Impact of Climate Change on Yield of Major Cereals in India and Nepal: A Micro Regional Analysis

Abstract

Rupandehi and Varanasi districts are located in the tropical region of Nepal and India. As a result, both districts experience warm temperature typical of this climate. The aim of the research is to study the effect of different climatic variables on selected cereals. The study examines the trend of three main climatic variable (e.g. maximum temperature, minimum temperature and rainfall) for the two districts of two different country India and Nepal, by using the time series data for the period 1980-2016 A.D and accesses the relationship between the variables and the yield of two major cereals rice and wheat crops. Multiple linear regression analysis model used in this study. The result from the finding reveals that impact of climatic variables on yield of rice and wheat is more in Rupandehi district 48% in rice and 16% in wheat. Where as in Varanasi district decrease in rice yield by 6.5% and wheat by 21%. For this result adverse effect of maximum temperature and rainfall are responsible in kharif season. The study also evaluates the local knowledge and resource-based adaptation techniques followed by the farmers against climate change.

Key Words: climate change, climatic variation, cereals yield, adaption, India and Nepal

1. Introduction

Climate change can directly and indirectly affect people's overall well-being, especially for communities that rely heavily on natural resources like agriculture and forest for their livelihoods. These groups are likely to experience the most significant impacts from climate change (Thapa and Joshi, 2014). Since 1980s, Earth's atmospheric temperature has raising, with the average surface temperature increasing by approximately 0.15 to 0.2 ^{0}C over the past century (Mendelson, 2007).

Climate change is the most serious concern throughout the world. However, impact of climate change has significant effect on various natural resources and biodiversity, leading to threats to forest conservation, species extinction and an increase in pest and disease (IPCC, 2007). Since the agricultural productivity is highly dependent on climate so sector is more vulnerable to climate change in developing countries (Lee, 2009; Ahmad et al., 2011). Agriculture sector has immense share in national GDP of any developing and least developed country like India and Nepal respectively, likewise huge number of populations also employed by this sector. Changes in temperature, and rainfall pattern have negative impact on agriculture for example widespread land degradation and increasing water scarcity limit the potential for yield increases. For the low-income countries, it is more challenging concern that without making an effort to reduce poverty, and to make the transition to an agriculture that is both productive and sustainable will find it difficult to ensure access to adequate quantities of food for all their population (world Bank,2003).

Climate change is now a global and so a significant issue of 21st century. The Intergovernmental Pannel of Climate Change has predicted 3.7 to 4.8 °C of warming if the activities as continued (IPCC, 2014). Indian agriculture is more dependent on monsoon from the ancient periods. Any change in monsoon trend drastically affects agriculture. In the past four decades (1969-2005), India's surface temperature has increased by 0.3 °C or by 0.08 °C per decade. In recent years, the climate change has been accompanied by increased incidence of natural calamities such as droughts, floods, cyclones and heat waves (Goswami et al., 2006). Nepal is highly vulnerable to the potential negative impacts of climate change. With an average of 0.06 °C per year, raise in temperature has been recorded from 1975 to 2006 by 1.8°C in Nepal (Malla, 2009).

The study was basically focused on the impact of climate change in two different districts of India and Nepal; Varanasi and Rupandehi. Varanasi is situated in the Agro climatic zone of eastern plain region of Uttar Pradesh, bordering the districts of Jaunpur in the North, Ghazipur in the North East, Chandauli in the east, Mairzapur in the South and Sant Ravidasnagar in the West. The total area of the district is 1535 sq.km, the district is stretched between longitude 82° 56'E - 83° 03'E and 25° 14'N - 25° 23.5'N. Varanasi is located at an elevation of 80.71 meters in the Centre of the Ganges valley of North India whereas Rupandehi district lies in Terai region. It is situated in the Lumbini zone of western development region of Nepal. It's headquarter is Bhairahawa. Geographically, Rupandehi district lies at longitude 83°12'16''east to 83°38'16" East and latitude 27°20'00"North to 27°47'25" North with the borders Nawalparasi in the East, Kapilvastu in the West, Palpa district in the North and India in the South. The altitude of Rupandehi district is 100m to 1229m from the South Sea. The total area of the district is 1360 sq.km.

2. Methodology

This study considers the widely used climate variables as rainfall and temperature to assess the impacts of climate change on the crop yield. To analyse the yield effect of major cereals due to change in climatic variables, multiple linear regression analysis model is used. Most of the research conducted in the past had used regression models on possible impacts of climate change on food crops (Sarkar et al., 2012; Boubacar, 2010) Both primary and secondary data should be collected through schedule and different governmental site respectively. Temperature and rainfall data were collected through Department of Hydrology, Nepal and Department of Geology, Banaras Hindu University for the time period of 1980- 2016. The yield of Rice and Wheat was collected for 10 years according to the availability of data through District Agriculture

Development Office, Rupandehi and Directorate of Economics and Statistics, Ministry of Agriculture and Farmer Welfare (GoI).

The daily maximum, minimum temperature is transferred into average crop growing season and daily rainfall is summed as cumulative rainfall. The selection of crops was based on their crossponding area of dominance and production. Rice and wheat both crops were also commonly used as main cereals for consumption purpose in both Rupandehi and Varanasi districts. For rice crop kharif season is taken from June to September and for wheat, rabi season is taken as October to March. The monthly average growing season with maximum, minimum temperature and average growing season rainfall was used in previous research (Granger, 1980; Chang, 2002).

The empirical relationship between climatic variables and cereals production was computed by multiple regression. Multiple regression analysis was carried out using the time series data from 1991/92- 2015/16 to find out the relationship between dependent and independent variables. Agricultural production was selected as dependent variables whereas minimum, maximum temperature and rainfall were taken as independent variables. For the analysis purpose, linear and Cobb- Douglas production function was estimated, Cobb-Douglas form gave the better fit as per the statistical criteria of high coefficient of multiple determination (R2) and low standard error The functional relationship of Cobb- Douglas function for the study was used as specified below.

The production function (Draper & Smith.1998) was fitted separately for different categories in the following form.

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}e^u$$

Where,

Y = Crop yield (qtl. /ha)

X_1 = maximum temperature (°C)

X_2 = minimum temperature (°C)

X_3 = rainfall (mm)

u = Error term

a = constant

e = Napier base,

b1………b3 are Regression coefficient

Cobb Douglas type of production function was converted into log linear form and the coefficient were estimated by using ordinary least square method (OLS). In logarithmic form, it assumed a log linear equation as follows.

$$\text{Log } Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + \ldots\ldots\ldots\ u \log e$$

The formula was used for estimating the parameters of the function based on sample data.

To analyze the pattern of change in climate parameters, trend analysis was done. It was used to determine the magnitude, direction and significance of the trend in annual and seasonal rainfall and temperature. The formula for calculating the trend was as follows.

$$Y = a + bT$$

Where,

Y = dependent variable for which trend is estimated

a= intercept

b= regression coefficient

T= time (independent variable)

Similarly, mitigation strategies followed by the farmers against climate change on the study area, total number of respondent and their perception about impact of climatic variables on crop were taken and percentage analysis was performed. The districts were purposely selected and multi stage sampling was followed for the sampling of the block and villages for the farmer perception about the adaption strategies to mitigate against the adverse climatic condition. Household survey, Key informant interview and group discussion was conducted on study area for information regarding adaptation strategies followed by the farmers. Marchawar village development committee was selected among 69 VDC's from Rupandehi district, which had highest production of rice and wheat. The VDC contain 920 household so 98 household were selected randomly. Similarly, Pindra block was selected from 9 blocks in Varanasi district. The Pindra block was selected due to its highest production of rice and wheat and covered highest cropping area. 200 household sample was selected randomly for the study.

3. Result and Discussion

Trend of climate change for past 36 years (1985-2016)

The estimation of pattern of climate change is done by computing different climatic variables. For the estimation of change in climate maximum temperature, minimum temperature and rainfall were selected from 1980-2016 for two distinct district Varanasi (U.P) and Rupandehi (Nepal).

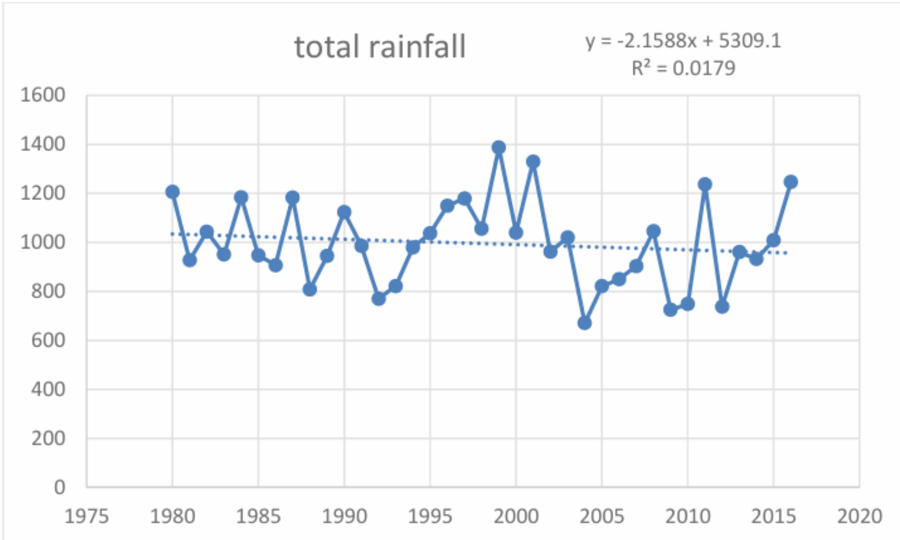
Table 1. Average annual change in maximum temperature, minimum temperature and rainfall in Varanasi district.

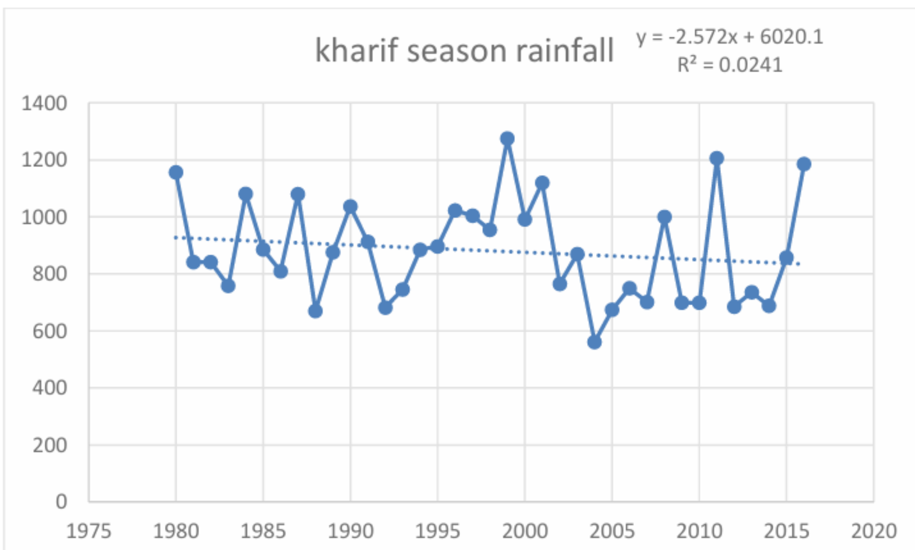
Particulars	Annual	Kharif season	Rabi season
Minimum temperature (°c)	0.0257	0.0173	0.0347
Maximum temperature (°c)	-0.0161	-0.0017	-0.0343
Rainfall (mm)	-2.1588	-2.572	0.4063

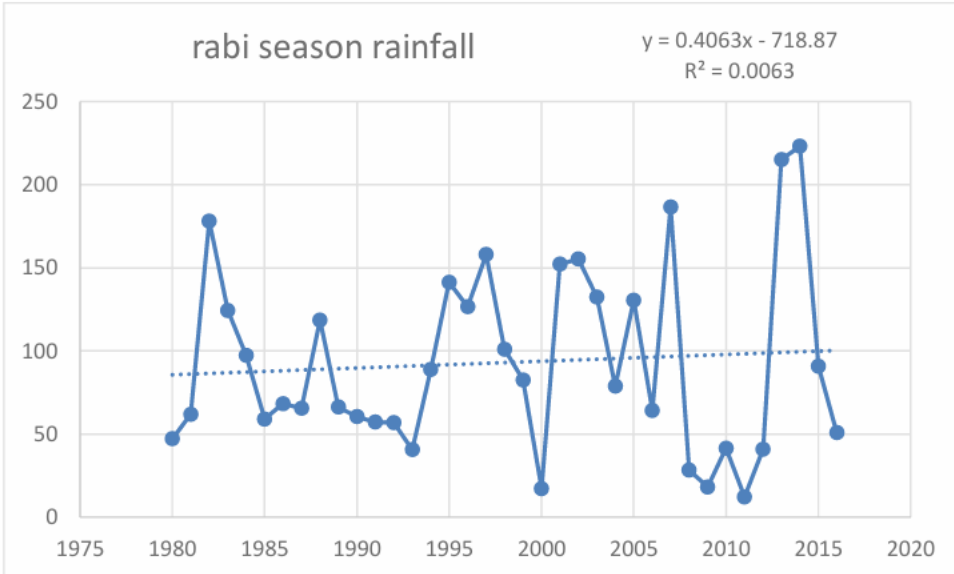
The above table 1 reveals the decreasing trend of annual rainfall in Varanasi district at the rate of 2.15 mm per year and the R^2 value is 0.017. Similarly, the kharif season or rice growing season observed decreasing rate viz. 2.57 mm per year and the R^2 value is 0.024. However, the trend of rabi season shows positive impact on wheat production. The increasing rate of rainfall is 0.40 mm per year and the R^2 value is 0.0063. The average annual temperature of Varanasi district is in decreasing trend. The rate of decreasing annual average maximum temperature is 0.016°c per year. And the R^2 value is 0.067. As well both kharif and rabi season maximum temperature indicates the decreasing rate of temperature at the rate of 0.0017 °C per year and R^2 value is 0.0003 and 0.034 °C per year and R^2 value is 0.18 respectively.

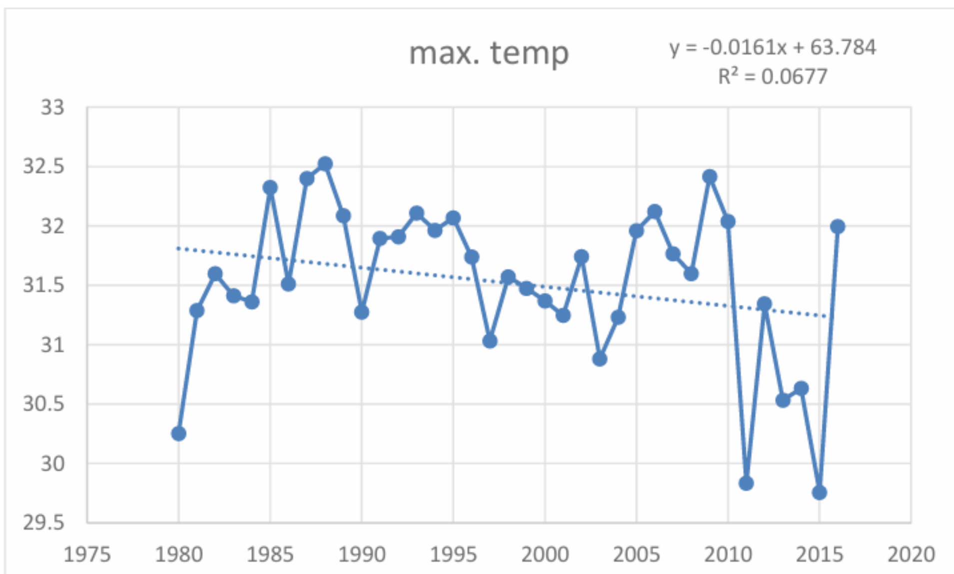
However, the annual average minimum temperature shows increasing trend in Varanasi district. The rate of increasing minimum temperature is 0.025°c per year and the R^2 value is 0.20. kharif season minimum temperature and the rabi season temperature both indicates the increasing trend of temperature at the rate of 0.017°c per year and R^2 value is 0.092.and 0.034°c and R^2 value is 0.033 respectively.

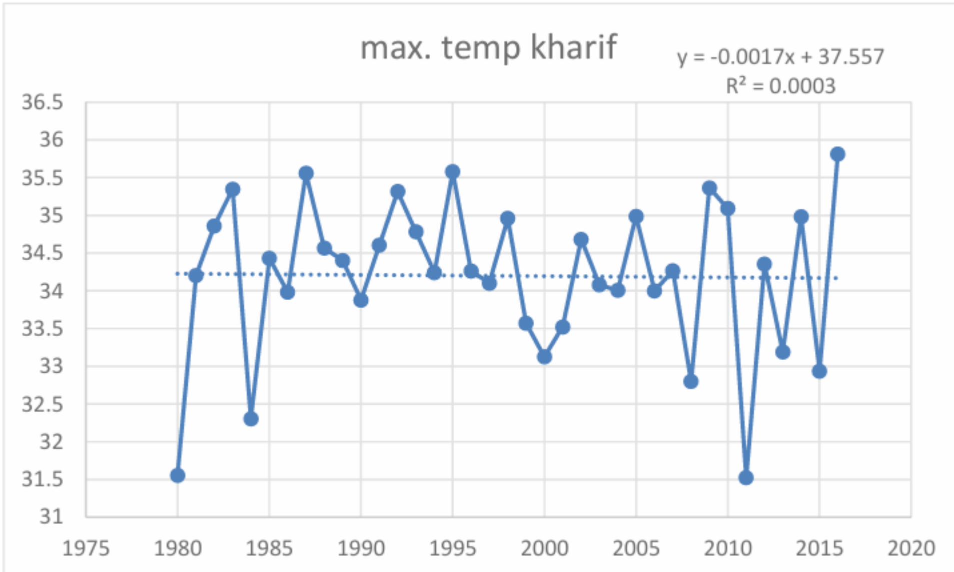
Fig. 1 Trend of average annual rainfall, maximum temperature and minimum temperature of Varanasi district (1980-2016).

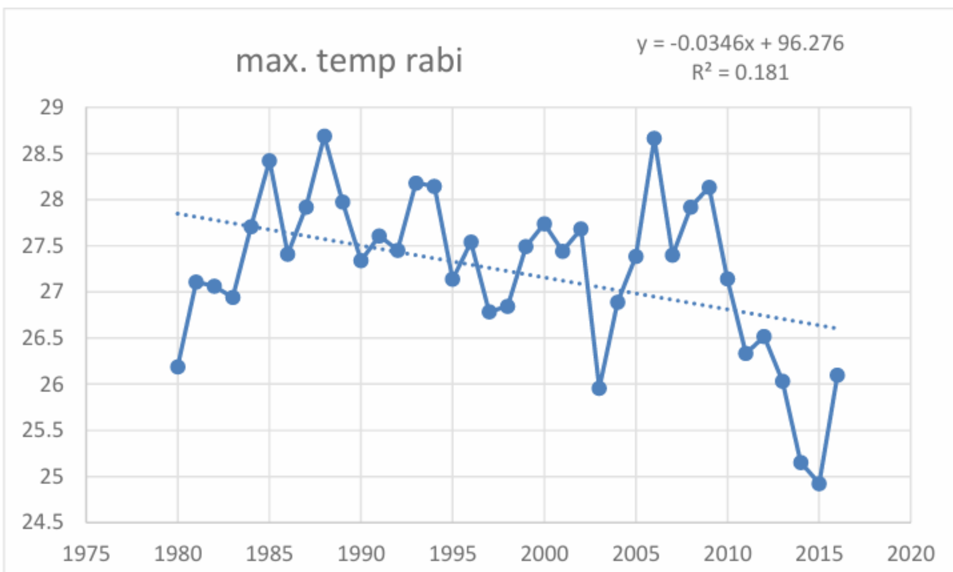

total rainfall
y = -2.1588x + 5309.1
R² = 0.0179
1600
1400
1200
1000
800
600
400
200
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

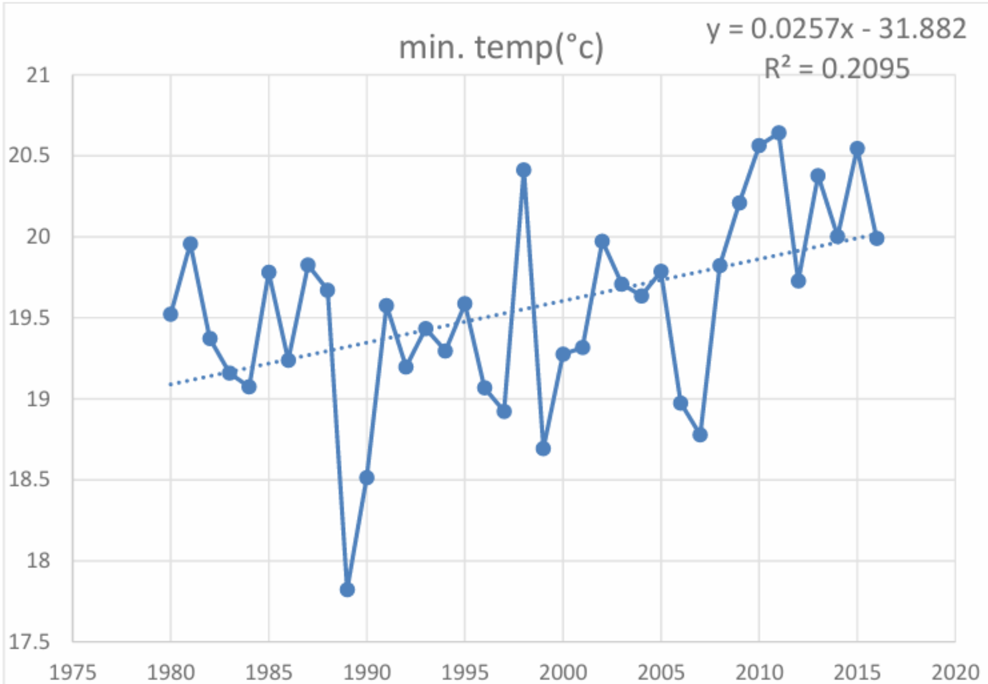

kharif season rainfall
y = -2.572x + 6020.1
R² = 0.0241
1400
1200
1000
800
600
400
200
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

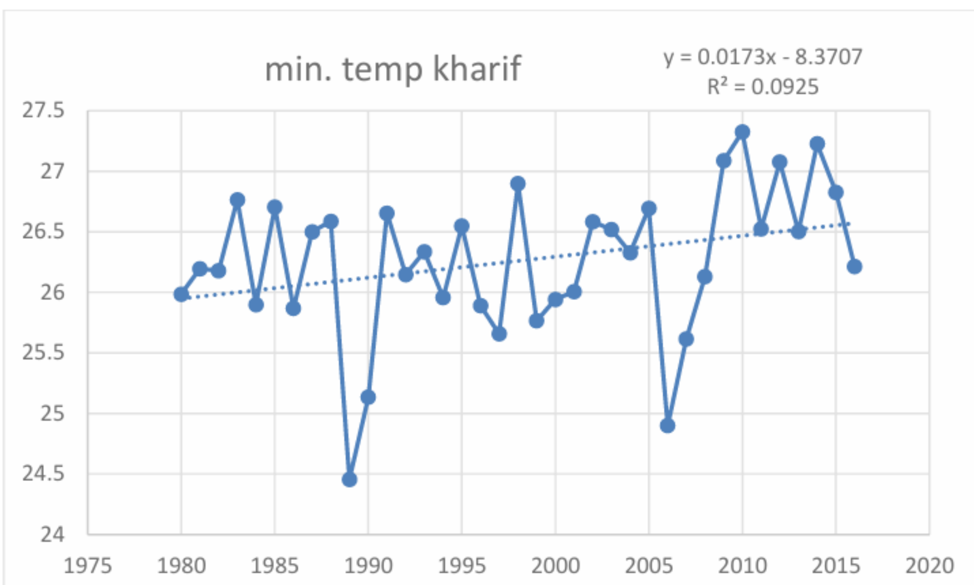

rabi season rainfall
y = 0.4063x - 718.87
R² = 0.0063
250
200
150
100
50
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


max. temp
y = -0.0161x + 63.784
R² = 0.0677
33
32.5
32
31.5
31
30.5
30
29.5
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


max. temp kharif
y = -0.0017x + 37.557
R² = 0.0003
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


max. temp rabi
y = -0.0346x + 96.276
R² = 0.181
29
28.5
28
27.5
27
26.5
26
25.5
25
24.5
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


min. temp(°c)
y = 0.0257x - 31.882
R² = 0.2095
21
20.5
20
19.5
19
18.5
18
17.5
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


min. temp kharif
y = 0.0173x - 8.3707
R² = 0.0925
27.5
27
26.5
26
25.5
25
24.5
24
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

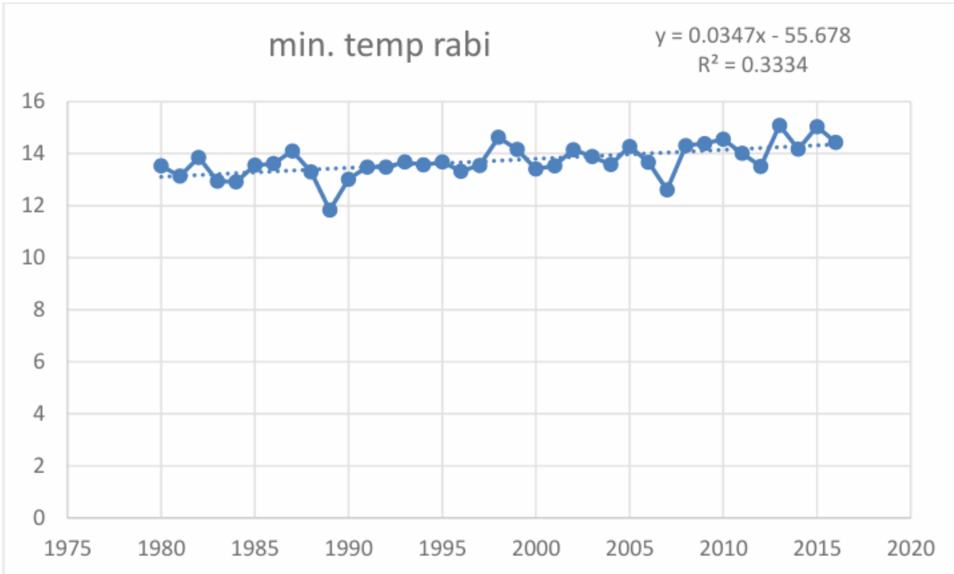


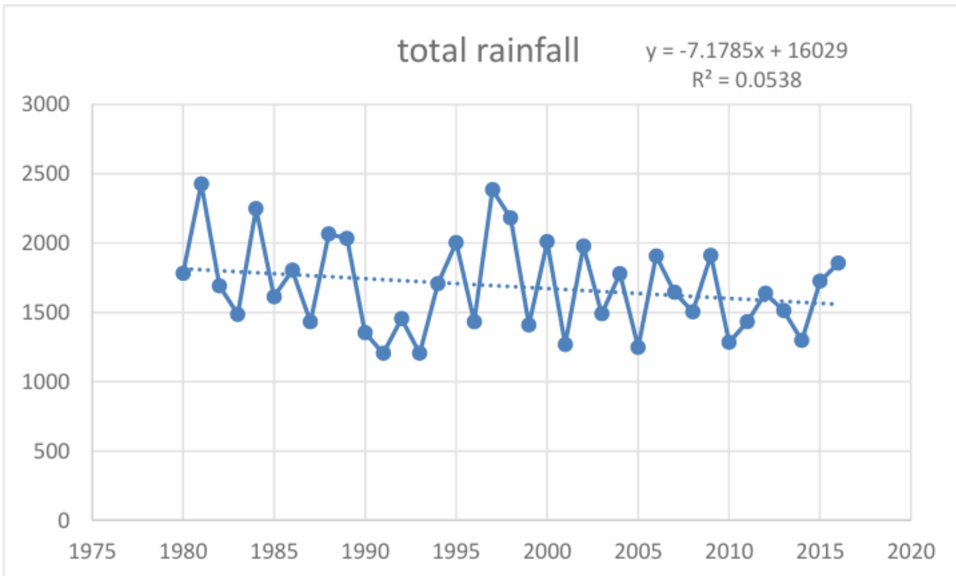
Table 2. Average annual change in maximum temperature, minimum temperature and rainfall in Rupandehi district.

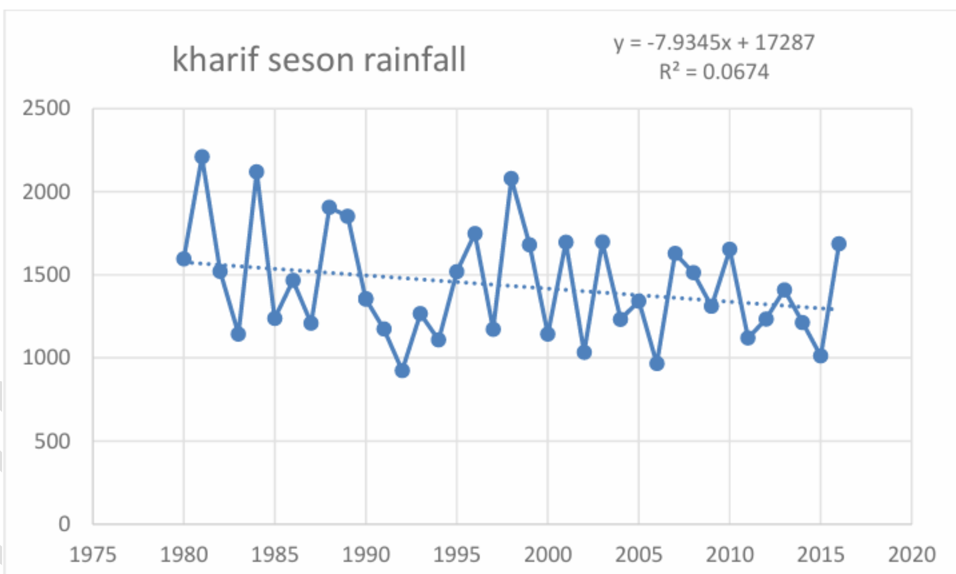
Particulars	Annual	Kharif season	Rabi season
Minimum temperature (°c)	0.0154	0.0205	0.0081
Maximum temperature (°c)	0.0095	0.0455	-0.0194
Rainfall (mm)	-7.1785	-7.9345	-0.6359

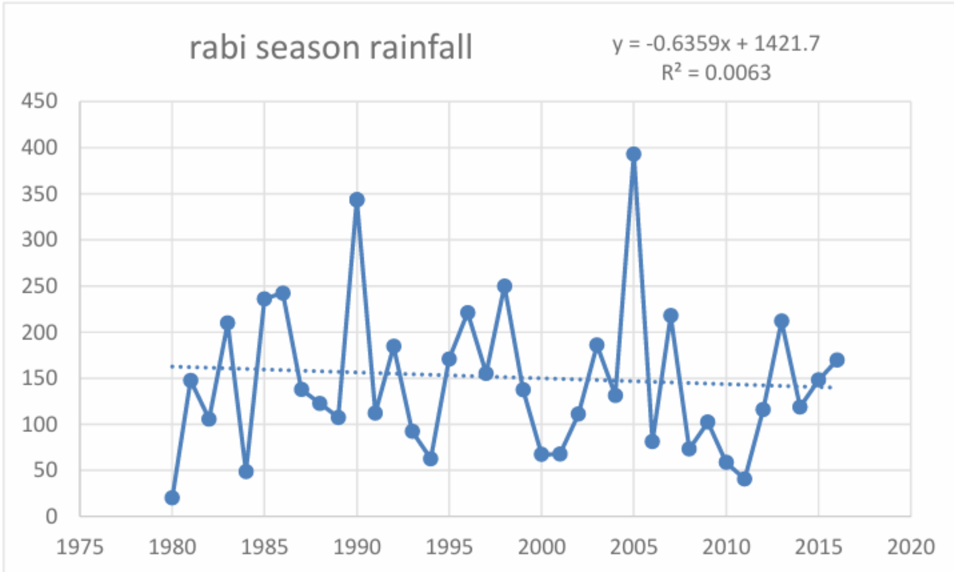
The above table 2 shows the gradually declining trend of rainfall in Rupandehi district over the period of 1980- 2016 at the rate of 7.17mm per year with an R^2 value of 0.05. kharif and rabi season also shows the decreasing trend of rainfall i.e.7.93 mm per year with R2 value 0.067 and 0.63 mm per year and R2 value 0.0063 in rabi season which is comparatively lower than kharif season. The increase in annual maximum temperature is observed over period of 1980-2016. The pattern of temperature trend is found irregular. The average annual maximum temperature for Rupandehi district is increasing at the rate of 0.009 °c per year and R^2 value is 0.060. The Kharif season maximum temperature indicates the increasing rate of temperature at the rate of 0.045°c per year and R^2 value is0.48. However, the Rabi season temperature indicate the decreasing trend at the rate of 0.019°c and R^2 value is 0.12.

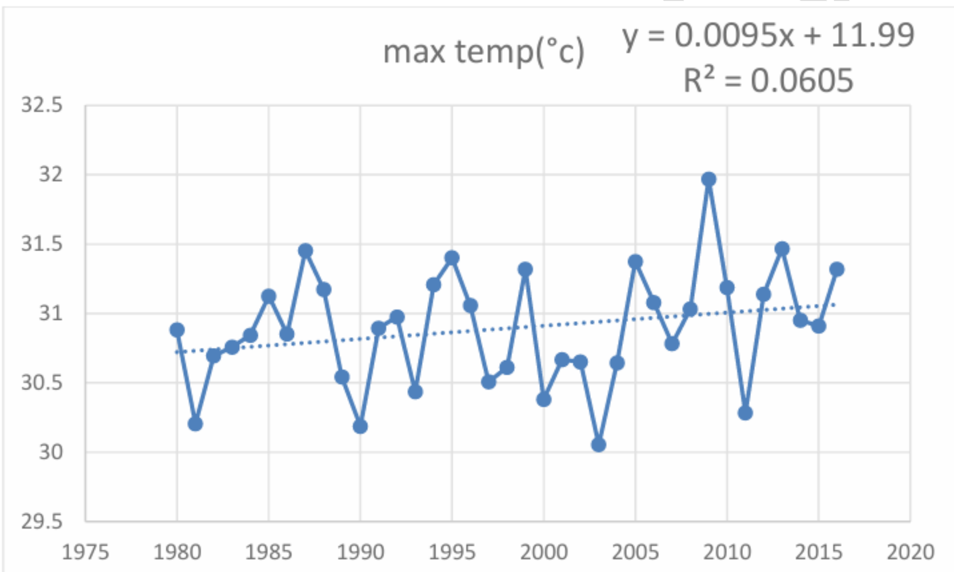
The annual average minimum temperature also shows the increasing trend in Rupandehi district. The rate of increasing minimum temperature is 0.019°c per year and the R^2 value is 0.14. Kharif season minimum temperature indicates the increasing rate of temperature at the rate of 0.02°c per year and R^2 value is 0.23. As well as the Rabi season temperature also indicate the increasing trend at the rate of 0.008°c and R^2 value is 0.026.

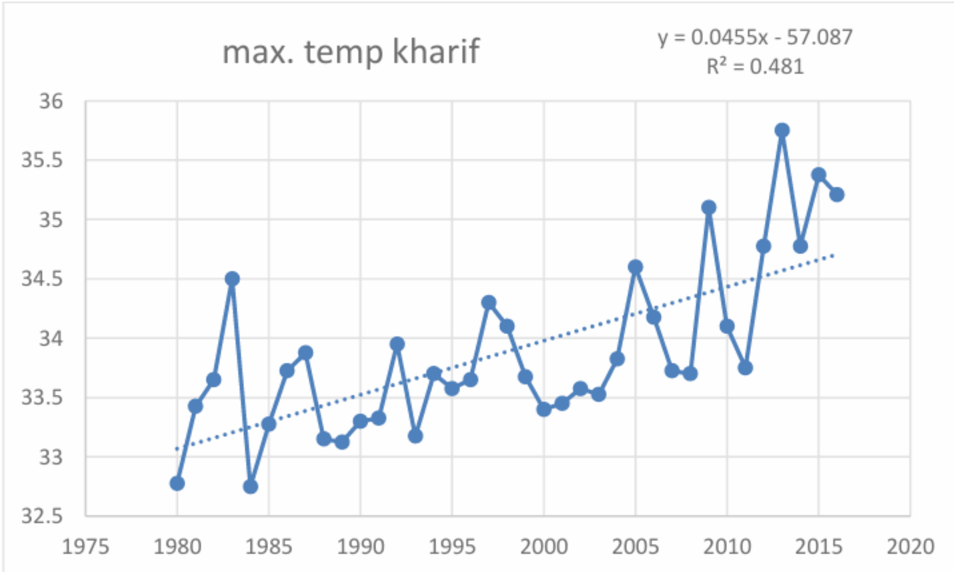
Fig. 2 Trend of average annual rainfall, maximum temperature and minimum temperature of Rupandehi district (1980-2016).

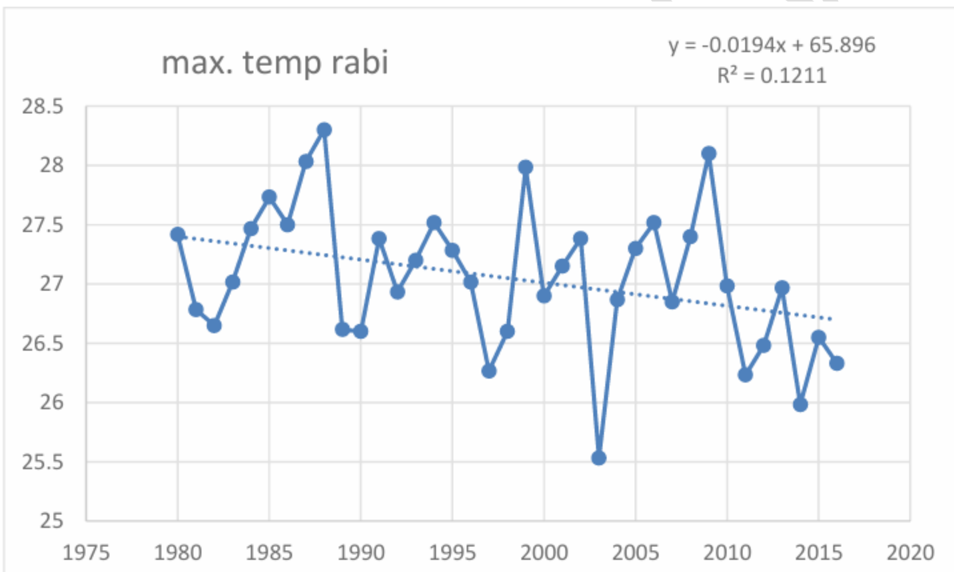


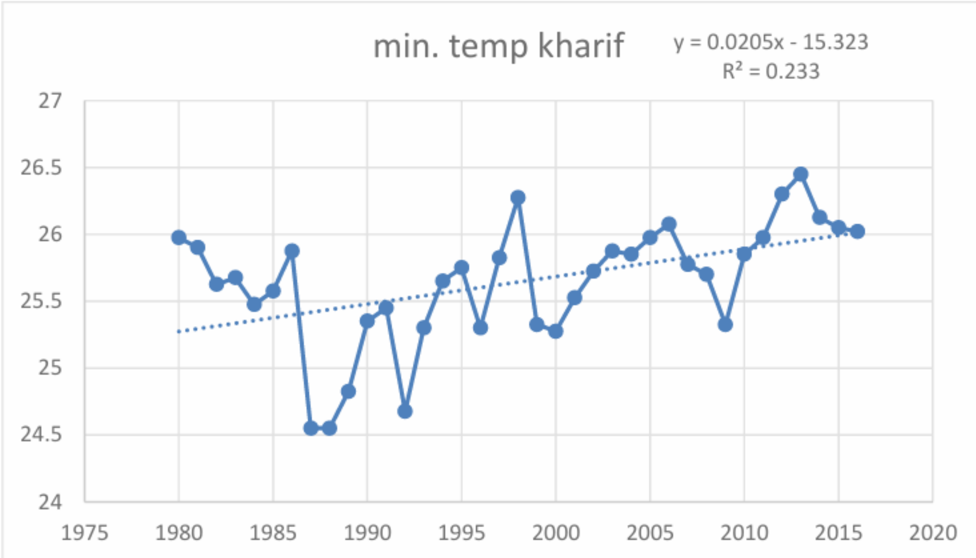


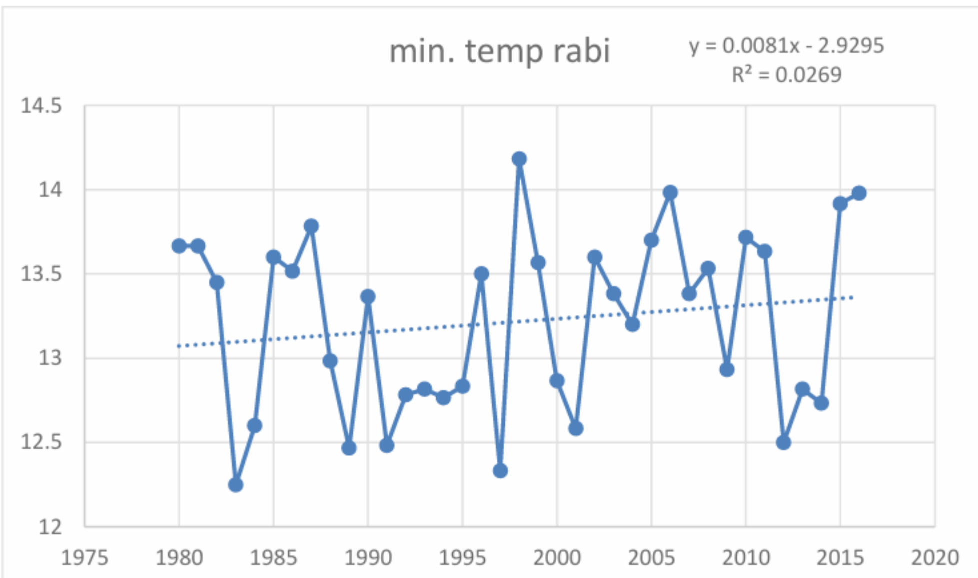

rabi season rainfall
y = -0.6359x + 1421.7
R² = 0.0063
450
400
350
300
250
200
150
100
50
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


max temp(°c)
y = 0.0095x + 11.99
R² = 0.0605
32.5
32
31.5
31
30.5
30
29.5
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


max. temp kharif
y = 0.0455x - 57.087
R² = 0.481
36
35.5
35
34.5
34
33.5
33
32.5
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


max. temp rabi
y = -0.0194x + 65.896
R² = 0.1211
28.5
28
27.5
27
26.5
26
25.5
25
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020





Comparison of the effect on the yield of major cereal due to different climatic factors.

The relation between yield and climatic factor or the impact of climatic factor and yield of different crop for both the study are analyzed by multiple regression analysis. For the best result of multiple regression higher value of coefficient of multiple determination (R^2) and low standard error is observe.

Table 3. Estimation of parameter influencing yield of rice in Rupandehi district (1992-2016).

Variables	Coefficient	Standard error	t- value

Maximum temperature	0.496**	2.884	2.596
Minimum temperature	0.291	4.986	1.523
Rainfall	-0.014	0.006	-0.86
Constant	-416.929	109.508	-3.807
R^2 value = 0.484 F value= 6.576 * * shows 5% level of significance			

The analyzed data in table below (Table 3) reveal that 48 percent of the variation in the rice yield is due to the impact of climatic factors. However, rest of 52 percent of yield loss of rice is due to other factors which are not explained in this model. The other factors may be irrigation, seed, cropping method, fertilizer and disease pest infestation etc. (Mamun et al.2015). From this figure we can construe that maximum temperature have significant and negative effect at 0.5 % level and minimum temperature have negative impact on rice yield. The result shows, one percent increase in maximum temperature leads to 0.496 percent increase in yield of rice. Similarly, one percent increase in minimum temperature increases 0.291 percent of rice yield. In case of rainfall, it has negative and non-significant effect in yield of rice viz. one percent decrease in rainfall leads to the 0.014 percent decrease in yield of rice in Rupandehi district.

Table 4. Estimation of parameter influencing yield of wheat in Rupandehi district (1992- 2016).

Variables	**Coefficient**	**Standard error**	**t- value**
Maximum temperature	-0.401	2.227	-1.999
Minimum temperature	-0.007	2.571	-0.033
Rainfall	0.40	0.018	0.195
Constant	145.116	67.490	2.150
R^2 value =0.166 F value=1.396			

In case of Rabi season or wheat crop in Rupandehi district, no significant result has found that means 16 percent of yield loss due to the explained variables (Table 4). The remaining 84 percent of impact on yield is due to other non-explained factor. The result reveal that both maximum and minimum temperature has negative impact on wheat yield. Every one percent increase in maximum and minimum temperature leads to the decrease in wheat yield by 0.40 and0.007 percent respectively. In rabi season, increase in maximum temperature has considerable effect on wheat yield (Brithal et.al, 2014) However, rainfall has positive impact on wheat yield in

Rupandehi district. It means one percent increase in rainfall leads to the 0.40 percent increase in yield of wheat.

Table 5. Estimation of parameter influencing yield of rice in Varanasi district (1992-2016).

Variables	Coefficient	Standard error	t- value
Maximum temperature	0.155	0.920	0.669
Minimum temperature	0.056	1.575	0.248
Rainfall	0.278	0.005	1.174
Constant	-14.452	50.213	-0.288
R^2 value =0.065 F value =0.488			

Table 6. Estimation of parameter influencing yield of wheat in Varanasi district (1992-2016).

Variables	Coefficient	Standard error	t- value
Maximum temperature	-0.452	0.730	-1.920
Minimum temperature	0.074	1.117	0.339
Rainfall	-0.213	0.010	-1.006
Constant	59.314	30.829	1.924
R^2 value =0.216 F value=1.931			

The impact of climatic variables on yield of rice in Varanasi district is quite different from Rupandehi district. The effect of explained variable is very negligible i.e. 6.5 percent and rest of loss in yield is due to other factor Table (5). All the explained variable has positive impact on rice yield. It means one percent increase in maximum, minimum temperature and rainfall also leads to the increase in rice yield by 0.155, 0.056 and 0.278 respectively.

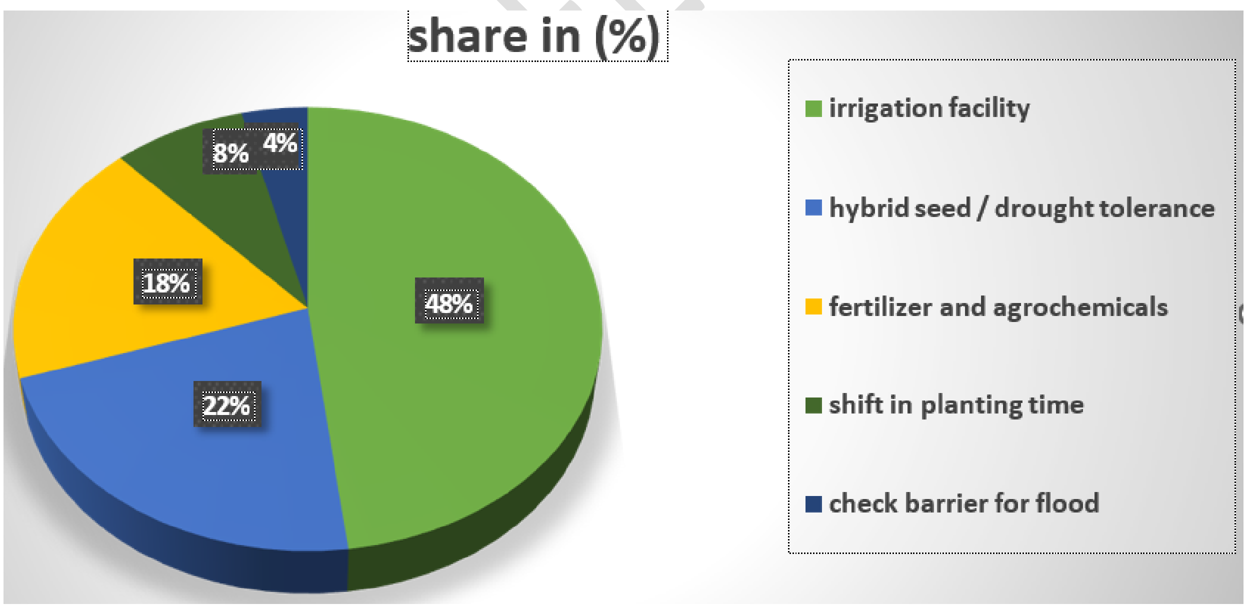
In context of wheat yield in Varanasi district 21 percent of losses due to explained variables (Table 6). Both maximum temperature and rainfall have negative effect on yield of wheat. It means one percent increase in maximum temperature and rainfall decrease the yield by 0.452 and 0.213. Although the rainfall at harvesting period should drop the yield of wheat. In another side the minimum temperature has positive effect in yield of wheat. The positive effect of raise in minimum temperature has found 5.9% increase in Wheat yield in India (Brithal et.al, 2014).

Mitigation strategies followed by farmers against climate change.

The impact of climate change on crop yield was found to be significant that observed by farmers from both the district Varanasi and Rupandehi when farmer was asked about consequences of climate change on crop production. Most of the respondent were agree about the problem of excessive drought, scarcity of irrigation water, uneven rainfall, disease, insect pest and weed infestation. Some part of Marchawar VDC in Rupandehi district are flood prone area so they were also facing problem of flood, unavailability of fertilizer and good quality of seed.

It is necessary to mitigate the effect of climate variables for better crop production. Although different sorts of measure have taken by the farmer to check the impact of climate variability on the basis of degree of vulnerability, awareness, perception, localities and availabilities of resources. However, these mitigating strategies are not sufficient as compare to the problem. Some measures followed by local farmer are set up submersible pump for irrigation, uses of high quality or hybrid seed as well as drought tolerant seeds, shifting of planting time, uses of chemical fertilizer and agrochemicals for checking weed, insect pest and diseases. Also, in the area for flood prone check barriers are constructed. Additionally, for severe sensitivity of rice production in response to climatic variables reveals to focused on climate resilient verities and varieties specific strategies should be followed (Mamun et al.2015).

Figure 3: The percentage share of different mitigation strategies followed by the local farmer.



4. Conclusion

The fundamental objective of the research was to compare the effect of climatic variables on the yield of rice and wheat in two districts (Varanasi and Rupandehi) of two different country India and Nepal. This data shows the change in climatic variables are more in Rupandehi district in comparison of Varanasi district. The result from multiple regression analysis reveals that impact of climatic variables on yield of rice and wheat is more in Rupandehi district 48% in rice and 16% in wheat. Where as in Varanasi district decrease in rice yield by 6.5% and wheat by 21%. For this result adverse effect of maximum temperature and rainfall are responsible in kharif season. However, increase in minimum temperature is beneficial for wheat production but untimely rainfall at harvesting time has adverse effect in wheat production. Although from this analysis we can draw a conclusion that other than explained variables which are not explained in this model are also have greater effect on yield of rice and wheat. In addition to the finding from above analysis, farmer have also observed the adverse effect of climatic variables on yield of rice and wheat. To minimize the risk of climatic variables farmers of both the district adopt different strategies such as set up of submersible pump for irrigation, uses of drought tolerant seed or hybrid seed, fertilizer and agrochemicals, change in planting time and check barriers for flood based on the perception and availability of resources.

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