently,

Figure 1. Map of Nepal showing Province No. 1.

the Far-western (Sudurpaschim) Province of Nepal gets higher precipitation. The winter precipitation gradually decreases as westerlies become weak from west to east of the country with the lowest precipitation in Province No. 1 and Madhes Province [17]. A study in the Koshi river basin found that by the end of the century, there will be 4 °C increase in temperature [18], the minimum and maximum temperatures are projected to increase by 6.33 °C and 3.82 °C respectively [19], and the likelihood of an increase in temperature will be higher in the mountains than in the plains [20].

The future projection of climatic variables is based on the two Representative Concentration Pathways (RCPs) - RCP4.5 and RCP8.5 [21]. Compared to the reference period (1981-2010), the precipitation is likely to increase in all the scenarios and periods for all districts, while higher for mountains and hills than for Terai. In the medium term, the precipitation would increase by 2.79 to 4.31% while it is projected to increase by 2.12 to 8.32% in the long term. The temperature increase ranged between 0.79% to 4.07% in the medium term and 0.98% to 1.76% in the long term compared with the reference period. It also shows that compared to the reference period, the number of rainy days and consecutive dry days is likely to decrease in all the districts. There will be an increase in warm days in all the districts which can be inferred about the overall temperature rise in the future. The changes in climatic parameters for the sample districts (of this study) are given in Table 1.

Table 1. Changes in climatic parameters in different periods.

S.N.	Districts	Reference Period (days)	RCP4.5		RCP8.5	
		1981-2010	2016-2045	2036-2065	2016-2045	2036-2065
1	Dhankuta					
	Change in Precipitation (%)	1916 mm	2.79	3.34	2.24	6.92
	Change in Temperature (°C)	17.2	0.79	1.13	0.99	1.68
	Change in no. of Rainy days (%)	180.3	–0.78	–0.36	–1.87	–1.30
	Change in Consecutive Dry Days (%)	44.8	1.96	–0.39	–0.95	–1.78
	Change in Consecutive Wet Days (%)	92.4	–8.34	–5.46	–5.41	–11.88
	Change in Warm Days (%)	37	8.12	10.97	9.13	15.22
2	Khotang					
	Change in Precipitation (%)	1717 mm	2.88	4.07	3.01	7.67
	Change in Temperature (°C)	15.9	0.79	1.13	0.99	1.67
	Change in no. of Rainy days (%)	174.4	–0.87	–0.31	–1.86	–1.40
	Change in Consecutive Dry days (%)	45.9	2.01	–2.07	–0.28	–0.62
	Change in Consecutive Wet Days (%)	90.9	–8.85	–5.75	–1.52	–8.96
	Change in Warm Days (%)	36.9	7.65	10.30	8.51	14.31
3	Morang					
	Change in Precipitation (%)	2015 mm	2.88	3.53	2.12	6.49
	Change in Temperature (°C)	23.2	0.84	1.2	1.04	1.76
	Change in no. of Rainy days (%)	173.8	–0.75	–0.52	–1.97	–1.34
	Change in Consecutive Dry Days (%)	51.8	2.99	–0.66	–0.34	–4.86
	Change in Consecutive Wet Days (%)	92.8	–5.91	–2.75	–4.73	–10.71
	Change in Warm Days (%)	37.3	7.63	10.36	8.93	14.94
4	Panchthar					
	Change in Precipitation (%)	2235 mm	3.52	3.68	2.21	7.79
	Change in Temperature (°C)	14.3	0.77	1.11	0.98	1.64
	Change in no. of Rainy days (%)	193.3	–1.18	–0.24	–1.44	–0.78
	Change in Consecutive Dry Days (%)	40.4	4.09	–0.54	–2.68	–5.57
	Change in Consecutive Wet Days (%)	103.9	–5.02	–1.55	–4.66	–10.35
	Change in Warm Days (%)	37.4	8.13	11.40	9.94	16.00
5	Taplejung					
	Change in precipitation (%)	2607 mm	3.45	4.31	2.68	8.32
	Change in Temperature (°C)	2.5	0.84	1.19	1.04	1.74
	Change in no. of Rainy days (%)	224.6	–1.01	–0.18	–0.78	–0.06
	Change in Consecutive Dry Days (%)	31.5	3.80	2.16	–2.28	–6.26
	Change in Consecutive Wet Days (%)	129.4	–1.09	–1.41	–3.44	–7.26
	Change in Warm Days (%)	37	7.32	10.49	8.40	14.39

Source: MoFE, 2019.

2.2 Sampling and Data Collection

In this paper, the data collected by the Central Bureau of Statistics for the National Climate Change Impact Survey 2016 [22] has been used. This data from CBS is still pertinent in analyzing the factors contributing to the adoption of irrigation practices such as supplemental irrigation in the rain-fed production system of Nepal. The sample selection was carried out in three stages: in the first stage the districts were selected, in the second stage the Primary Sampling Unit (PSU), and in the final stage the households. This process was adopted for each of the 16 domains distinctly which were treated as a stratum. Independent samples in each stratum were selected. For sample selection, the Probability Proportional to Size (PPS) sampling technique was used in all stages, where the size measure adopted for each was the number of expected households in that district.

After selecting districts with 16 domains, a sample of PSUs was selected to represent each district. The number of PSUs chosen from each district was governed by dividing the number of households to be selected in each domain by 20, divided by the number of districts selected in that domain. The listing of the households was based on 45 years or older age of the potential respondents and living in that area for at least 25 years. Furthermore, large PSUs were sub-divided into a more convenient size and one of these sub-divided PSUs was carefully chosen to represent the whole PSU using PPS sampling. In addition, the PSUs with more than 500 households were subdivided into smaller units. A total of 253 PSUs were selected as a sample consisting of a sample of 5060 households.

Among the seven provinces of Nepal, this study is focused on Province No. 1 comprising 5 districts - one each from the Mountains (Taplejung) and Terai (Morang) and three from the hilly (Panchthar, Dhankuta, and Khotang) ecological region of Nepal. The Primary Sampling Unit (PSU) from 101-140 (representing Province No. 1) with a sample size of 800 households was considered as a sample size.

The data was collected by using a pre-tested questionnaire. The data included broad topics such as demography, socioeconomic aspects, knowledge and perception, climate-induced disasters and socioeconomic impacts, natural resources, and adaptation practices adopted by households to cope with adverse situations created due to changing climate. The data collection was primarily based on the memory recall method. The respondents provided information related to changes in temperature, precipitation, and seasonal shift in the last 25 years and on the impact of climate-induced disasters in the last 5 years.

2.3 Analytical Framework

Many adoption studies assume that farmers behave rationally whose goal is to maximize an unobserved expected utility function [23]. Farmers' adoption of climate change adaptation practices like supplemental irrigation is assumed to be based upon utility maximization. Farmers maximize the utility of the adoption of such practices than not adopting them. In other words, farmers adopt practices only when the utility they get from such practices is higher than the utility they get without adopting them. Although one cannot directly observe the utility farmers get, the decision of farmers to adopt can be observed. The utility function which motivates the farmers in deciding on adopting technology can be given as:

$$U_{i1} = \beta_1 X_i + \varepsilon_{i1} \tag{1}$$

$$U_{i0} = \beta_0 X_i + \varepsilon_{i0} \tag{2}$$

Equation (1) is for adoption whereas Equation (2) is for not adopting practice/technology. In the above equations, U_{i1} and U_{i0} represent perceived utilities from adoption and non-adoption, respectively. X_i is the vector of explanatory variables that are assumed to affect the perception of the household's utility. β_1 and β_0 are the parameters to be estimated and εi_1 and ε_{i0} are error terms with a zero mean.

If the i^{th} household makes a decision to adopt the practice/technology, the utility from the adoption is greater than the utility received from not adopting it, which can be described as:

$$U_{i1}(\beta_1 X_i + \varepsilon_{i1}) > U_{i0}(\beta_0 X_i + \varepsilon_{i0}) \tag{3}$$

Hence, the probability that the i^{th} household will adopt an adaptation practice can be defined as:

$$\begin{aligned} P(1) &= P(U_{i1} > U_{i0}) \\ P(1) &= P(\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0}) \\ P(1) &= P(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 X_i - \beta_0 X_i) \\ P(1) &= P(\varepsilon_i < \beta X_i) \\ P(1) &= \Psi(\beta X_i) \end{aligned} \tag{4}$$

where P is a probability function and U_{i1}, U_{i0} and X_i are as defined above. β is a vector of parameters that will be estimated by maximum likelihood. Ψ is a cumulative distribution function of the standard normal distribution.

As the values of the dependent variable are dichotomous (0, 1), the probit model is used. This model is used in several previous studies on irrigation technology adoption [24,25] as it permits the analysis of farmers' decisions between adoption and non-adoption, with a binary variable as a dependent variable. It is generated by a latent model in the form shown in the following equation:

$$\begin{aligned} &Y_i^* = \beta_i X_i + \varepsilon_i \quad \varepsilon_i \backsim N(0,1) \\ &Y_i = 1 \;\; if \; Y_i^* > 0 \\ &\quad\;\; 0 \;\; if \; Y_i^* \leq 0 \end{aligned} \tag{5}$$

where Y_i^* is a latent variable representing the i^{th} household's utility from adopting adaptation practice depends on a vector of characteristics, X_i. Y_i denotes an observable variable taking a value of 0 or 1.

2.4 Variables Used

Different types of variables related to demographic, socioeconomic, topographical and institutions affect the adoption of irrigation practices among farming households. Based on the previous studies and considering the context, the explanatory variables considered include gender, operational land holding, education, location of the farm, farming experience, proximity to the market, membership in community organizations, perception of the increase in temperature and decrease of winter precipitation and receiving remittance (Table 2).

The dependable variable (PracAdopt) is the adoption of supplemental irrigation practice by each household (a binary variable). The explanatory variables are related to socio-economic, demographic, institutional, and climate change perceptions.

$$\text{PracAdopt} = \beta_0 + \beta_1 \text{GENDER} + \beta_2 \text{EXPERI} + \beta_3 \text{EDUCATION} + \beta_4 \text{LANDHOLD} + \beta_5 \text{COMMUNORG} + \beta_6 \text{LOCATION} + \beta_7 \text{DISTANCE} + \beta_8 \text{TINSUMMER} + \beta_9 \text{PRECDEC} + \beta_{10} \text{REMIT} + \varepsilon_i$$

β_0 ... β_{10} are the parameters to be estimated, ε_i is the error term.

Table 2 presents the definition of variables used in this analysis. It shows that over three-fourths of the households are headed by males, on average the household head has 33 years of experience in farming, no. of years of formal education is 3 years, the distance of the household is 5.87 km from the motorable roads, and a farming household is having about 17 ropani① of operational landholding. Furthermore, 41% of the households have received membership in a community organization, 33% of the households are located in Terai, and 27% of households receive remittances. In terms of climate change perception, 86% of the households have perceived increasing summer temperatures while 77% of the households perceived decreasing winter precipitation. Only 26.7% of the households have used supplemental irrigation practices as a coping strategy/adaptation to climate change.

3. Results and Discussion

3.1 Descriptive Analysis

This section summarizes the percentage distribution of households under different categories of perceptions on changes in temperature and rainfall, facing droughts and the level of its impact over the last 25 years period, and adoption of supplemental irrigation practices. Such information is analyzed and described below:

3.1.1 Perceptions on Climatic Factors

It is revealed that around 50% of households have heard about climate change [22]. Households reported a significant change in summer and winter temperatures over the period of the last 25 years. The households' perception regarding the summer temperature shows that over three-fourths of the households perceived increasing temperature. This is the highest in Dhankuta district while lowest in Taplejung district. On the other hand, the majority of the households in Taplejung and Panchthar perceived no change in winter temperature while households in the other three districts perceived decreasing winter temperature (Table 3).

Table 2. Definition and summary statistics of variables.

Definition of Variables	Mean	Standard deviation
GENDER- Gender of the household head (1 for male and 0 otherwise)	0.78	0.41
EXPERI- No. of years of experience in farming	33.25	18.82
EDUCATION-No. of years of schooling of household head	3.00	3.94
LANDHOLD-Operated landholding (ropani)	16.87	19.72
COMMUNORG- Membership in community organization (1 for memebership, and 0 otherwise)	0.41	0.51
LOCATION- Ecological region (1 for the district in Terai, and 0 otherwise)	0.33	0.47
DISTANCE- Distance to motorable roads (km)	5.87	9.85
TINSUMMER- Perception about the increase in summer temperature (1 for increase, and 0 otherwise)	0.86	0.35
RECDEC- Perception about the decrease in winter precipitation (1 for decrease, and 0 otherwise)	0.77	0.42
REMIT-Household receiving remittance (1 for receiving household, and 0 otherwise)	0.27	0.44

Source: Authors' estimation.

① 1 ropani equals 508.74 square meter

Table 3. Perception of changes in temperature in the last 25 years period (% of households).

Districts	Summer Temperature			Winter Temperature		
	Increased	Decreased	No Change	Increased	Decreased	No Change
Taplejung	76.7	1.1	22.2	9.4	32.8	57.8
Panchthar	87.5	0.8	11.7	25.8	20.8	53.3
Morang	88.8	3.8	7.3	31.2	57.7	11.2
Dhankuta	92.5	0.0	7.5	27.5	55.0	17.5
Khotang	87.5	5.8	6.7	20.8	70.0	9.2

In case of changes in the monsoon and winter rainfall, households reported significant changes over the last 25 years. Most of the households in all districts (except Taplejung) perceived that monsoon is decreasing while there is a mixed perception among the households in Taplejung. Over two-thirds of the households in Taplejung perceived no change in winter rainfall while over 97% of households perceived decreasing winter rainfall in other districts (except Panchthar). In Panchthar, 57.5% of the households felt decreasing monsoon rainfall while 40.8% felt no change in winter rainfall (Table 4).

3.1.2 Drought Occurrence and Impacts

A significant number of households have been facing drought in the last 25 years. Over one-third of the households in Taplejung, all households in Dhankuta, and about 96-97% in other districts were experiencing drought (Table 5). Among the climate-induced disasters, most of the households incurred losses from drought in the last five years [19].

The distribution of households on the extent of drought in the last 25 years is given in Table 6. It is observed that extremely low response for drought was the highest in Morang district whereas extremely high response was in Panchthar district. In other districts, the majority of the response was from moderate to high.

3.1.3 Application of Supplemental Irrigation Practices

The households have used different supplemental irrigation practices as one of the coping strategies for climate change adaptation (Table 7). Overall, it is revealed that only about 27% of households have adopted this practice. Among the districts, the household adoption is the highest in Dhankuta (47.5%) followed by Taplejung (31.1%), Morang (24.2%), and Panchthar (15.8%). This is the lowest in Khotang (8.3%).

3.2 Factors Influencing Adoption of Supplemental Irrigation

The factors affecting the adoption of supplementation irrigation practices as a coping strategy for climate change are analyzed by using the probit model. The result of the analysis is presented in Table 8. The Likelihood Ratio Chi-square value was 126.10 indicating that the model fits very well with the data, that is, the probability of the null

Table 4. Perception of changes in rainfall in the last 25 years period (% of households).

	Monsoon rain			Winter rain		
Districts	Increased	Decreased	No Change	Increased	Decreased	No Change
Taplejung	31.1	38.3	30.6	1.1	32.2	66.7
Panchthar	5.0	78.3	16.7	1.7	57.5	40.8
Morang	1.9	95.8	2.3	0.8	96.5	2.7
Dhankuta	0.80	97.50	1.7	0.00	98.30	1.7
Khotang	11.7	85.8	2.5	0.8	97.5	1.7

Table 5. Households facing drought in the last 25 years period.

Districts	No. of households	Percentage
Taplejung (n = 180)	62	34.4
Panchthar (n = 120)	116	96.7
Morang (n = 260)	251	96.7
Dhankuta (n = 120)	120	100
Khotang (n = 120)	115	95.8

Table 6. The level of impact of drought in the last 25 years (%).

Districts	Extremely Low	Low	Moderate	High	Extremely High
Taplejung	7.5	20.8	33.3	23.3	15
Panchthar	7.5	20.8	33.3	23.3	15.0
Morang	38.1	23.2	25.2	13.3	0.2
Dhankuta	0.0	0.0	60.0	40.0	0.0
Khotang	3.3	11.7	47.5	34.2	3.3

Table 7. Households adopting supplemental irrigation practices.

Districts	No. of households	Percentage
Taplejung	56	31.1
Panchthar	19	15.8
Morang	63	24.2
Dhankuta	57	47.5
Khotang	10	8.3

hypothesis which states that the coefficients are equal to zero being correct is extremely low.

Out of ten variables estimated, 7 variables were statistically significant in explaining the adoption of supplemental irrigation. Most of the variables analyzed had the expected hypothesized signs. The results indicate that farmers' decisions to adopt climate change adaptation practices like supplemental irrigation are determined by some factors. It shows that farming experience, education, operational landholding size, and location were significant at a 1% significance level while the distance to motorable roads and membership in community-based organizations were significant at a 5% level. On the other hand, the perception of summer temperature increase was significant at the 10% level. Other variables such as gender, perception of the change in winter rainfall, and remittance were positive but not significant.

Several years of experience in farming have a positive effect on the adoption of practices as the household head's average experience is over 33 years. They are believed to have added skills and technical knowledge over time and therefore have a better position to adopt such practices. This is in harmony with the findings of the previous studies [26-28]. For a unit increase in farming experience, the likelihood of adoption of supplemental irrigation practices would increase by 0.74 percent.

Education is explained as the number of years spent in formal schooling positively influencing the adoption of supplemental irrigation. In this case, the average year of formal schooling is 3 years and over 25% of household heads are having 5 years and above of education. It can be said that as farmers spend more years in formal schooling, their understanding of the gains from the adoption of coping strategies like supplemental irrigation for climate adaptation enhances. In addition, more educated farmers have better access to information, respond to expected changes, and have the capacity to forecast future scenarios than uneducated or less educated ones. For a unit increase in education, the likelihood of adoption of supplemental irrigation practices would rise by 1.54 percent. This is consistent with the previous findings [29,30].

The size of the operational landholding significantly and positively affected the adoption decision as the household's average operation landholding is about 17 ropani. With one unit increase in the size of land holding, the likelihood of adoption of climate change adaptation practices would increase by 0.36%. This implies that the bigger the size of operational landholding, the higher the probability of adopting supplemental irrigation for adapting to climate change. Adopting supplemental irrigation practices such as constructing different types of ponds and application of water needs financial resources for procuring materials that are affordable to bigger farmers than the smaller ones.

The probability of adopting supplemental irrigation practice is higher for those households that have membership in community-based organizations (CBO) than the non-members. In this case, 41% of households have membership in CBOs and are involved in social learning. Through their participation, they learn more by sharing their experience and knowledge, also they may have the opportunity to observe the practices adopted by other members, which enhances their confidence. In addition, the farmers have the chance to see the adaptation options of other CBO members, which may improve their trust in adaptation strategies and increase adoption rates which is consistent with the findings of previous researchers [31,32]. The adoption would be higher by 8.46% for CBO members than the non-members.

The location of the household (ecological dummy) is also positive and significant which implies that the probability of adoption to households located in the Tarai (plain area) is higher (19.49%) than the households located in other ecological regions. This is because the farmers in Tarai have better physical access, access to information and communication, and technologies. On the other hand, the significant and positive coefficient of the distance of household to market suggests that the likelihood of adoption of supplemental irrigation practices would be higher for those households that are at a distance from the road heads than those near road heads. This is contrary to the findings of a previous study [33]. Usually, the households residing near road heads may have access to information and materials required for irrigation than the households in interior parts. However, there could be variations in the quality and nature of roads (fair-weather, graveled, and blacktopped) in Nepal, especially in the rural areas that may have some effect on adoption.

The dummy variable for households who have perceived increasing summer temperature (86% in this case) enhances the probability of adoption. This may be true because the households might have perceived the threat of increasing temperature with the anticipation of droughts and dry spells and adopting supplemental irrigation as a response to mitigate the likely effects. which is consistent with previous findings [34,35].

Table 8. Probit regression estimates.

Variables	Coefficient	Marginal effects[1]
GENDER	0.1806	0.0533
EXPERI	0.0242***	0.0074
EDUCATION	0.0502***	0.0154
LANDHOLD	0.0119***	0.0036
COMMUNORG	0.2710**	0.0846
LOCATION	0.5986***	0.1949
DISTANCE	0.0128**	0.0039
TINSUMMER	0.3025*	0.0852
PRECDEC	0.1308	0.0390
REMIT	0.1493	0.0469
CONSTANT	–2.8038***	

No. of observations = 800 Log likelihood = –400.5449

LR chi^2 (10) = 126.10, Prob > chi^2 = 0.0000

Pseudo R^2 = 0.1360, Predicted value of y = 0.2344

[1] Marginal effects refer to the partial derivatives of the expected value with respect to the vector of characteristics.

4. Conclusions and Policy Implications

This paper has analyzed the perceptions on climate change and identified the factors influencing the adoption of supplemental irrigation practice as an adaptation strategy among households.

In the study province, the average level of pre-monsoon precipitation is higher while the winter precipitation is lower than in other provinces. There is a spatial and temporal variation in precipitation and temperature changes across the province. Compared with the reference period, the precipitation would increase for all districts. However, it will be higher for the hills and mountains than in Terai. The temperature is projected to increase in the future. In addition, the number of rainy days will decrease while warm days will increase.

There was a variation in households' perceptions of temperature and rainfall. Most of the households perceived increasing summer temperature while there is no such response in the case of winter temperature. It either decreased or remained constant. The household perceived decreasing levels of both monsoon and winter rainfall. As the households have perceived these changes, they have also been affected by weather-related risks such as drought although its impact is not uniform across districts. The households have used different supplemental irrigation practices as one of the coping strategies for climate change. However, only about one-fourth of the households are adopting this practice and a wide variation was observed across districts. The adoption of supplemental irrigation practice is influenced by socio-economic, demographic, institutional, and climate-related variables.

The agricultural sector in Nepal would be affected immensely due to increasing temperatures, and erratic time and intensity of rainfall which may result in dry spells and droughts in the future. In this context, proper consideration needs to be given to such variables that are influential in making adoption decisions by the households while formulating policy. The policy and strategy should focus on enhancing the capacity of farmers through organizing different types of technical and managerial training on supplemental irrigation practices and their appropriateness to mitigate the impact of climate change. It is equally important to raise awareness about climate change and its impact on the agricultural sector through different media and campaigns, workshops, and publications. The significant effect of membership in community-based organizations implies strengthening such social networks to make them effective for sharing and exchanging knowledge and skills. Currently, the adoption level of supplemental irrigation practices is quite low in the province. In this regard, it is necessary to further carry out research and studies on the sustainable complementary practices for diverse commodities and ecosystems considering social, economic, and technical perspectives and devising support measures for different tiers of governments and private sectors for scaling up. As this practice also involves some financial investment, creating additional on-farm and off-farm income-generating opportunities is essential to mitigate the capital constraint, and improve physical access which demands further investment increment.

Author Contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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