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Impact of climate change on paddy-wheat production and the local adaptation practices by farmers of Bardiya, Nepal

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Abstract

In 2018, survey was carried out at 120 households of Motipur and Kalika villages of Bardiya district to assess the perception of climate change of farmers and documentation of adaptation practices of paddy and wheat production. Perception analysis revealed that majority of farmers experienced rise in temperature, decrease in monsoon rainfall, and increase in drought length and drought severity. Men Kendal test and Sen's slope was used analyze climatic trend of 33 years (1986-2018) where annual maximum temperature (0.039°C/year) and annual minimum temperature (0.020°C/year) were significantly increasing while annual rainfall had insignificantly decreasing trend (-0.75 mm/year). First difference regression model was used to analyze the relationship between crop yield and climate data of crop-growing period of 31 years (1986-2016). It revealed that the minimum temperature is significantly augmenting paddy production ($p<0.001$) while rise in maximum temperature is significantly inhibiting wheat production in Bardiya ($p<0.10$). Changing sowing/planting dates, use of improved varieties, using more chemical fertilizers and using pest management practices are locally adapted by farmer to cope with climate change. This study concludes that it is crucial to sensitize farmers about climate change impacts, its adaptation, extension of stress tolerant varieties, and climate smart practices to cope with climate change.

Key words: Climate Change, Adaptation, First difference

Introduction

Paddy and wheat are the major staple crop of Nepal. In Nepal, the yield of paddy and wheat is 3.506 ton/hac and 2.757 ton/hac respectively (MoAD, 2020). Similarly, in Bardiya, average yield of paddy and wheat is 4.211 ton/hac and 3.703 ton/hac respectively (MoAD, 2020). Mostly farmers are small land holders in Nepal, almost 67% of arable landholding are less than 1 hac (CBS, 2013). Smallholder farmer are most vulnerable to climate change as smallholder farmer have low adaptive capacity to changing climate (Regmi, Paudyal, and Bordoni, 2009).

Climate is the most important factor affecting the production and productivity of agrarian communities (Lybbert and Sumner, 2012). In the last decade, visible impact was seen on agriculture due to consistent warming and rise in global temperature whereas the vulnerability is higher in high altitude as compared to low altitude (Karki and Gurung, 2012). The climate change shows physical effects including crop and livestock yield along with potential economic changes in yield. The positive and negative impacts of climate change have been seen in agriculture production but the impact varies globally (Aydinalp and Cresser, 2008). The developing and least developed countries are more vulnerable to climate change, their livelihood mostly depends on agriculture production and their low per capita income resist them to sustain variability (Barrios, Ouattara, and Strobl, 2008; Lybbert and Sumner, 2012).

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The rising temperature along with precipitation has already affected the country's agricultural production affecting the food security and livelihood (Pokhrel and Pandey, 2011). Variability in hydrological parameters like rainfall and temperature mainly used for characterization of climate change (Sharma, Panda, Pradhan, Singh, and Kawamura, 2016). In Nepal the issue of climate change prevails due to increasing stress in water resources and other climate sensitive resources which affects agricultural production, food security and rural livelihood (Khanal, 2009). According to a report of the Department of Hydrology and Metrology, Nepal, a climatic trend analysis of forty-three years (1971-2014) showed that annual maximum temperature has positive significant trend while minimum temperature and precipitation has positive insignificant trend (DHM, 2017).

The variation in maximum temperature and rainfall signifies there impact on yield of paddy. Increase of maximum temperature increases the paddy production in Hilly regions while in plains (*Terai*) increase of maximum temperature decreases paddy yield (Adhikari, Devkota, and Phuyal, 2017). The adverse climate change results in extinction of local landraces of paddy varieties, local wheat and maize varieties along with other agricultural crops (Paudel, 2013). Increase in temperature and precipitation has decreased yield of wheat (Poudel and Shaw, 2016; Thapa-Parajuli and Devkota, 2016) while another research (Devkota and Phuyal, 2015) shows that rainfall has non-significant impact on wheat yield. With increase in maximum temperature, increase in precipitation reduces net revenue and wheat yield whereas increase in average and minimum temperature, precipitation increases wheat yields as well as revenue (Devkota and Phuyal, 2015). The effective adaptation measures like heat and drought tolerant varieties along with irrigation and soil conservation plans and dissemination of adequate strategies against climate change knowing farmers education, experience, land tenure land holding is very important (Abid, Scheffran, Schneider, and Ashfaq, 2015; Howden et al., 2007).

Most importantly, temperature and rainfall variations have greatly affecting cereal production in Nepal. However, climate change impact analysis and documentation of farmer's adaptation practices on cereals production for Bardiya district is very low. Thus, this study aims to analyze farmer's perception, trends of climate change, the impact of climate change in paddy and wheat production and documentation of adaptation measures of local farmers in paddy and wheat farming.

Methods

Study Area

The research area is purposively selected which is rain-fed Terai region and located the western part of Nepal. Motipur is located at 28°11′643″ N and 81°26′229″ E and Kalika is located at 28°15′578″ N and 81°32′244″ E village of Bardiya district shown in Figure 1.

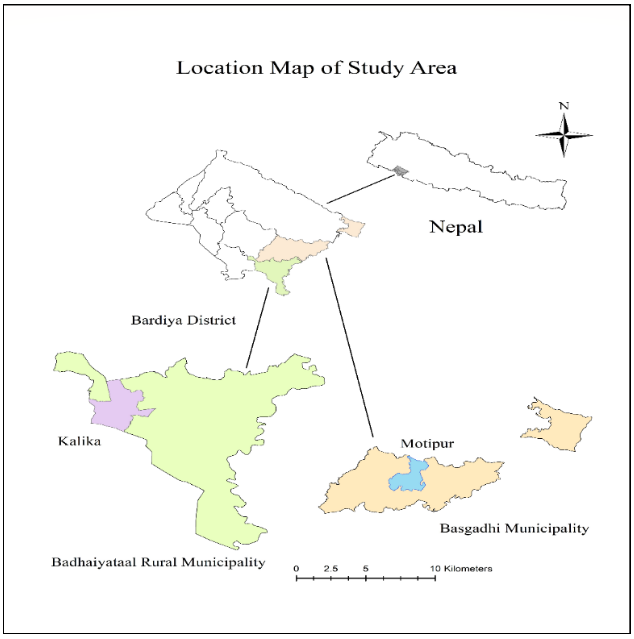

Figure 1. Study area of Bardiya District

Data collection and analysis

The data was collected from primary and secondary sources. Semi structured questionnaires were prepared and administered for data collection through household survey, focus group discussion and key informant survey. Pretesting of the questionnaire was done by interviewing ten respondents near the study area and some necessary adjustments were made. Household survey was conducted in May, 2018. Altogether 120 households were randomly selected from paddy and wheat growing farming communities of the Bardiya district. For primary data collection, different RRA (Rapid Rural Appraisal) tools such as key informant survey focal group discussion, crop calendar, and direct field observation. Mainly two focal group discussions and three key informant interviews were conducted to crosscheck and generate more information of farmer's experiences and perceptions, problems in paddy and wheat production, their indigenous knowledge and different adaptation measures adopted. Moreover, local people of age above 30 years were selected in sampling because young respondents would not have more years of experience to properly distinguish climate change.

Secondary data was collected from different sources including climate data temperature and rainfall data from Central Bureau of Statistics (CSB), Ministry of Agriculture and Development (MoAD) website and Department of Hydrology and Meteorology (DHM).

For household data analysis, R software was used for descriptive tools like frequency counting, average, standard deviation, percentage, etc. The descriptive statistics was used to describe the respondents' socioeconomic characters. Regression analysis was used to understand the relation among the independent variables and dependent variable. Secondary data were used for prediction and forecasting using regression.

Monthly data showing temperature and rainfall of a nearby station (Ranijharuwa station) for Bardiya district was collected for the period of 33 years (1986-2018 AD) from DHM were taken as independent variables. Average temperature and rainfall data during paddy and wheat growing period was taken into account and yield of the same period was assumed as annual yield of the Bardiya district. The paddy and wheat production data were collected for the period of 30 years (1986-2016) from Ministry of Agriculture and Development (MOAD) (Annex 1).

Annex 1. Data of climatic parameters (Ranijharuwa Station, Bardiya) and yields of paddy and wheat (Bardiya)

Year	Annual average maximum temperature (^{O}C)	Annual average minimum temperature (^{O}C)	Annual total Rainfall (mm)	Paddy Yield (Mt)	Wheat Yield (Mt)
1986	30.5	17.5	1385.5	2.28	1.5
1987	31.6	17.9	1222.2	2.1	1.5
1988	31.6	18.2	1848.7	2.3	1.5
1989	30.6	17.6	1559.4	2.49	1.6
1990	30.4	18.6	1667.7	2.5	1.6
1991	31.0	18.1	879.1	2.37	1.4
1992	31.0	17.5	1139.3	1.95	1.4
1993	30.6	17.8	1241.7	2.85	1.5
1994	31.6	17.8	568.9	2.54	1.6
1995	31.4	18.3	1772.1	2.48	1.5
1996	30.9	18.3	1414.4	2.53	1.7
1997	29.9	17.7	1630.2	2.4	1.7
1998	30.4	18.8	1624.4	2.65	1.9
1999	30.6	17.8	1400.1	2.74	2.2
2000	30.4	17.7	1259.7	3.02	2.3
2001	31.1	17.8	1329.7	3.12	1.8
2002	31.2	18.0	1223.4	3.01	2.3
2003	30.6	17.3	1287	3.12	2.5
2004	30.8	18.3	830	3.12	2.4
2005	31.4	17.8	1195.2	3.24	2.4
2006	31.2	17.8	716.4	2.9	2.6
2007	30.6	18.8	1649.8	3.18	2.8
2008	31.5	17.6	1270.2	3.2	2.5
2009	32.8	17.5	1172.1	3.21	2.6
2010	32.5	18.4	929.5	3.5	2.8
2011	32.3	20.2	998.9	4.15	2.9
2012	33.0	20.8	1526.45	3.55	3.2
2013	32.8	20.5	1988.6	3.838	3.7
2014	32.5	20.4	1369.3	4.227	3.9
2015	31.2	17.6	1160.91	3.577	3.5
2016	32.0	19.0	1082.6	4.056	3.7
2017	31.3	18.4	1450.1		
2018	30.6	17.8	1058.9		

Mann-Kendall (MK) test

For non-parametric trend, analysis of climatic variables Mann-Kendall test is widely used (Khatiwada et al., 2016; Patle et al., 2016).

Major advantage of using Mann-Kendall test in trend analysis is it helps to find out whether the trend has significant or non-significant difference. Here, the null hypothesis assumes that there is no significant trend difference of parameters whereas alternative hypothesis assumes that there is a significant trend (Kendall, 1948).

The standard test statistic Z_{mk} is calculated as follows:

The standard test statistic Z_{mk} is calculated as in equation 1.

$$z = \begin{cases} \frac{S-1}{\sigma} \text{ for } S > 0 \\ \frac{S+1}{\sigma} \text{ for } S < 0 \\ 0 \text{ for } S = 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where the value of Z is the Mann-Kendall test statistics that follow the standard normal distribution with a mean of zero and a variance of one. Thus, in a two-sided trend test, the null hypothesis H_O is accepted if $-Z_{1-\alpha/2} \leq Z_{mk} \leq Z_{1-\alpha/2}$, where α is the level of significance that indicates the trend strength.

Sen's slope estimator test

Similarly, the trend was quantified using Sen's slope method. Sen's slope is another index to quantify the trend using the non-parametric procedure developed by Sen in 1968 (Sen, 1968). The slope is computed using equation 2;

$$Q_i = \frac{x_j - x_k}{j - k} \quad \dots\dots\dots\dots\dots\dots(2)$$

Where x_j and x_k are data values at time j and k (j>k), respectively. The median of these N values of Q_i is Sen's estimator of slope.

Sen's estimator is computed using equation 3;

$$Q_{med} = \begin{cases} Q\dfrac{N+1}{2} \; if\ N\ is\ odd \\ \dfrac{1}{2}\left\{Q\left(\dfrac{N}{2}\right) + Q\left(\dfrac{N+2}{2}\right)\right\} \; if\ N\ is\ even \end{cases} \quad \dots\dots(3)$$

Finally, Q_{med} is tested by a two-sided test at a 100% $(1-\alpha)$ confidence interval, and the true slope is obtained.

Box and Whisker Plot analysis

Box and whisker plot provides summary of data in graphical way including median, quartile range and outer range (Banacos, 2011). Box contains median at the center, upper part of the box is upper quartile and lower part of the box is lower quartile. Whisker are the two lines extended from the box which indicates minimum and maximum values of the data set. Longer box and whisker indicates the high variations in data. Short box and whisker indicates the low variations in data (Banacos, 2011).

Regression analysis

For regression analysis, the dependent variable is paddy yield/wheat yield while independent variables are rainfall, maximum temperature and minimum temperature of growing period from 1986-2016. Here, paddy-growing period is June to November and wheat-growing period is November to March for Bardiya. First difference method for detrending is used for regression analysis (Joshi, Maharjan, and Piya, 2011; Lobell and Field, 2007). Here first difference method of crop yield and climatic variables was done. Then regression analysis is computed using equation 4;

$$\Delta Y = \alpha_1 \Delta R + \alpha_2 \Delta T_{max} + \alpha_3 \Delta T_{min} \dots\dots\dots\dots..(4)$$

Here, ΔY is the change in crop yield, ΔR is the change in rainfall, ΔT_{max} is the change in maximum temperature, ΔT_{min} is the change in minimum temperature while α_1, α_2, α_3 are the coefficient of rainfall, maximum temperature and minimum temperature.

Result and discussion

Perception on climate change

The descriptive analysis for climate change perception indicated that about 40% farmers responded the cause of climate change was due to human activities (Figure 2), while 25% responded it's due to natural. Similarly, 25% of farmers believed that climate changed occurred due to both natural as well as human activities. However, 10% of farmers did not have any idea about the cause of climate change.

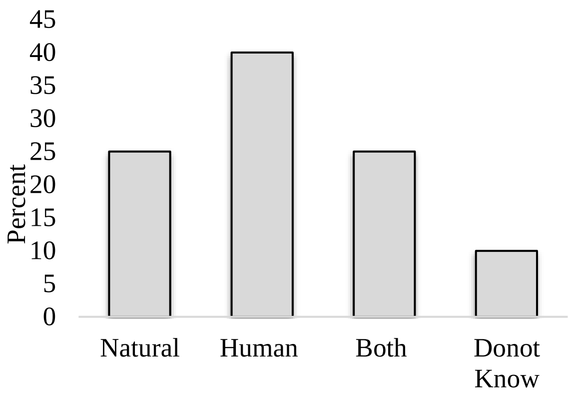

Figure 2. Perception on cause of climate change

Perception on climate conditions

The descriptive analysis regarding perception on different climatic parameters showed different respond from respondents. All the respondent agreed that temperature is increasing, and they experienced increased level of temperature in their locality (Table 1). About 95% of farmers perceived that monsoon rainfall is decreasing. Similarly, 95% of farmers experienced increased drought length (number of drought days) and 90% of farmers responded that drought frequency is increasing.

Table 1. Perception on Climatic Condition (%)

Type of weather	Increase	Decrease	No change	Don't know
Temperature	100.00	0.00	00.00	0.00
Monsoon rainfall	0.00	95.00	5.00	0.00
Drought length	95.00	0.00	5.00	0.00
Drought frequency	90.00	0.00	10.00	0.00

Varietal adaptation

Among identified varieties, farmers were growing 22 and 17 different paddy varieties in Motipur and Kalika respectively. About 78% and 71% of paddy varieties in Motipur and Kalika were long duration paddy varieties respectively. Similarly, about 73% and 76% of paddy varieties in Motipur and Kalika were high water requiring paddy varieties.

Among identified varieties, farmers were growing 4 and 8 different wheat varieties in Motipur and Kalika respectively (Table 2). In some cases, name of paddy and wheat varieties were not distinguished by the respondents (Annex 2).

Annex 2. List of varieties under different parameters

Parameters	Motipur	Kalika
No of rice varieties	23*	18*
Short duration varieties	*Radha 4, Sukkha 2, Sukkha 3, Ganga kabeyri, Krangi, Saurav*	*Sukkha 2, Sukkha 3, Sukkha 5, Radha 4, Suprime sona*
Long duration varieties	*Sahba sub 1, Swarna Mansuli, Hybrid 6444, Bahuguni 1, Hybrid 606, Sabitri, Saurav, Hybrid 612, Hybrid 2245, Sundaram, Mahendra 606, Sarju 52, Hybrid idea, Anadi, Ram dhan, Sahba mansuli,*	*Swarna sab 1, Hybrid 6444, Surbi, Sahba mansuli, Anadi, Goraknath, Annapurna, US 312, Ram dhan, Sabitri, Radha 9, Bahuguni 1*
Low water needed	*Sukkha 2, Sukkha 3, Ganga kabeyri, Krangi*	*Sukkha 2, Sukkha 3, Sukkha 5*
Medium water needed	*Radha 4, Saurav*	*Radha 4*
High water needed	*Sahba sub 1, Swarna mansuli, hybrid 6444, Bahuguni 1, Hybrid 606, Sabitri, Hybrid 612, Hybrid 2245, Sundaram, Mahendra 606, Sarju 52, Hybrid idea, Anadi, Ram dhan, Sahba mansuli,*	*Swarna sab1, Hybrid 6444, Suprime sona, Surbi, Sahba mansuli, anadi, Goraknath, Annapurna, US 312, Ram dhan, sabitri, Radha 9, Bahuguni 1*
No of wheat varieties	5*	9*
Name of wheat variety	*Bijaya, Gautam, Banganga, Adithya, Unidentified variety*	*Bijya, Gautam, Rohini, Barnganga, Aditya, Bhirkuti, NL 971, Tilotama, Unidentified variety*

* indicate it includes unidentified variety

Table 2. Details of varietal adaptation (of identified varieties)

	Motipur		**Kalika**	
	Count	**Percentage**	**Count**	**Percentage**
No of paddy variety	22		17	
Short duration	6	27%	5	29%
Long duration	17	78%	12	71%
Low water needed	4	18%	3	18%
Medium water needed	2	9%	1	6%
High water needed	17	73%	13	76%
No of Wheat Variety	4		8	

Problem analysis in paddy and wheat cultivation

Late onset of monsoon leading to delayed transplanting of paddy was the major problem in Bardiya. The other important problems were inability to set seed bed on time, weed, pest and disease problem, post monsoon rainfall during harvesting, unavailability of fertilizers on time and flood and hailstorm during crop period (Table 3). Major problem in wheat cultivation was the unavailability of irrigation facilities on time, followed by diseases and pests outbreak and pre-monsoon rainfall. The study area is rain fed area where most of the available water resources get dried and farmers depend on uplifted water for irrigation. Pre monsoon rainfall affects ripening and harvesting of wheat. Post-harvest preservation/storage and unavailability of fertilizer on time are other problems in wheat cultivation (Table 4).

Table 3. Problem in paddy cultivation

Problem in paddy cultivation	**Weighted Score**	**Rank**
Unable to transplanting seedling on time (due to delay in rainfall)	10	1
Unable to set seed bed on time (due to delay in rainfall)	8	2
Problems of weeds, pest and disease	5	3
Rainfall during harvesting	4	4
Unavailability of fertilizers on time	2	5
Flood and Hailstorm	0	6

Table 4. Problem in wheat cultivation

Problem in wheat cultivation	Weighted Score	Rank
Unavailability of irrigation facilities on time	8	1
Incidence of diseases and pest	6	2
Pre monsoon rainfall damage	4	3
Post-harvest preservation/storage	2	4
Unavailability of fertilizer on time	0	5

Trend analysis

Box and Whisker plot analysis

For Box and Whisker plot analysis, data of rainfall, maximum temperature and minimum temperature from 1986 to 2018 was used. Box and Whisker plot showed the maximum amount of rainfall occur in July, August and June with higher variation in rainfall amount; as length of box and whisker is long compared to other as shown in Figure 3. June, July and August lie on vegetative growth period of paddy. Higher variation in this period can significantly affect the growth of paddy subsequently will reduce productivity of paddy (Karna, 2014). Similarly, plot showed low amount of rainfall in November, December and March with low variation in rainfall amount; as length of box and whisker is small compared to other months. Maximum temperature plots showed that the gradual increase of maximum temperature from January to May as shown in Figure 4. May is the hottest amongst the other months in the studied area. Length of box seems to be more or less same in all months while length of Whisker is long in January.

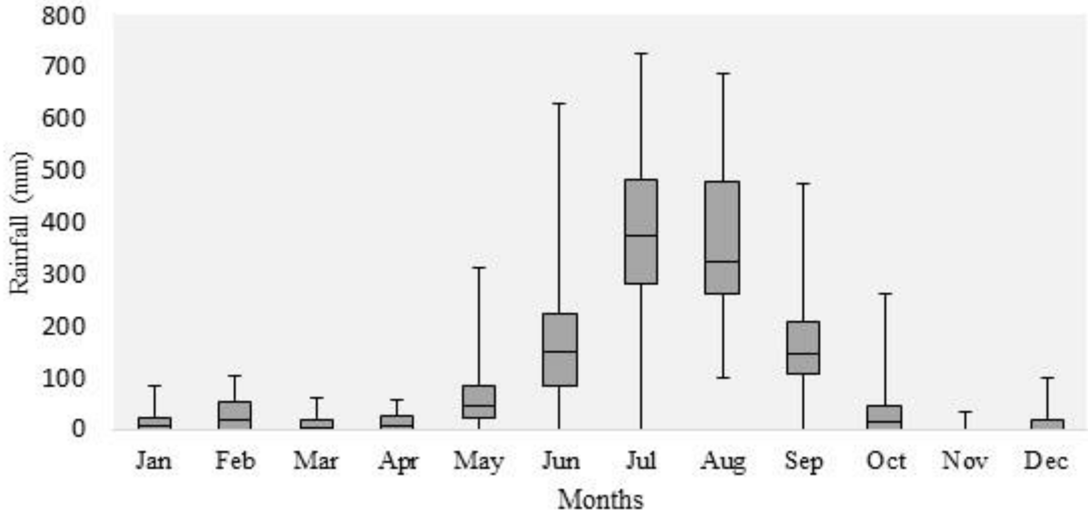

Figure 3. Box and Whisker plot of the monthly rainfall (mm) from 1986 to 2018 of Bardiya

Minimum temperature plots showed that there was a gradual increase of minimum temperature from January to July as shown in Figure 5. The minimum temperature was highest in and lowest in January. Length of box was long in February and March while short in August and September. Similarly, length of Whisker is long in August and October.

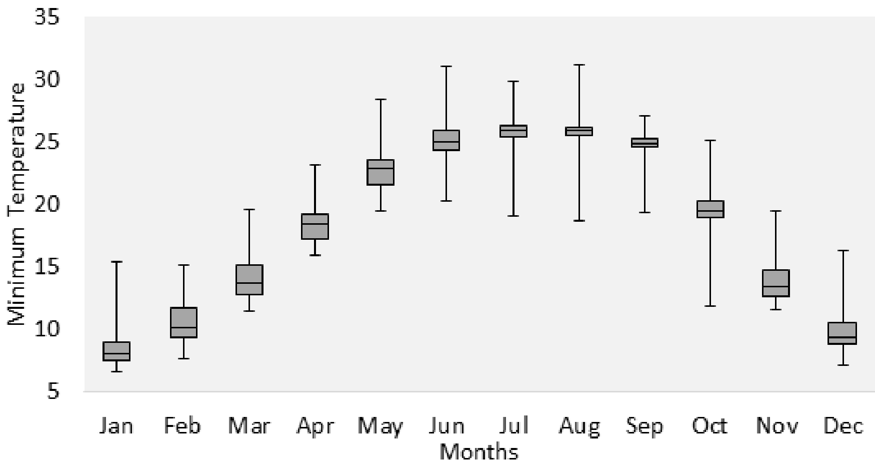

Figure 4. Box and Whisker plot of the monthly maximum temperature (°C) from 1986 to 2018 of Bardiya

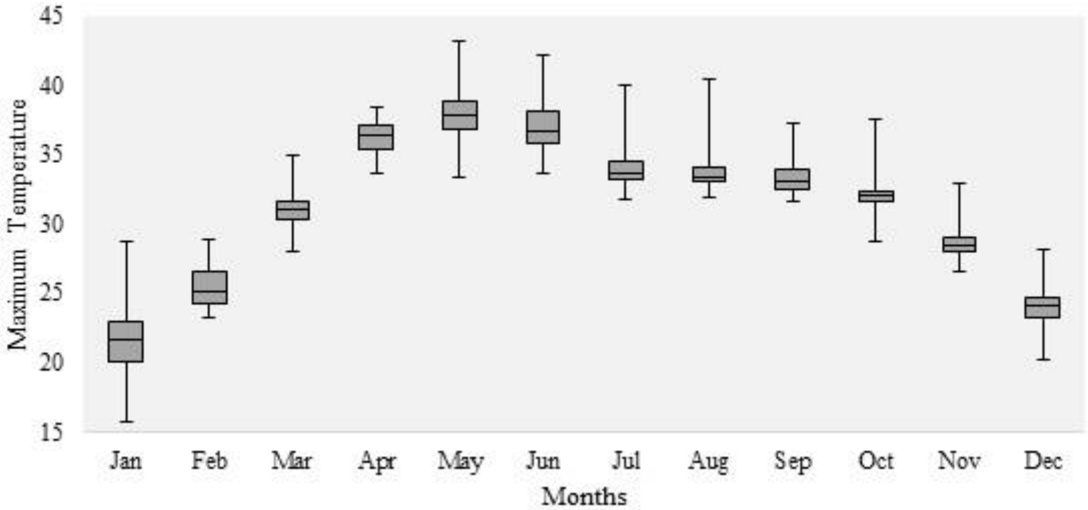

Figure 5. Box and Whisker plot of the monthly minimum temperature (°C) from 1986 to 2018 of Bardiya

Mann Kendall's and Sen's Slope analysis

Temperate and rainfall data had non normal distribution. Thus for non-normal data distribution, non-parametric trend analysis was used. Mann Kendall's and Sen's slope was used to know trend of annual maximum temperature, annual minimum temperature and annual rainfall Bardiya district. The result showed that annual maximum temperature and annual minimum temperature has significantly positive trend in 5% and 10% level of significance respectively as shown in Table 5. This indicates that annual maximum temperature and annual minimum temperature were significantly increasing at the rate of 0.039°C/year and 0.020°C/year. Whereas all Nepal annual maximum temperature is significantly increasing at the rate of 0.056°C/year and all Nepal minimum temperature is significantly increasing at the rate of 0.002°C/year for the period of 1971 to 2014 (DHM, 2017). Moreover, annual rainfall has no significant negative trend. Which indicates that annual rainfall is decreasing at 0.75 mm/year. Terai regions of Nepal have shown insignificant positive trend in all season expect in post monsoon (DHM, 2017).

Regression Analysis

Three climatic variables of effective growing period (months) were used in regression analysis; rainfall, minimum temperature and average maximum temperature. Climate change has an impact on yield of paddy and wheat as seen in table 6.

Regression analysis of Paddy

Regression model suggest that the model is able to define the variation in the yield of paddy by 40%. In other words, 40% of variation in paddy yield is due to maximum temperature, minimum temperature and rainfall. Change in minimum temperature had significant positive relationship with change in paddy yield at 1% level of significance. One unit increase in minimum temperature has increased paddy yield by 183 Kg/Ha. This result is in contrast with (Ladha et al., 2003) which explains decrease in radiation and increase in minimum temperature has negative relation with paddy yield as due to decreased photosynthesis. Whereas (Chen, Chen, and Xu, 2014) study shows increase in minimum temperature at vegetative phase has positive relation with paddy yield. Furthermore, change in maximum temperature and change in rainfall has no significant relationship with change in paddy yield (Table 6).

Regression analysis of wheat

Regression model suggest that the model is able to define the variation in the yield of wheat by 23%. In other words, 23% of variation in wheat yield is due to maximum temperature, minimum temperature and rainfall. Change in maximum temperature had significant negative relationship with change in wheat yield at 10% level of significance. Where, one unit increase in maximum temperature has decreased wheat yield by 77.62 Kg/Ha. This might be due to high temperature during grain filling. Temperature during grain filling stage of wheat is most critical (Asseng, FOSTER, and Turner, 2011). Maximum temperature for grain filling stage is 34ºC. Similarly in Bardiya, grain-filling stage of wheat falls nearly in between February to March. Extreme maximum temperature from February to March goes up from 30 to 36 ºC (Figure 4). Effect of increasing heat stress has negative relation on various metabolic reactions and photosynthesis process (Farooq, Bramley, Palta, and Siddique, 2011; Mathur, Agrawal, and Jajoo, 2014).

Likewise, change in minimum temperature and change in rainfall has no significant relationship with change in wheat yield (Table 6).

Table 5. Trend analysis of climatic factors (from 1986 to 2018)

Climatic factors	Linear trend	Mann-Kendall (Z)	Sen's Slope
Annual Maximum temperature	0.040	2.36**	0.039
Annual Minimum temperature	0.041	1.74*	0.020
Annual Rainfall	-0.407	-1.35	-0.757

*and** indicates significance levels at 10% and 5% respectively.

Table 6. Relationship of paddy and wheat yield with climatic variables

Variables	**Paddy**		**Wheat**	
	Coefficient	**P value**	**Coefficient**	**P value**
Rainfall	-0.828	0.331	-4.531	0.183
Minimum temperature	182.512	0.001***	-30.350	0.425
Maximum temperature	-133.173	0.113	-77.628	0.064*
R sq.	39.8		22.6	
Change of yield	1776		2224	

1 % level of significance- ***, 5 % level of significance-**, 10 % level of significance- *

Climate change adaptation practices

Major problems faced by farmers for crop production are loss of production, low water availability/drought, disease and insect outbreak, and weed infestation as shown in Table 7. To minimize the loss of crop production, farmers have autonomously started adapting high yielding paddy and wheat varieties. Majority of the farmers are using improved and hybrid seeds of paddy and wheat. Use of chemical fertilizer has increased especially in paddy and wheat with subsequently low use of FYM/Compost. Low use of FYM/Compost is due to a smaller number of cattle's and buffalo in household. Generally, farmers prefer hand weeding to chemicals for weed.

As study area is rainfed, farmers unconventionally started changing sowing/transplanting date of paddy to manage water availability/drought making, farmers to grow different drought tolerant varieties. In paddy, *Sukkha* series are popular among farmers especially *Sukkha 2*, *Sukkha* 3, *Sukkha* 5. Some farmers use electric motor pumps for nursery bed preparation in paddy, watering during field preparation of cereals and watering during different growth stages of wheat. But the luxury of using electric motor pumps are only limited to rich farmers. Farmers are aware of removing disease part or pest during field inspection/monitoring, using chemical fungicides and pesticides, using IPM techniques and botanical pesticides.

To lower down moisture in cereals grains, farmers are adapting cheapest methods of properly drying of paddy and wheat before storing. Farmers use neem leaves to mix it with grains and store in metal bin, super bags and earthen bins (in Tharu community). However, some of the farmers use chemicals like *chelphos* (Aluminium Phosphide powder) during storing grains in bins and bags.

Table 7. Adaptation practices by the paddy and wheat-growing farmers

Problems	**Adaptation practices**
Loss of crop production	• Adaptation of high yielding varieties • Weed infestation- Hand Weeding • Use of more chemical fertilizer • Use of less FYM/Compost on paddy, wheat field
Low water availability/Drought	• Sowing/transplanting after rainfall (shifting the time of sowing/transplanting) • Drought tolerant varieties • Use of electric motor pumps (use is limited to rich farmers)
Disease and insect pest attack	• Removing of diseased or pest attacked plants/parts • Spraying chemical fungicides and pesticides, • IPM practices; Botanical pesticides

Store grain and pest	• Proper drying, • Storing in *dekari* (soil structure made to store grain in Tharu community)/metal bin, super bag (plastic bags) • Mixing neem leaves, *chelphos*

Conclusion

Rain-fed agriculture, covering most of the crop production in Nepal, which is highly vulnerable to climate change. Hence, with the objectives to assess the climate change perceptions of farmers and to investigate prevailing local adaptation practices of paddy and wheat production was carried out at 120 households of Motipur and Kalika; village in Bardiya district.

There are more numbers of varieties in paddy than wheat. Majority of varieties in paddy were long duration and more water requiring.

Delay in transplanting of paddy, delay of seed bed preparation, problem of weeds, pest and disease, rainfall during harvesting, unavailability of fertilizers on time, and flood and hailstorm are the problems present in paddy cultivation.

Unavailability of irrigation facilities, incidence of disease and pest, pre monsoon rainfall, post-harvest preservation/storage and unavailability of fertilizer are the problems prevalent in wheat cultivation.

The descriptive analysis revealed that most farmers believed the cause of climate change is human activities. Farmers perceived increase in temperature, decrease in rainfall and increase in drought length and drought frequency in recent years.

Analysis of month-to-month basis of climatic data from 1986 to 2018 showed that July recorded the highest rainfall with the highest variation of rainfall. Similarly, May recorded the highest maximum temperature where January has the highest variation in temperature. Likewise, the highest minimum temperature with the highest variation was in August. On trend analysis, Mann-Kendall test indicated significant increase in annual maximum temperature (by 0.039 ºC/yr) and annual minimum temperature (0.020 ºC/yr) while test showed negative non-significant trend in rainfall (-0.757 mm/yr). Trend analysis revealed in line with farmer's perception of increasing temperature, rainfall variability and increase in drought.

Regression analysis of paddy and wheat yield with climatic variables (rainfall, minimum temperature and maximum temperature) was conducted and result suggested that minimum temperature has positive significant relation with paddy yield. This means that increase in optimum minimum temperature will increase paddy production in Bardiya district. Likewise, the maximum temperature has negative significant relation with wheat yield. This means that increase in maximum temperature will decrease in wheat yield.

Relating Men Kendal's test and Sen's slope with regression analysis shows that there is significant increase in minimum temperature which is favoring paddy production in Bardiya district. Whereas, significant increase in maximum temperature is reducing wheat yield. Thus selecting varieties which are heat tolerant will help farmers to obtain better wheat yield.

To cope the impact of climate change, farmers are adopting different activities in response to the changing climate. Similarly, farmers are adopting high yield varieties, hand weeding, and application of more chemical fertilizer to increase crop production against climate change effect. To cope with water scarcity, they are adopting drought tolerant varieties, sifting of transplanting to appropriate time and use of electric motors for nursery bed preparation in paddy. In response to insect and disease attack, farmers rely on chemical methods rather than ethnobotanical practices. Properly drying under sun, storing in metal bin/*dekari*/super bag, mixing neem leaves or using chemicals, as *chelphos* (Aluminium Phosphide powder) were adaption practices of farmers.

Further research should focus on documenting and testing ethnic practices related to climate change. Extension services related to the promotion of heat tolerant varieties of wheat should be formulated and implemented in the area. Similarly, in depth analysis of climate change impact should be studied in case of Bardiya to see impact in agriculture production and program should be designed and implemented respectively.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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