Available Online at http://www.journalajst.com

ASIAN JOURNAL OF
SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 10, Issue, 11, pp.10484-10492, November, 2019

RESEARCH ARTICLE

CROP YIELD RESPONSE TO CLIMATE CHANGE IN DIFFERENT ECOLOZICAL ZONES OF NEPAL

[1,*]Hem Raj Regmi, [2]KedarRijal, [3]Ganesh Raj Joshi, [4]Ramesh P Sapkota, [5]Arun GC. and [6]Sridhar Thapa

[1]PhD Student, Central Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal
[2]Professor, Central Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal
[3]Visiting Professor, Central Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal
[4]Assistant Professor, Central Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal
[5]Agriculture Extension Officer, Ministry of Agriculture, Singh durbar, Kathmandu
[6]VAM Officer, UN World Food Program, Chakupat Lalitpur

ARTICLE INFO

Article History:
Received 25th August, 2019
Received in revised form
09th September, 2019
Accepted 17th October, 2019
Published online 27st November, 2019

Key words:

Crop Yield,
Climate Change,
Rainfed, Regression,
Time Series Analysis.

ABSTRACT

Agriculture is the mainstay of the Nepalese population, contributing more than one fourth to the national economy and more than 60 percent on employment. Climate change seems to be major challenge to Nepalese agriculture due to higher dependency on rain fed agriculture. The study thus aims to examine the impact of climate change and variability on crop productivity using crop production data from the Ministry of Agriculture and Livestock Development and climatic data from the Department of Hydrology and Meteorology located in three districts viz. Banke, Dailekh and Mugu districts. Multivariate time series regression analysis is used considering crop yield as dependent variable and precipitation, minimum and maximum average temperature as explanatory variables. The precipitation and average minimum temperature are found positively significant in most of the cases while the effect of average maximum temperature is negative in general. Precipitation seems to have more impact on rain fed agriculture while rising of maximum temperature is found to be positive impact in mountain district mainly for winter crops, while maximum temperature shows a positive impact on crop productivity at national level. Policy needs to be identified adaptation options for crops suitable in the different agro ecological belts as well as enhanced irrigation facilities in general to reduce risk from the climate change.

Citation: ***Hem Raj Regmi, KedarRijal, Ganesh Raj Joshi, Ramesh P Sapkota, Arun GC., Sridhar Thapa.*** **2019.** "Crop yield response to climate change in different ecolozical zones of Nepal", *Asian Journal of Science and Technology*, 10, (11), 10484-10492.

INTRODUCTION

Nepal is predominantly an agrarian country relying about 60 percent of the total population and contributing about 64 percent of share in the total industrial sector. Majority of the population live in rural areas (83% in 2011 and about 40% estimated in 2018), who mostly depend on agricultural activities as their principal source of income, employment and livelihood. In spite of rapid growth on some sectors of the economy, dependence on agriculture is still significant. Despite primary sector of the country providing high priority, this sector is facing several challenges, threatening its growth and sustainability due to rapid change of the physical and economic environment which often affect agricultural activities.

Corresponding author: **Hem Raj Regmi,**
PhD Scholar, Central Department of Environment Science, Tribhuvan University, Kathmandu, Nepal.

This necessitates preparedness to face upcoming challenges and unfolding new reality. Many changes affecting agriculture transcends geography and are trans-boundary in nature: climate change, trans-boundary animal and plant diseases pose formidable challenges. Another serious disadvantage faced by the farmers in the country is heavy dependence on rain-fed agriculture.

About 50 percent of total arable land has irrigation facilities . Livelihood security, eradication of poverty, reduction in hunger, and sustainable and inclusive growth of economy of the country thus critically hinge on the future of agriculture. As Nepal is vulnerable to climate change, this can have multiple impacts on the agriculture sector of the country. In Nepal, irrigation facilities are limited and crop production is highly affected by unusual weather patterns (Regmi, 2007). This unusual weather patterns need to be assessed and got more insights to the impact of climate change on crop yield because of dominance of rain fed agriculture in Nepal. This study thus aims to analyze the variability of precipitation and both minimum and maximum temperature on crop yield of major crops such as paddy, maize, wheat, millet, barley and potato of Nepal. We took three districts such as Mugu, Dailekh and Banke from different ecological belts viz. mountain, hill and terai, and national average in order to understand the impact of climate variabilities and variations in the impact on crop production in different ecological zones.

In a country like Nepal, the importance of accurate and timely agricultural as well as meteorological data is significant. Variations in climate conditions are associated with the variability of crop yield . Climate change affects crop growth and development, due to changes in the mean and variability of temperatures and precipitation. Temperature rise and rainfall variation cause different rapid as well as slow onset disasters like floods, landslides, debris flow, soil erosion, drought and cold waves (IPCC, 2007). The year to year variability of rainfall and temperature is the primary source of agriculture production risk that causes uncertainty in crop yield. There is no uniformity in the direction and magnitude of climate variable effects on crops . The studies of climate change impacts on crop yield have noticed regionally and globally. The impact of climate change on crop yield were found different in various areas, in some regions it increased, in others it decreased with the latitude of the area and irrigation application.

Impacts of future climate change on crop production has also been estimated in several other studies; (Malla, 2009). Loss of local crop varieties, changes in cropping systems, water scarcity during water requiring months and increasing of incidences of diseases and pests have been observed in Nepal; ; however, there are few studies in Nepal to show how climate change has affected different ecological regions, as each of the region has a distinctive agricultural and forestry land utilization pattern and has been adversely affected due to global warming and anthropogenic activities . Several studies have pointed that crop production may gain in the higher altitudes of Nepal; ; , but quantitative study is lacking, therefore, examining and comparing the nature of the impacts on a finer spatial scale across ecological region is essential to properly assess the impacts of climate change and to instigate suitable adaptation measures in the mentioned areas.

The study on climate change and agriculture arises with the increasing impact of climate change in the world. Most studies often highlight that the impact of climate change on agriculture is significant in Nepal (Malla, 2009); ; ; and). For example, (Malla, 2009) showed that temperature and rain had positive effect in yield of rice and wheat, but negative effect in maize particularly in Terai, the southern plain of Nepal. opined that extreme climate variabilities leading to torrential rains, flash floods and mass movement often negatively affected to the agricultural production. Likewise, (Maharjan & Joshi, 2013) analyzed the effect of observed climate variables on yield of major crops such as rice, wheat, maize, millet, barley and potato. They found a mixed result of climate change. For example, increase in summer rain and maximum temperature could negatively affect to the yield of maize and millet, while yield of wheat and barley could positively affect by winter rain and temperature. Conducted a study on the effect of climate change on crop production using the Ricardian approach and found that relatively low precipitation and high temperature seem to have a positive impact on net farm revenue during fall and spring, while net farm revenue is likely to have positive impact by summer precipitation but not by temperature. conducted a study to show the link between climate variables and rice production in major rice producing districts of Nepal. The author (Karn, 2012) found that increases in maximum temperature during the ripening phase contribute to an increase in rice yield up to a critical threshold of 29.9^{o} C, while the results showed a negative impact of precipitation on rice yield. assessed the effects of climate variables on yield of rice, maize, wheat and potato in the three districts of tropical regions and explored that climate variables significantly affect the crop yield but not uniformly on all crops. The authors concluded that climate variables and their deviations within growing seasons were important determinants of crop yield. In this regard, studies related to responses to crop yield due to climate change in different ecological zones of Nepal is urgently required to develop future adaptation planning strategies to address the food security situation in the country. Based on the above discussion, this study aims to examine the yield response of climate change using time series data on precipitation and temperature that have effect on the yield of crops such as paddy, maize, wheat, barley and potato.

METHODOLOGY

Regression models are commonly used to predict crop yield with a number of climatic variables such as precipitation and temperature, based on historical data on crop and climate variables mainly rainfall and temperatures, , (Lobell et al., 2008), (Lobell & Burke, 2010). The regression model using observed data of crop yield and climate variables is based on time series data. In this analysis, multivariate time series regression model is applied. The primary advantage of time series regression models over the static models are that such models capture the behavior specific to the given area and control the errors from omitted variables such as crop management and soil quality that vary spatially (Lobell & Burke, 2010). We use log linear model to assess the crop response to climate change using time series data of climate change (participation and temperature) and crop production, the functional form of the model is as follows:

$$Log(Y_{it}) = \alpha_0 + \alpha_1 T_t + \alpha_2 P_t + \varepsilon_t$$

Where, Y_{it}, T_t, P_t are yield, growing average maximum and minimum temperature, and growing season total precipitation respectively, where $\varepsilon_t$is an error term with zero mean and constant variance.

Data and descriptive statistics: The data used in this exercise are mainly secondary; obtained from Government of Nepal, Ministry of Agriculture and Livestock Development (MoALD) for crop yield of different crops of Mugu, Dailekh and Banke districts and Department of Hydrology and Metrology (DHM) under Ministry of Environment Science and Technology (MoEST) for climate related data mainly rainfall, minimum and maximum temperature as well as their averages from different field stations. These data follow the country's budgeting system (fiscal year) which begins from mid-July of the English year. The crop yield data represent the district average, which is the annual average of its growing seasons. The temperature (maximum and minimum) and precipitation data used from June to September for paddy and maize as summer crops, while data for winter crops such as wheat, barley and potato used from October to March for a period 37 years (1981 to 2017). In the study area paddy, maize and millet are grown in summer season, wheat and barley in winter season and potato in both the seasons.

Study Area

For analyzing effect of climate change on crop production and food security, we selected one district from each three ecological belt viz. Mountain, Hill and Terai with consideration of vulnerability as well as food security situation, together with capturing ecological variability. The basis for selecting Mugu district from Mountain belt is due to very high overall vulnerability index and food insecurity . Mugu is known for being both the most remote district in Nepal, as well as the least developed. Mugu's geography is very rugged. Likewise, Dailekh from hill region again with moderate vulnerability and moderate food insecurity and Banke from terai region with very low vulnerability as well as good food security. All these three districts are based on Karnali river basin and mid-western part of the country and selected to capture the variation of climate change in crop production in different ecological belts, while

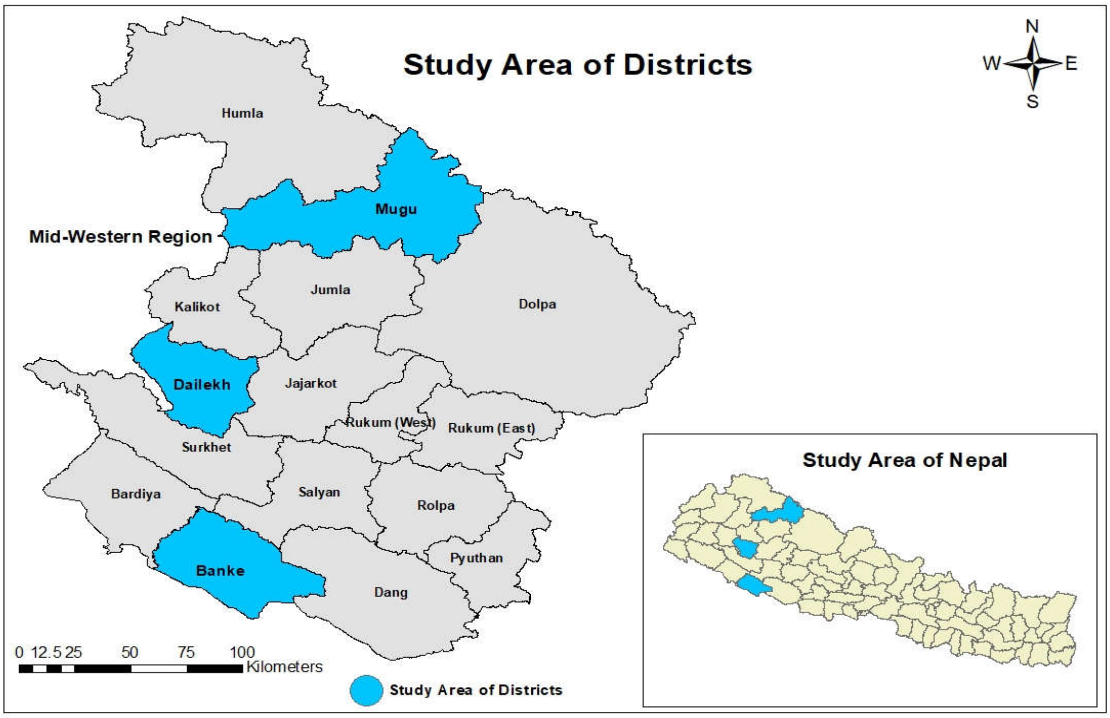
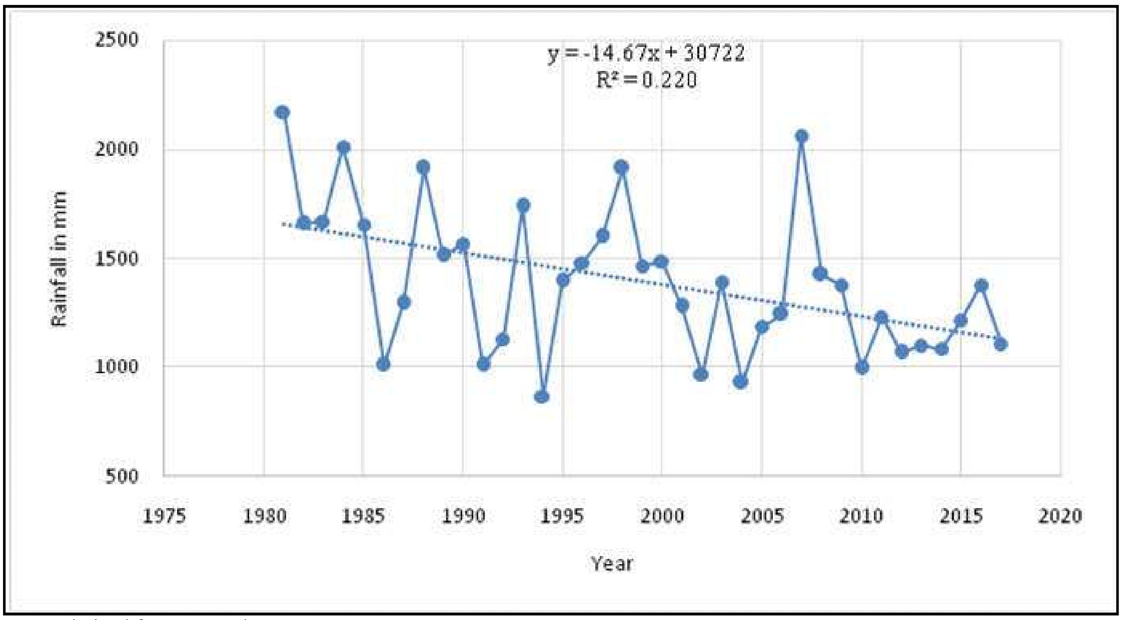
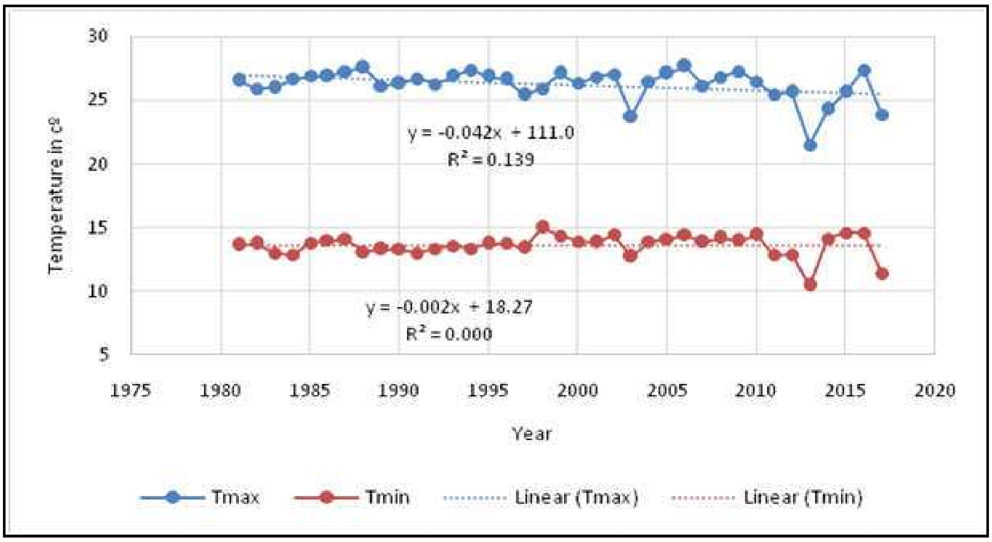


Figure 1. Map of Nepal and mid-western region (colored districts are Study Area)



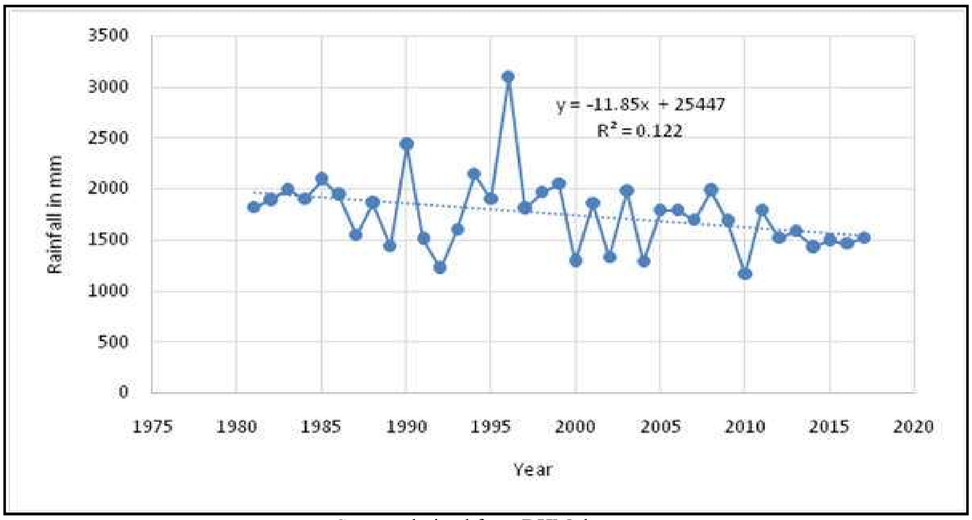
Source: derived from DHM dataset

Figure 2. Actual and linear trend of annual rainfall (in mm) in Banke from 1981 to 2017



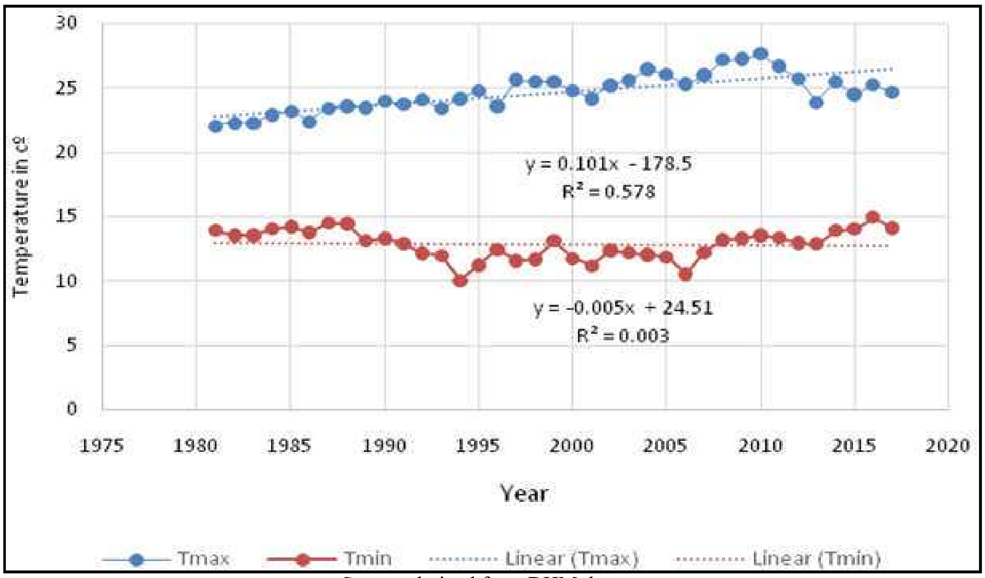
Source: derived from DHM dataset

Figure 3. Annual trend of maximum and minimum temperature in Banke from 1981 to 2017



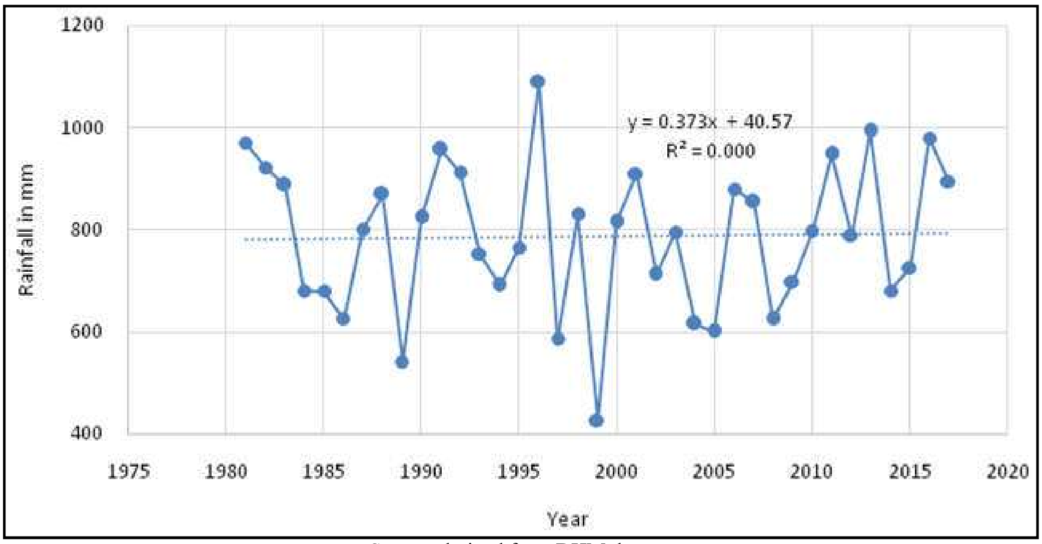
Source: derived from DHM dataset

Figure 4. Actual and linear trend of annual rainfall (in mm) in Dailekh from 1981 to 2017



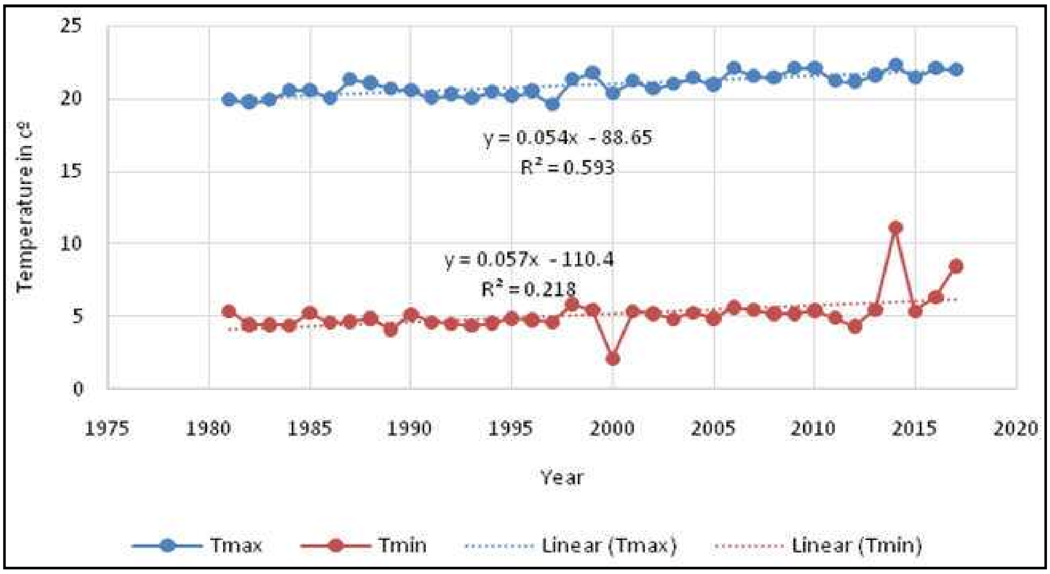
Source: derived from DHM dataset

Figure 5. Annual trend of minimum and maximum temperature in Dailekh from 1981 to 2017



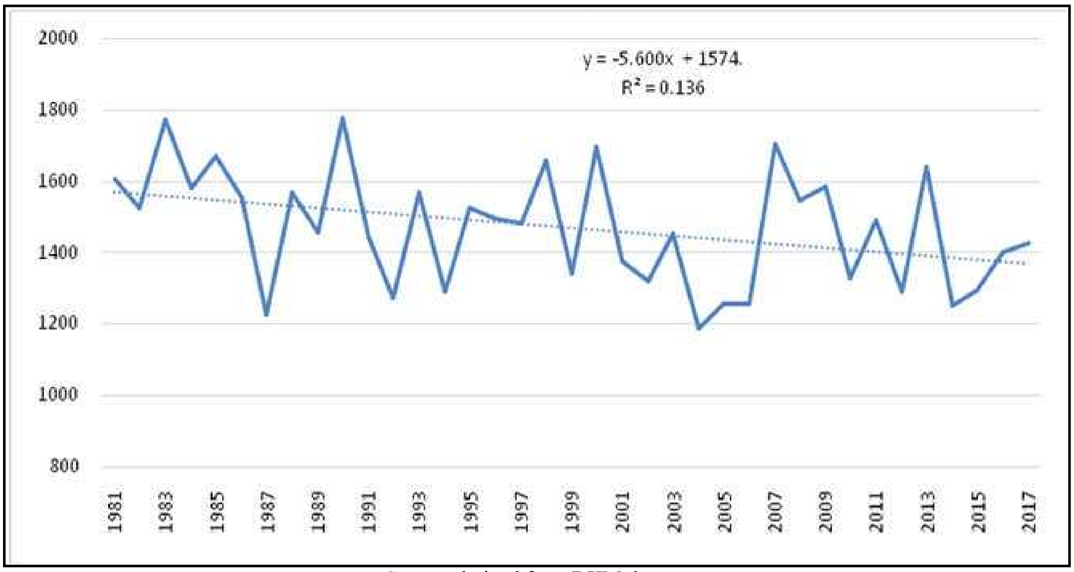
Source: derived from DHM dataset

Figure 6. Actual and linear trend of rainfall (in mm) in Mugu district from 1981 to 2017



Source: derived from DHM dataset

Figure 7. Annual trend of maximum and minimum temperature in Mugu from 1981 to 2017



Source: derived from DHM dataset

Figure 8. Actual and linear trend of rainfall (in mm) in Nepal from 1981 to 2017

The figure 4 indicates that annual precipitation in Dailekh is in declining trend. Though the rainfall trend seems relatively low fluctuations, but there is a high fluctuation between the period of 1990 to 2000. Figure 5 presents the trend of minimum and maximum temperature over a period in which the average maximum temperature shows an increasing trend while the average minimum temperature is almost stable over the last 37 years in Dailekh district. Figure 6 shows the increasing trend of rainfall as well as relatively high fluctuations in Mugu district compared to other districts. Both Minimum and maximum temperature in Mugu have recorded increasing trend over the last 37 years. Overall trend of temperature seems to be increasing mostly in the hill and mountain. Overall, national annual average rainfall shows a declining trend over a period from 1981 to 2017 with high fluctuations mainly from 1999 to 2015. This is an indication of increasing dry spell and drought in the country. Figure 9 presents the annual trend of maximum and minimum temperature in Nepal. It is interesting to note that the trend of maximum temperature is slightly moving upward which shows an indication of rising global temperature. However, there is a fluctuation in some periods. Table 1 presents the descriptive statistics of productivity of different crops and climatic data such as temperature minimum and maximum, precipitation by crop cycles of month from June to September for summer crops like paddy, maize and millet and October to March for winter crops like wheat and barley. Annual averages are taken in case of Potato, since it is grown in both the seasons. The average annual precipitation in Banke district over last 37 years is about 1395 mm with a range from 868 mm to 2173 mm per annum and shows a high deviation (Standard Deviation of more than 338). The average maximum temperature ranges from 26 to 31 with standard deviation of less than one and average minimum temperature ranges from 15 to 20 degrees Celsius again with standard deviation of less than one showing almost no change on its trend value. In Dailekh district, the data show a high variation in minimum and maximum temperature, including precipitation in different crop cycles. The overall results in Mugu district show the high variation of variables of crop yield, temperature and precipitation, as there is high difference between mean and standard deviation. Annual national maximum temperature during summer ranges from 22 to 31 centigrade, while annual minimum temperature during winter season ranges from 14 to 19 centigrade. Annual national minimum temperature is from 9 to 19 centigrade. Annual average rainfall during summer is about 212 mm, while in winter it is about 32 mm.

Results and Discussions

The effect of climate change on agriculture can be various forms, through changes in average temperature, rainfall and climate extremes. This study examines the crop yield response to climate changes using log linear models in three districts of three ecological belts such as mountain, hill and terai. The results from log linear model using crop yield as dependent variables regressed with maximum and minimum temperature of winter and summer, and winter and summer rainfall show a positive impact with rainfall and temperature maximum in Mugu district. The coefficient of rainfall is statistically significant at 5 percent and has positive sign, meaning that an increase with the rainfall from plantation to maturity period is more likely to increase crop yield of paddy, maize, millet, wheat and barley. For example, an increase in one mm rainfall during growing period of paddy crop is likely to increase 0.4 percent of productivity. Similarly, one mm rise in rainfall would help to increase wheat crop productivity by 1.2 percent. This seems to be consistent with studies carried by various researchers that climate change has higher impact on rainfed agriculture as compared to irrigated farm land .Likewise, the coefficient of maximum temperature is significant and positive for maize, wheat and potato yields. Crop yield of these crops is likely to be better if the maximum temperature increases. This seems to be for the district in the mountain, as many studies show that climate change would have positive impact on crop production . However, the coefficients of minimum temperature are not significant, applying that this does not show any significant impact on crop yield at least in this data set. Table 3 presents the results of log linear regression models of crop yield and climatic variables such as temperature minimum and maximum, and precipitation in Dailekh district.

In Dailekh, the coefficients of precipitation are significant and positive with millet and barley, implying that an increase of precipitation is more likely to increase productivity of millet and barley. As these crops such as millet and barley are often cultivated on upland, higher or sufficient rainfall could help to grow better and have higher yield. However, despite positive relation yield of paddy, maize and wheat with precipitation, none of precipitation coefficients are statistically significant. The coefficients of maximum temperature are statistically significant and positive sign with crop yield of paddy, wheat and potato, indicating that the rise of maximum temperature from crop plantation to maturity period will likely increase the crop yield. However, the coefficients of minimum temperature do not show any significance in these exercises. The results of log linear regression models for crop yield of paddy, maize and wheat with climate variables such as precipitation, maximum and minimum temperature are presented in Table 4. The coefficients of maximum temperature and minimum temperature are statistically significant with wheat crop yield, where crop yield will likely decrease with the rise of maximum temperature but increase with the decrease of minimum temperature in Banke district. For instance, rise in one degree Celsius maximum temperature is more likely to reduce wheat crop productivity by 0.8 percent, one the contrary it will increase productivity of wheat crop by 0.7 percent with an increase of minimum temperature.

It is noteworthy to highlight that yields of paddy and maize did not show any impact by climatic variations in Banke. Perhaps this may be due to good irrigation facilities in Banke compared to other hill and mountain districts, leading to relatively low impact of climate change on irrigated land as compared rainfed land. Table 5 exhibits the results of log linear model of crop yield response to climate variables mainly maximum and minimum temperature, together with summer rainfall for summer crops such as paddy, maize, millet and potato, and minimum and maximum winter temperature and rainfall for winter crops such as wheat and barley in Nepal. The results from the models show an impact of both maximum and minimum temperature on crop productivity of respective seasons but not from the rainfall. For example, rise in 1 degree Celsius maximum summer temperature is more likely to increase the productivity by 5 percent for paddy and maize and 2 percent millet, including the wheat crop productivity by 6 percent with the rise of one degree maximum winter temperature, while rise in minimum temperature is more likely to decrease crop productivity of paddy, maize, millet and potato.

Table 1. Descriptive Statistics of the study variables

Variable	Obs	Unit	Banke		Dailekh		Mugu		Nepal	
			Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std.Dev.
Paddy	37	Kg/ha	2133.6	379.9	1970.6	360.5	1747.6	187.7	2558.12	480.3
Maize	37	Kg/ha	1683.5	224.1	1730.2	246.2	1568.0	176.3	1863.41	340.27
Wheat	37	Kg/ha	1634.2	463.6	1300.3	349.0	1125.6	235.1	1737.91	428.55
Millet	25	Kg/ha	268.4	439.8	1119.8	102.8	1019.4	101.0	1082.46	76.8
Barley	37	Kg/ha	976	54.5	1029.6	176.2	977.7	129.6	1012.91	131.3
Potato	37	Kg/ha	10779.5	2734.9	8607.2	3250.1	7414.2		10464.9	2354.62
T_{max}	37	c°	30.5	0.96	24.6	1.4	20.9	0.8	26.44	0.76
$T_{max(JJAS)}$	37	c°	33.6	1.3	28.5	1.8	25.0	0.6	30.38	0.81
$T_{max(O\_M)}$	37	c°	26.3	1.2	20.4	1.5	17.6	1.1	22.49	0.85
T_{min}	37	c°	19.2	0.82	12.9	1.2	5.2	1.4	14.65	0.42
$T_{min\ (JJAS)}$	37	c°	25.8	1.3	17.6	2.1	14.2	0.7	19.77	0.53
$T_{min(O\_M)}$	37	c°	13.6	0.9	8.8	0.9	-1.1	1.9	9.53	0.46
Rain Annual	37	mm	1394.9	338.5	1754.3	366.9	787.2	145.7	1468	164.3
Rain (JJAS)	37	mm	1186.6	307.4	1450.0	363.1	559.3	122.1	1134.2	132.1
Rain (O_M)	37	mm	125.1	82.6	169.0	85.5	144.6	60.9	190.2	71.3

Source: derived from MoAD and DHM data set

Table 2. Log linear regression results of crop yield and climatic variables in Mugu district

Variables	Paddy	Maize	Millet	Wheat	Barley	Potato
Rain	0.004**(0.002)	0.01***(0.002)	0.01***(0.002)	0.012*(0.006)	0.011**(0.01)	0.000 (0.00)
T_{max}	-0.002 (0.016)	0.04***(0.014)	0.01 (0.013)	0.05***(0.014)	0.013 (0.01)	0.095***(0.02)
T_{min}	0.01 (0.012)	0.011 (0.011)	0.01 (0.010)	0.004 (0.01	0.001 (0.01)	-0.001 (0.01)
Constant	3.1***(0.358)	1.9***(0.310)	2.6***(0.295)	2.18***(0.26)	2.7***(0.19)	1.8***(0.39)
R^2	0.14	0.39	0.29	0.38	0.18	0.52
F-test	1.78*	7.034***	4.610**	6.64***	2.36*	11.68***
Obs.	37	37	37	37	37	37

*** p<0.01, ** p<0.05, * p<0.1 Standard Error (SE) value is inside the bracket

Table 3. log linear regression results of crop yield and climatic variables in Dailekh district

Variables	Paddy	Maize	Millet	Wheat	Barley	Potato
Rain	0.001 (0.001)	0.001(0.001)	0.002***(0.001)	0.01 (0.01)	0.01*(0.003)	0.00 (0.00)
T_{max}	0.02* (0.01)	0.00 (0.02)	0.001 (0.004)	0.05***(0.01)	0.032 (0.01)	0.09***(0.01)
T_{min}	0.01 (0.01)	0.004 (0.01)	-0.001 (0.003)	-0.009 (0.02)	-0.002 (0.01)	0.02 (0.015)
Constant	2.71***(0.34)	3.12***(0.29)	2.95***(0.16)	2.08***(0.22)	2.33***(0.14)	1.36***(0.43)
R^2	0.09	0.03	0.25	0.45	0.46	0.67
F-test	1.09	0.32	3.65	9.13	9.29	22.35
Total Obs.	37	37	37	37	37	37

*** p<0.01, ** p<0.05, * p<0.1 Standard Error (SE) value is inside the bracket

Table 4. Log linear regression results of crop yield and climatic variables in Banke district

Variables	Paddy	Maize	Wheat
Rain	0.001 (0.001)	0.000(0.001)	-0.01 (0.01)
T_{max}	-0.001 (0.03)	0.01 (0.02)	-0.08***(0.02)
T_{min}	0.01 (0.03)	-0.01 (0.02)	0.07** (0.03)
Constant	3.55***(0.40)	3.16***(0.31)	4.32***(0.22)
R^2	0.03	0.05	0.32
F-test	2.35	3.06	5.09
Total Obs.	37	37	37

*** p<0.01, ** p<0.05, * p<0.1 Standard Error (SE) value is inside the bracket

Table 5. Log linear regression results of crop yield and climatic variables in Nepal

Variables	Paddy	Maize	Millet	Wheat	Barley	Potato
Rain	0.001(0.35)	0.001(0.002)	0.0001(0.01)	0.003(0.006)	-0.001(0.01)	-0.001(0.002)
$T_{max.}$	0.05** (0.02)	0.05** (0.02)	0.02**(0.01)	0.06**(0.001)	0.02 (0.01)	0.07***(0.02)
$T_{min.}$	-0.08***(0.03)	-0.07***(0.03)	-0.03**(0.01)	-0.05(0.04)	-0.03 (0.02)	-0.09**(0.03)
Constant	3.43***(0.54)	3.3***(0.52)	2.95***(0.22)	2.35***(0.52)	2.82***(0.28)	3.8***(0.65)
R^2	0.26	0.24	0.18	0.16	0.12	0.26
F-test	3.87**	3.38**	2.35*	2.1	1.5	3.8**
Obs.	37	37	37	37	37	37

*** p<0.01, ** p<0.05, * p<0.1 Standard Error (SE) value is inside the bracket

Climate change affects crop productivity with a number of ways such as changes in temperature and precipitation which is being serious threat to crop productivity, thereby threatening to food security. The findings from the study of the effect of climate change variability on crop production show that overall rise in temperature has positive impact on crop productivity in the mountains, including the positive impact of increase in average precipitation mainly in the rainfed crops such as millet, barley, wheat and maize. However, rising temperature is likely to have negative impact on crop productivity mainly in terai with sub-tropical climate.

Conclusion

The findings from log linear models show both positive and negative impacts of climate variability on crop productivity. Precipitation has more likely to have impact on crop productivity mainly in rainfed land and crops. For example, rise in average precipitation is more likely to contribute for increasing crop productivity for the crops such as millet, barley, wheat and maize as compared to paddy which is cultivated in irrigated land. Likewise, rising maximum temperature has positive impact on crop productivity, mainly in the mountain for winter crops such as wheat and barley which is not the case for summer crops. However, the impact of climate variability does not show significant change in the crop productivity in Banke district.

This could be the fact that most farm land in Banke has irrigation facilities which may not have significant impact of climate change in irrigated land as compared to rainfed land. At national level, change in rainfall does not show any significant change in crop productivity, however the rise in maximum temperature of both winter and summer seasons has positive impact on crop productivity of paddy, maize, millet and wheat. On the contrary, rise in minimum temperature has negative impact on crop productivity. Overall, change in rainfall pattern seems to be less effect as compared to temperature. Similarly, paddy crop has relatively less impact of climate change as compared to rainfed crops such as millet, barley and maize.

Policy Implication: Since the study shows both the positive and negative impact of climate variability on crop productivity, there needs to be addressed the climate change issue with proper climate change adaptation programs wherever feasible. As the result shows an evidence of climate change and its impact on crop productivity, adaptation practices should be used as feasible options such as flood and heat tolerant, drought resistant, or less susceptible to pests and diseases, and improving water management through irrigation and water harvesting. Moreover, diversifying crops to minimize risks, changing planting dates and cultivating off-season vegetables could be other likely options for adaptation to climate change in Nepal. Technical support and intervention of market-based instruments such as crop insurance could help to minimize dependency on rainfall as well as reduce crop loss from climate change. Early information on climate forecast could also help to cultivate crop with change in climate. As the study simply assessed the impact of climate variability on crop productivity, it would be good to apply more robust models which can capture the variability climate change and intensity of rainfall on crop production to get better insights and measure the climate change impact on agriculture sector.

Acknowledgements

We would like to thank Ministry of Agriculture and Livestock Development, Central Bureau of Statistics and Department of Hydrology and Meteorology, Nepal for providing and allowing data for the analysis. The views expressed in this paper are those of the authors, and they do not necessarily represent those of any institution. Special thanks are also to the chief editor and other team members of this journal for accepting this paper to publish in this journal.

REFERENCES

ADB 2012. *Agriculture Development Strategy, Inception Report. Technical Assistance for the preparation of the Agriculture Development Strategy.* Kathmandu, Nepal.

Alexandrov, V. 2000. The impact of climate variability and change on crop yield in Bulgaria. *Agricultural and Forest Meteorology, Vol. 104, No.4*, 315-327.

Arnell NW, C. M. 2002. The consequences of CO2 stabilization for the impacts of climate change. *Climate Change*, 413-446.

Babel MS, A. A. 2011. Evaluation of climate change impacts and adaptation measures for rice cultivation in Northeast Thailand. *Climate Resillient*, 137-146.

Berg A, d. N.-D. 2012. Projections of climate change impacts on potential C4 crop productivity over tropical regions. . *Agriculture For Meteorology*.

Bhatt D, M. S. 2014. Climate trends and impacts on crop production in the Koshi River Basin of Nepal. . *Reg. Environ Change, 14*, 1291-1301.

BSO Banke. 2017. *District Profile of Banke District.* Statistics Office Banke.

Calzadilla. 2013. Climate change impacts on global agriculture. *Climate Change, Vol 120, Issue 1-2, September 2013*, 357-374.

CBS. 2011. *Nepal Living Standard Survey 2011/12.* Kathmandu, Nepal.

CBS.2013. *National sample census of agriculture Nepal 2011/12*. National report published by Central Bureau of Statistics, Government of Nepal, 2013.

Dahal, N. 2005. Perceptions of Climate Change in the Himalaya, *Tiempo: Climate Change Bulletin, Stockholm, Sweden*.

Granger, O. 1980. The impact of climate variation on the yield of selected crops in three California counties. . *Agricultural Meteorology, Vol 22, Issues 3 - 4*, 367-368.

IPCC.2007. *Climate change 2007: impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Edited by: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE. Cambridge University Press; 2007.

Kang, Y. K. 2009. Climate change impacts on crop yield, crop water productivity and food security – A review. *Progress in Natural Science, Vol 19*, 1665-1674.

Karki, R. A. 2012. An overview of climate change and its impact on agriculture: a review from least developing country, Nepal. . *International Journal of Ecosystem, Vol 2 Issue 2*.

Karn, P. 2012. The Impact of Climate Change on Paddy Production in Nepal. *5thSouth Asia Economic Summit Making Growth Inclusive and Sustainable in South Asia.* Islamabad, Pakistan.

Lobell DB.2007. Changes in diurnal temperature range and national cereal yields. *Agric For Meteorol* 145:229–238

Lobell, D.B. and Burke, M.B. 2010. On the use of statistical models to predict crop yield responses to climate change. *Agricultural and Forest Meteorology*, Vol 150, Issue 11, October 2010, 1443-1452pp.

Lobell, D.B., Field, C.B., 2007. Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental Research Letters* 2, 004000 (7 pp.)

Maharjan, K. L. 2011. Determinants of household food security in Nepal: A binary logistic regression analysis. . *Journal of Mountain Science, 8(3), DOI: 10.1007/s11629-011-2001-2*, 403-413.

Malla, G. 2008. Climate change and its impact on Nepalese agriculture. *The Journal of Agriculture and Environment*, Vol: 9, June 2008.

MoE. 2010. *NAPA Vulnerability Assessment Report.* Singh Durbar, Kathmandu: Ministry of Environment, Government of Nepal.

MoALD.2013. *Food balance sheet of Nepal 2013*. Ministry of Agriculture and Livestock Development, Singh Durbar, Kathmandu, Nepal, 2013.

MoALD.2017. *Statistical information on Nepalese agriculture*. Various issues, Ministry of Agriculture and Livestock Development, Singh Durbar, Kathmandu, Nepal.

NAPA. 2010. *National Adaptation Programme of Action (NAPA)*. Government of Nepal, Ministry of Environment, Kathmandu, Nepal; 2010.

NeKSAP. 2011. *Food Security Situation among the districts of Nepal.* Ministry of Agriculture and Cooperatives, World Food Program.

NPC.2019.*15th Plan Approach Paper*. National Planning Commission Secretariat, Government of Nepal, 2019.

Pant, D. K. 2012. CLIMATE CHANGE AND FOOD SECURITY IN NEPAL. *The Journal of Agriculture and Environment Vol:13.*

Pant, K.P. 2011. Economics of climate change for smallholder farmers in Nepal: a review. *The Journal of Agriculture and Environment*, Vol:12, June 2011.

Panthi J, A. S. 2015. Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. . *Reg. Environ. Chang*, 1-12.

Parry ML, R. C. 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Glob Environ Chang*, 53-67.

Poudel S, S. R. 2016. The Relationships between Climate Variability and Crop Yield in a Mountainous Environment: A Case Study in Lamjung District, Nepal. *Climate, 4:13*.

Regmi, B. A. 2007. Human Development Report 2007. *Climate Change and Human*.

Thapa S., Joshi, G. R. & Joshi, B. (2015). Impact of Climate Change on Nepalese Agriculture. *Journal of Nepalese Agriculture Economic Society*, Issues 2-3, 64-78pp

Tiwari, U., Joshi, GR and Bauer, S. 2015. Crop yield responses to climate change in the tropical region of Nepal. *Nepalese Journal of Agricultural Economics*, Vol 2-3, March 2015, 88-107pp.

****