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Research article

EFFECT OF PRECIPITATION AND TEMPERATURE VARIATION ON THE YIELD OF MAJOR CEREALS IN DADELDHURA DISTRICT OF FAR WESTERN DEVELOPMENT REGION, NEPAL

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ABSTRACT: This study examines the effect of precipitation and temperature variation on the yield of major cereals (e.g., rice, wheat, maize, millet and barley) in Dadeldhura district of Nepal. I use the time series information of yield and seasonal meteorological data (e.g., precipitation and temperature) to assess the effect using the exponential growth regression methods. The findings of this study confirm that maximum temperature and minimum precipitation have had adverse effects on the yield of rice and maize. Temperature is statistically significant for the yield of all cereals whereas precipitation is statistically significant for the yield of maize and barley. Finally, precipitation and temperature have a statistically significant effect on rice and maize yield. Nonetheless, the influence of maximum temperature and minimum precipitation plays an important role in the growth of major cereals in Nepal. The low rainfall and high temperature during the crops growing seasons has severely affected the yield of major cereals in Dadeldhura district. 1979, 1980, 1982 and 1987 are the major agriculture drought years in Dadeldhura district of far western development region, Nepal.
Key Words: Precipitation, temperature, yield, Dadeldhura, Nepal.

INTRODUCTION

Temperature and precipitation are the two most important aspects of climatic variation in Nepal. Temperature has been an important climatic factor determining the cropping pattern and quality of products in the country. The seasonal and spatial variation of temperature and rainfall, to a great extent, regulates the agricultural activities in the country. As most of the farmers have to depend on suitable weather conditions to commence their farm activity, seasonal variation in climate has remarkable implication in the sustainability in the Nepalese agriculture.

In Nepal, the average temperature has increased by 1.8^0C during the last 32 years. In Nepal, the average temperature increase was recorded as 0.06^0C per year and that in Terai and Himalayas was 0.04^0C and 0.08^0C per year respectively. Precipitation is the most important climatic element for agriculture development and hydrology. The average precipitation in the country is 1768 mm, but varies greatly from place to place owing to sharp topographical variation. Eastern parts of the country receives an increasing amount of rainfall in the summer monsoon whereas reverse is true for winter precipitation depending on the location.

In general, temperature will reduce yields and quality of food-crops thereby exacerbating vulnerability in food supply. Similarly, changes in precipitation patterns i.e., intensive rain concentrated in a particular month has a devastating effect on crop production [1, 2, 25]. Except for paddy, which has high water demand and thrives on water logging condition, other summer crops are adversely affected by increase in rainfall and maximum temperature [18].

Despite such a high degree of vulnerability to climate change for agriculture welfare in developing countries, there are limited researches conducted in case of developing countries [7, 15, 35, 26] and very few in the case of Nepal [24]. The vast majority of such researches are done in developed countries [19, 10, 17, 12, 20, 34]. There are very limited literatures in the case of developing countries, which are going to be adversely affected by predicted climate change [16, 17, 20, 34, 31, 12].

Monsoon precipitation coinciding with snowmelt in the mountains could lead to floods during rainy seasons damaging not only agriculture and livestock but also the livelihoods of many people. All this would culminate to decreased crop yield and lower livestock productivity which if uncompensated by rising imports may threaten even the food security concerns. Due to climate change and the rising temperatures, Nepal could face drier phases during dry seasons with wetter monsoon (as much as three times the current level of rainfall) with chances of flooding and landslides during rainy seasons with subsequent impacts on agriculture and livelihoods [3].

Agricultural drought is defined as a reduction in moisture availability below the optimum level required by a crop during different stages of its growth cycle, resulting in impaired growth and reduced yields. Most of the country is in the grip of drought from the end of March to when the monsoon arrives in June. Deficient rainfall in the winter of 2008 resulted in a severe drop in crop production right across the country. Wheat and barley production declined 14 and 17 percent respectively. In some districts of Mid- and Far-Western Nepal which received less than half of average rainfall from November 2008 to February 2009 report that crops yields declined by more than half. Drought results in crop failures and famine, both during the monsoon season and during the rest of the year, when winter crops are sown. In fact, Nepal's Ministry of Agriculture and Cooperatives (MoAC) has identified drought as the greatest risk to agriculture [27], particularly as year-round irrigation facilities supply only 38% of arable land; the rest is rain-fed. Whether or not drought conditions prevail is based on two factors: the amount of rainfall brought by the westerlies during the winter and the timing of the advent of the monsoon. For every day the monsoon is delayed, crops are adversely affected, even if winter precipitation has been good, because soil moisture drops below the minimal level needed for crop maturation. If it is available, irrigation with canals or groundwater can provide a buffer, warding off crop failure.

Paddy (Oryza sativa L.) is the most important cereal, both in terms of cultivated area (taking on average 46 percent of total cereal cultivated area) and in terms of production. Paddy yield is quite variable from farm to farm and from country to country. Many factors such as fertility of the soil, farm management practices, variety, prevalence of diseases and insects, and the weather are responsible for this variation [30]. On an average, the amount of water required for paddy is 500-650mm per month depending upon the prevailing conditions such as solar radiation, temperature, growth duration, variety, location etc [28]. The optimum temperature for the better growth of paddy and good yield is 22-30^{o}C. The maximum and the minimum temperature at which there is good growth of paddy is 37^{o}C is 12^{o}C respectively [13]. [5] reported that to produce 1 kg paddy tentatively 3,000 liter of water is required whereas to grow paddy in one hectare of land it needs 800,000 liter water. Paddy is more vulnerable to climate change in comparison with wheat, maize, millet and barley. For paddy, an increase in the temperature has unfavorable effects in the hotter region while it has favorable effects in the colder region. The wider variation in temperature is detrimental for the paddy yield. The consequence of rainfall on paddy yield is observed to be either beneficial or harmful depending on the seasons and altitudes. Spring rainfall is valuable for paddy in the low-altitude region while summer rainfall is beneficial for the mid-altitude region. Similarly, summer rain is destructive for the low altitude region and spring rain is harmful for the mid-altitude region in terms of yield but both of these reduces the risk of yield variability. The wider variation in rainfall is detrimental to the paddy yield. Paddy yield and yield variability are affected by temperature, rainfall and their variations across growing seasons and altitude. Maize (Zea mays L.) is the second most important cereal in terms of total cereal cultivated area (24 percent). The total water requirement of maize from sowing to harvesting period is 486.6 mm. The optimum temperature for the better growth of maize and good yield is 18-20^{o}C.The seasonal water requirement of maize is 400-500 mm. Maize is adversely affected by the current climate trend in Nepal. With this, we can recommend that any program dealing with minimizing adverse impact of climate change on food-crops production should first consider the crops like maize and potato, which are being affected at higher degree compared to other food-crops [18].

Wheat (Triticum aestivum L.) is the third most important cereal in terms of total cereal cultivated area at 20 percent. It is desirable that the minimum and maximum temperature during the wheat growing period should be 30^{0}C to 32^{0}C and the mean daily temperature for optimum growth is between 20^{0} C and 25^{0} C [8]. For higher yields, water requirements are 350-500 mm depending on climate and length of growing period in Nepal. About 237.8 mm of rainfall is good for the wheat yield in west Nepal [6].

For wheat, increasing temperature is useful in the hotter region while it is largely harmful in the colder region. Wheat yield is robust against variation in the temperature and is found to cause the risk through a change in yield variability. However, wheat yield and its variability are largely robust against the level as well as the variance of rainfall. In the case of wheat, the effect is observed only for the mean temperature on mean yield. Mean rainfall and the variation in temperature and rainfall all have a largely null effect on wheat yield and yield variability.
Millet (Eleusine coracana L.) is the fifth most important cereals in the world after wheat, maize, rice and barley [33]. It is a relatively minor cereal in terms of area, occupying only 8 percent of total cereal cultivated land area.
Barley (Hordeum vulgare L.) occupies a very small area and is a cereals with particularly low yields of around one ton per ha. Because of its small area, the variability in production is quite high, as minor absolute changes of a few thousand hectares may result in big changes in crop production.
The total yield (TY) of five major cereals (viz. paddy, wheat, maize, millet and barley) for 19 years from 1976 to 1994 is below average except in the years as 1989, 1990, 1991 and 1993 respectively. The TY of five major cereals in the years 1979, 1982, 1986, 1992 and 1994 has been reduced sharply. Dadeldhura is the district where the total yield of cereals has reduced and is below average in all the five different years.
This study is conducted to study on the effect of precipitation and temperature variation on the yield of major cereals in Dadeldhura district of far western development region of Nepal.

GENERAL DESCRIPTION OF THE STUDY AREA

The study was carried out in Dadeldhura district of Far –Western development region (FWDR) of Nepal. This is situated in Mahakali zone as in figure 1. The traditional agricultural practice is prevalent in this district. The latitude and longitude is 29° 18′ 0″ N and 80° 35′ 0″ E respectively.

Fig.1. Map of Nepal and location of Dadeldhura district

METHODOLOGY

1. Empirical model selection

The objective of this analysis is to explore the relationship between rice yield and climate variables to estimate the potential effects of rainfall and temperature on the yield of major cereals using regression models and time series data at an aggregate level. This objective can be accomplished by using equation of exponential growth curve as below.

$Y = b^X . c^Z$

$\text{Log } Y = X \text{ Log } b + Z \text{ Log } c$……………………………………….(i)

where, Y = Yield of cereals (Dependent variable), X = Precipitation (Independent variable) and Z Temperature (Independent variable); b and c are constants

Following [29, 22, 4], I used two climatic variables as independent variables: rainfall and temperature. The average growing season temperature is a key determinant of average yield [9]. So the seasonal rainfall and temperature is used to identify the effect of climatic variables on yield. The monthly average growing season maximum and minimum temperature and the total growing season rainfall have been used in previous studies [14, 11, 23, 21].

The rice yield data are regressed on the climatic variables to estimate their effects on the rice yield [32]. In this study also, the yield of major crops are regressed on the rainfall and temperature to estimate the effects on yield. I checked the distribution of each cereals yield against time by scatter graph before I selected the exponential growth curve. An inspection of the graph revealed that the yields did not follow a normal distribution. Therefore, exponential growth curve model is selected for this study. This method is best suited for the estimation of coefficient of determination (R^2) as in Table 5. Therefore, on the basis of the distribution of the yields (dependent variables) for five major cereals, the following regression model through the origin is employed.

$\text{Log } Y_{rice} = X_{rice} \text{ Log } b + Z_{rice} \text{ Log } c$ .... (ii)

$\text{Log } Y_{wheat} = X_{wheat} \text{ Log } b + Z_{wheat} \text{ Log } c$ ………………..(iii)

$\text{Log } Y_{maize} = X_{maize} \text{ Log } b + Z_{maize} \text{ Log } c$ ………………..(iv)

$\text{Log } Y_{millet} = X_{millet} \text{ Log } b + Z_{millet} \text{ Log } c$ ………………..(v)

$\text{Log } Y_{barley} = X_{barley} \text{ Log } b + Z_{barley} \text{ Log } c$ ……………….(vi)

2. Data sources and analysis

Temperature and rainfall data of Dadeldhura district are collected from the Department of Hydrology and Meteorology (DHM) Nepal. Agricultural data are collected from MoAC. Yield of major cereals viz. Rice, Wheat, Maize, Millet and Barley has been analyzed for the 19 years from 1976 to 1994 by using EXCEL and SPSS to study the statistical analysis with seasonal rainfall and temperature.

The seasonal rainfall and temperature varies for different crops growing seasons as in Table 1. The rainfall and temperature data are regressed with the yield of individual crop data of Dadeldhura district of FWDR to establish the relationship between crop yield and climatic variability.

Table 1.Different crops growing seasons with optimum temperature and rainfall

Crops	Growing seasons	Optimum temperature (^{0}C)	Optimum rainfall (mm)
Rice	July-November	22-30	1000-1500
Wheat	November-March	16-22	150-200
Maize	March-June	18-20	400-500
Millet	July-November	NA	NA
Barley	November-March	NA	NA

Source: MoAC, 2012; NA: Not Available

DATA ANALYSIS

Analysis of Annual and Seasonal Rainfall data

In Dadeldhura, the annual minimum and maximum rainfall recorded is 988 mm and 2073 mm in the year 1992 and 1983 respectively. The mean annual average rainfall recorded is 1401 mm. The mean annual rainfall is below mean annual average rainfall in the years 1976, 1977, 1978, 1979, 1981, 1984, 1987, 1989, 1991, 1992 and 1994 respectively. Similarly, the seasonal mean rainfall is 871.79 mm, 215.37 mm and 391.74 mm during paddy/millet, wheat/barley and maize growing seasons respectively as in Table 2.

Table 2. Descriptive statistics for the seasonal rainfall data for the 1976-1994 period

Statistics	**Rainfall (mm)**		
	Paddy/Millet	Wheat/Barley	Maize
Mean	871.79	215.37	391.74
Std. deviation	235.971	91.513	97.905
Maximum	1394	395	566
Minimum	511	59	225
Skewness	0.848	0.287	0.236
Kurtosis	0.876	-0.61	-0.67

Analysis of Annual and Seasonal Temperature data

In Dadeldhura, the annual mean temperature is found to be 15.6 ^{0}C. The annual mean temperature from 1976-1994 exceeds the annual average temperature in the years 1979, 1980, 1984, 1985, 1988, 1991, 1992, 1993 and 1994. The highest temperature is observed in 1994 i.e. 16.2^{0}C. In some years the data was missing. Similarly, the seasonal mean temperature is 17.77 ^{0}C, 10.47 ^{0}C and 16.9 ^{0}C during paddy/millet, wheat/barley and maize growing seasons respectively as in Table 3.

Table 3. Descriptive statistics for the seasonal temperature data for the 1976-1994 periods

Statistics	Temperature (^{o}C)		
	Paddy/Millet	Wheat/Barley	Maize
Mean	17.771	10.476	16.909
Std. deviation	0.448	0.953	1.154
Maximum	18.7	11.7	19.1
Minimum	17.1	8.1	15.5
Skewness	0.076	-0.727	0.657
Kurtosis	-0.367	0.799	-0.784

Variation on the yield with seasonal rainfall and temperature

The yield differs due to many reasons. The meteorological factors mainly affect the yield of crops. However, there are also the other prominent factors that distinguish the yield. The mean yield of different cereals is tabulated in Table 4. However, these descriptive statistics do not provide any evidence of changing climate. To build the quantification justification for the climate change during the growing seasons of five major cereals, I estimate exponential trend model for two major climatic variables. The results are illustrated in Table 5

Table 4. Descriptive statistics for the yield data for the 1976-1994 periods

Statistics	Yield (Kg/ha) of crops				
	Paddy	Wheat	Maize	Millet	Barley
Mean	1682.06	964.39	1581.56	1074.5	897.22
Std. deviation	504.903	194.896	173.749	139.086	88.174
Maximum	2770	1430	1957	1200	1000
Minimum	810	701	1388	799	700
Skewness	0.343	0.768	0.779	-0.853	-1.186
Kurtosis	0.05	0.301	-0.623	-0.415	1.357

Yield of Paddy and Millet

The yield of paddy is in decreasing trend and the yield of millet is in increasing trend with the decreasing amount of seasonal rainfall and increasing seasonal mean temperature as shown in the fig. 2a and fig. 2b. The mean annual average seasonal rainfall recorded is 871.7 mm. The seasonal minimum and maximum rainfall recorded is 511 mm and 1394 mm as in Table 2 in the year 1979 and 1983 respectively. The years 1976, 1979, 1981, 1982, 1984, 1987, 1988, 1989, 1992 and 1994 has rainfall below the annual average seasonal rainfall. The seasonal mean temperature is found to be 17.77 ^{0}C. The annual mean temperature from 1976-1994 exceeds the annual average temperature in the years 1978, 1979, 1982, 1983, 1984, 1987, 1989, 1993 and 1994. The maximum temperature is 18.7^{0}C that is observed in 1987 and the minimum temperature is 17.1^{0}C that is observed in 1980 and 1985 respectively as in Table 3. In the years 1976 and 1977 the temperature data was missing.

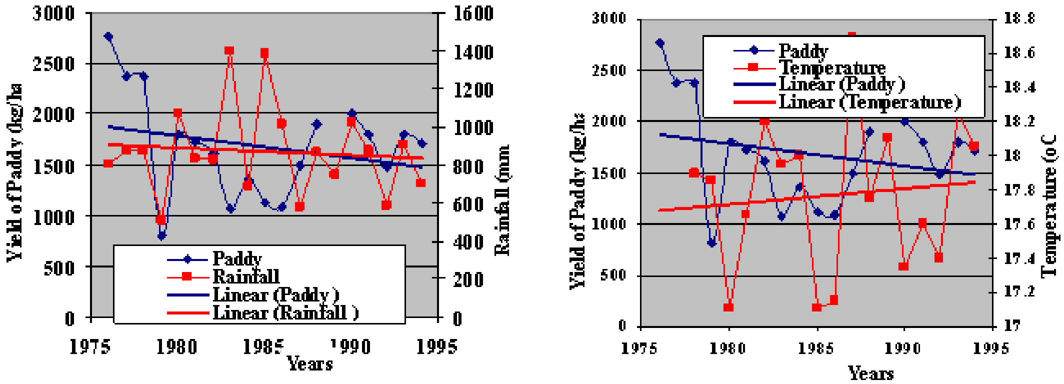

Figure.2a. Variation on the paddy yield with seasonal rainfall and temperature

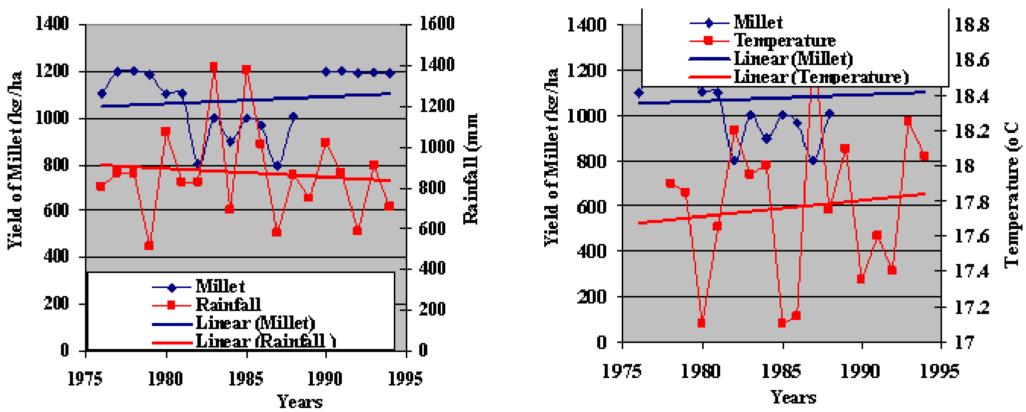

Figure.2b. Variation on the millet yield with seasonal rainfall and temperature

Yield of Maize

The yield of maize is in increasing trend with the stable amount of seasonal rainfall and seasonal mean temperature as shown in the fig. 3. The mean annual average seasonal rainfall recorded is 391.7 mm. The seasonal minimum and maximum rainfall recorded is 225 mm and 566 mm as in Table 2 in the year 1985 and 1983 respectively. The years 1976, 1977, 1980, 1985, 1987, 1988, 1989, 1991 and 1992 has rainfall below the annual average seasonal rainfall. The seasonal mean temperature is found to be 16.91 ^{0}C. The annual mean temperature from 1976-1994 exceeds the annual average temperature in the years 1980, 1984, 1985, 1988, 1989, 1992 and 1994. The maximum temperature is 19.05^{0}C that is observed in 1985 and the minimum temperature is 15.45^{0}C that is observed in 1991 respectively as in Table 3. In the years 1976 and 1977 the temperature data was missing.

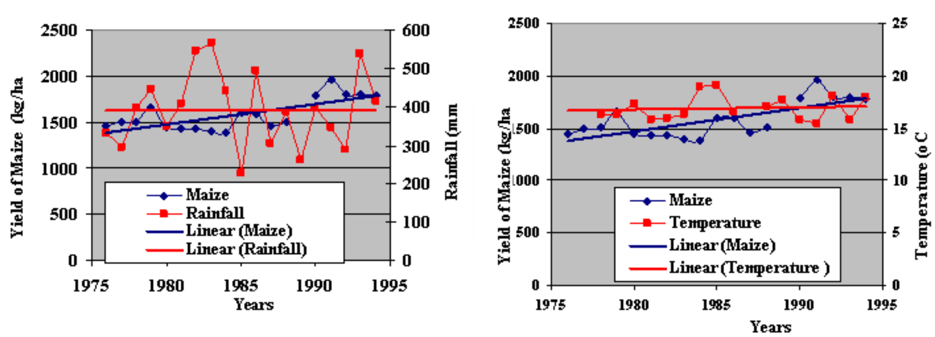

Figure.3. Variation on the maize yield with seasonal rainfall and temperature

Yield of Barley and Wheat

The yield of wheat is in increasing trend and the yield of barley is in decreasing trend and with the increase amount of seasonal rainfall and seasonal mean temperature as shown in the fig. 4. The mean annual average seasonal rainfall recorded is 215.36 mm. The seasonal minimum and maximum rainfall recorded is 59 mm and 395 mm in the year 1977 and 1982 respectively as in Table 2. The years 1976, 1977, 1980, 1983, 1985, 1986, 1987, 1989, 1992 and 1994 has rainfall below the annual average seasonal rainfall. The seasonal mean temperature is found to be 10.50 ^{0}C. The annual mean temperature from 1976-1994 exceeds the annual average temperature in the years 1979, 1980, 1987, 1988, 1990, 1993 and 1994. The maximum temperature is 11.7^{0}C that is observed in 1993 and the minimum temperature is 8.1^{0}C that is observed in 1978 respectively as in Table 3. In the years 1976 and 1977 the temperature data was missing.

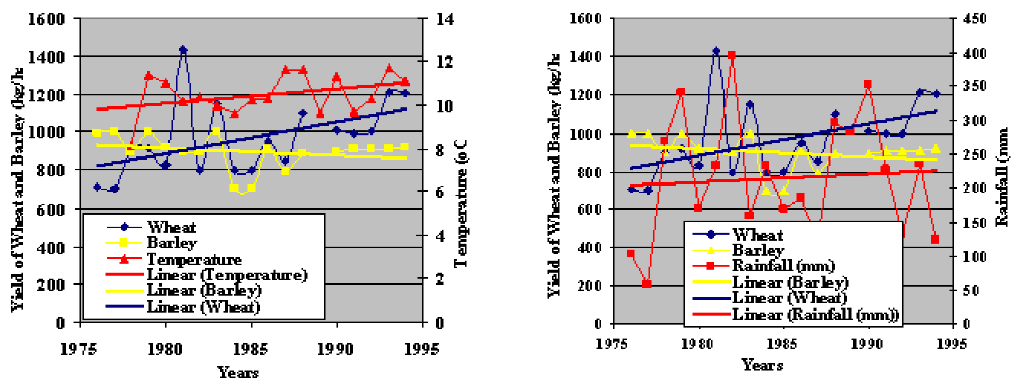

Figure.4. Variation on the wheat and barley yield with seasonal rainfall and temperature

RESULTS OF THE ANALYSIS

The annual rainfall below average and annual temperature above average is observed in the years 1979, 1984, 1991 and 1994.

The average yield of paddy for 19 years is 1682 kg/ha. The seasonal rainfall below average and seasonal temperature above average is observed in the years 1979, 1982, 1987, 1989 and 1994 during paddy and millet growing period. In those years the yield of paddy is below average and is reduced significantly in the year 1979. The average yield of millet for 19 years is 1075 kg/ha. In those years the yield of millet is below average except in 1979 and 1994 and is reduced significantly in the year 1982 and 1987. The average yield of maize for 19 years is 1582 kg/ha. The seasonal rainfall below average yield and seasonal temperature above average is observed in the years 1980, 1985, 1988, 1989 and 1992 during maize growing period. In those years except 1985 and 1992 the yield of maize is below average and is reduced significantly in the year 1980.

The average yield of barley for 19 years is 897.2 kg/ha. The seasonal rainfall below average and seasonal temperature above average is observed in the years 1980, 1987 and 1994 during barley and wheat growing period. In those years except 1980 and 1994 the yield of barley is below average and is reduced significantly in the year 1987. The average yield of wheat for 19 years is 964.39 kg/ha. In those years except 1994 the yield of wheat is below average and is reduced significantly in the year 1980 and 1987.

The yield of paddy, wheat, maize, millet and barley in the year 1989 is unavailable.

The effects of climatic variables viz. rainfall and temperature on yield of cereals are shown in Table 5, which indicates that the overall yield of cereals is statistically significant. The R^2 value indicates that rainfall and temperature are the important parameters for the yield of cereals. The t-value and p-value of temperature is significant and revealed that temperature has contributed for the reduction in the yield of cereals. However, the yield of maize and barley is influenced by the rainfall and temperature, which is indicated by the p-value as shown in Table 5.

Table 5. The results of the exponential trend model of changes in climate variables for the 1976-1994 period

Type of crop	R^2	t-Value		p-Value	
		Rainfall	Temperature	Rainfall	Temperature
Paddy	0.999	0.664	4.015	0.517	*0.001
Wheat	0.999	1.661	6.080	0.119	*0.000
Maize	0.999	2.512	5.793	*0.026	*0.000
Millet	0.999	1.031	6.258	0.320	*0.000
Barley	0.999	6.470	2.519	*0.000	*0.025

* Correlation is significant at 5% level

CONCLUSION

The objective of this study was to study the effect of precipitation and temperature variation on the yield of major cereals in Dadeldhura district of far western development region, Nepal using time series information of yields. So, exponential growth curve model is used for the study. The overall findings reveal that two climatic variables have substantial effect on the yield of different cereals. For the rice, wheat, maize, barley and millet temperature is statistically significant. For the rice, wheat and millet rainfall is statistically not significant. But, for maize and barley rainfall is significant. However, for the rice, rainfall is sufficient to affect positively, although this effect is not significant. Maximum temperatures and rainfall have positive effect on rice and maize yields.

The yield of paddy is reduced significantly in 1979. The yield of millet is reduced significantly in 1982 and 1987. The yield of maize is reduced significantly in 1980. The yield of barley is reduced significantly in 1987. The yield of wheat is reduced significantly in the year 1980 and 1987. In the year 1979 and 1987, the rainfall is below average in all the crop growing seasons. So, the yield of paddy, maize, wheat, barley and millet is reduced. In 1980, the rainfall was less during the wheat, barley and maize growing seasons. The temperature was also high which has reduced the yield of the crops. Similarly, in the year 1982, the low rainfall and low temperature reduced the growth of paddy and millet. Therefore, 1979, 1980, 1982 and 1987 are the major agriculture drought years in Dadeldhura district of far western development region, Nepal. Two climate variables (namely, high temperature and low rainfall) are found to adversely affect the rice and maize yield. However, some variety of wheat, millet and barley can even tolerate high temperature and low rainfall to give substantial yield. Changes of climatic patterns in the recent days are contentiously recognized to have serious implications on agricultural productivity especially in developing countries like Nepal. This study could be considered useful in that we have characterized climatic impacts on crop yield and its variability of paddy, wheat, maize, barley and millet in Nepal. It is observed that an increase in the variances of both temperature and rainfall have adverse effects on crop production in general. On the other hand, a change in the level of temperature and rainfall induces heterogeneous impacts, which can be considered either beneficial or harmful depending on the season, altitude and type of crop. Given this severe sensitivity of cereal yields to climate factors, variety-specific adaption strategies must be adopted to mute the adverse effects of climate change. The supply of timely climate information and the development of climate-resilient (temperature-tolerant) varieties are two key options that the government of Nepal should address urgently. Therefore, future research should focus on analyzing data at regional level to capture regional variations of yield with some other variables including rainfall and temperature to obtain a more comprehensive image on the yield of major cereals in Nepal.

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