IMPACT OF CLIMATE VARIABLES TO MAJOR FOOD CROPS'YIELDIN MIDHILLS OF WESTERN DEVELOPMENT REGION, NEPAL

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ABSTRACT

Climate change is threatening the agriculture sector especially on present and future food security in low income countries. Primary and secondary data collected through household survey and collected from different secondary source were used to assess the effects of climate variables on crop yield and the uniformity of effects across crops and growing seasons in Kaski district considering six major food crops as paddy, maize, wheat, millet, Barley and potato. A multivariate regression analysis, based on the first difference time series of crop yield and climate variables, is employed to estimate the empirical relationships between crop yield and climate variables. The results are discussed at district level empirically. It showed that climate variables significantly influence the crop yield, but not uniformly on all crops and in all growing seasons.

Key words: *Climate change, crop yield, food crops, regression analysis*

INTRODUCTION

Climate change is a phenomenon due to emissions of greenhouse gases from fuel combustion, deforestation, urbanization and industrialization resulting variations in solar energy, temperature and precipitation. Climate change affects crop growth and development, due to changes in the mean and variability of rainfall and temperature (Challinora and Wheeler, 2008).Temperature rise and rainfall variation cause drought, flood, landslide, and soildegradation that lead to declining global agricultural productivity (IPCC, 2007). The year-to-year variability of rainfall and temperature is the primary source of agricultural production risk that causes uncertainty in crop yield (Cabas*et al.*, 2010). There is no uniformity in the directionand magnitude of effects of climate variable on crops (Granger, 1980).Higher variability intemperature (higher maximum and lower minimum) negatively affects the yieldof several crops (Mc Carl *et al.*, 2008). Though developing countries did not contribute much in increasing the level of GHGs they are highly affected by climate change and have low adapting capacity. Climate Change has serious impact on cereal crops and livelihood of farming community.). Effects of climate change on agriculture are particularly high as the agriculture produces food and provides the primary source of livelihood for large chunks of weaker sections of the society (Pant, 2012). Its impacts are severe in developing countries because they have rain-fed farming systems and weak capabilities in their technological adaptation (Ogallo*et al.*, 2000). Rain-fed agriculture is likely to be affectedadversely by climate change (Pant, 2009). Because of high dependence on theagricultural sector, loss of agricultural productivity due to climate change significantly affects the economy of many developing countries (Gebreegziabher*et al.*, 2011). The impacts of climate change have already been noticed in theagricultural sector in Nepal. Nepalese agriculture is rain-fed and relies mainly on weather patterns, so even small and short period weather extremities adversely affect the production.The agricultural sector dominates

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Nepalese economy; the contribution of agriculture and forestry sectors to total Gross Domestic Product (GDP) over 2001/02 to 2010/11 is 34.2% on average (MoAD, 2012). Agricultural dependence makes the economy sensitive to climate variability (World Bank, 2002). Intensive rain concentrated in a particular month has a devastating effect on crop production (McCarl*et al.*, 2001). If agricultural production in Nepal is adversely affected by the climate change, the livelihoods of two-thirds of the labor force, particularly of the rural poor will be at threat.

Previous studies by Welch *et al.*, 2010; Sheehy *et al.*, 2006; Chen *et al.*, 2004 suggest that there are heterogeneous effects of climate variables on crop yield that depend on crop types, growing seasons, and regions. The existing studies do not cover the assessments of the intra-regional site-specific variations of the impacts of climate change on crop yield. Spatial patterns of climate and their effects on crop yield are essential to identify vulnerability and determine the suitable regional agricultural adaptive strategies to climate change (Tao *et al.*, 2008). A betterunderstanding of the empirical relationships between crop yield and climate variables is essential for implementing adaptation to climate change inagriculture (OECD, 2012). There are few studies in Nepal (Poudel and Kotani, 2012; Pant, 2012; Joshi *et al.*,2011; Malla, 2008) that empirically evaluate the effects of climate variables oncrop yield. Malla (2008) analyzes the relationships between climate scenariosand agriculture, which is based on datagenerated in a controlled experimental condition. Joshi *et al.* (2011) assess the relationships between crop yield and climate variables by using time series analysis, but their study does not cover the heterogeneity of climate change impacts on crop yield across spatial dimensions within Nepal and has limitations in capturing the effects of the intra-seasonal variations of climate variables on crop yield. Poudel and Kotani (2012) assess the relationships between crop yield and climate variables and the heterogeneity of impacts across growing seasonsand altitudes in the central region of Nepal, but do not assess the heterogeneity ofclimate change impacts on crop yield within geographic regions and their study has limitations in capturing the effects of day versus night temperature on crop yield.

This study evaluates the empirical relationships between crop yield and the corresponding growing seasonal climate variables in different sites within Kaski district of Nepal. The study assesses the impacts of growing seasonal climate variables on the yield of the major food crops (paddy, maize, wheat, millet, barley and potato) across crop types, growing seasons, and adds information and insight to the existing literature of climate change impacts on Nepalese agriculture. The findings are useful for estimating climate variable effects on crop yield and identifying the most vulnerable crops for prioritizing strategies for adapting to climate change. An understanding of the impacts of recent climate trends on major food-crops would help to anticipate impacts of future climate changes on food self-sufficiency of the country.

Both maximum and minimum air temperatures are considered to assess the effects (direction and magnitude) of the day and night temperature on crop yield, assuming difference in the influence of day versus night temperature on crop. Maximum and minimum temperature can impact differently indifferent crops and on different regions; temperature increase during the day can have different effects on the crop than temperature increase during the night. The understanding of the effects of temperature during the day and night on crop yield is necessary because warming trend during the day and night differs; minimum temperature has been rising faster than the maximum temperature in some Asian countries (Welch *et al.*, 2010). In most regions, maximum temperature increase is more harmful to crop yield than minimum temperature increase (Lobell, 2007).

METHODOLOGY

Precipitation and temperature are the most widely used climate variables to assess the impact of climate change. Rainfall is the most important form of precipitation in terms of meeting water requirement of agricultural crops. Daily mean air temperature is the widely used temperature variable to assess the effects of global warming on grain yield. The use of mean air temperature assumes no difference in the influence of day versus night temperature. However, the inclusion of minimum and maximum temperature in the assessment will capture differential effects of day and night temperature as well as climate extremities to some extent.The study is based on primary (household survey)and secondary data.Literatures relating to the climate change and food security are reviewed in addition to the national policies relating to the food security directly and indirectly. Regression models are useful to predict crop yield changes due to changes in climate variables, based on historical data on crop yield and climate variables, is common (Poudel and Kotani, 2012; Joshi *et al.*, 2011; Lobell and Burke, 2010; Kim and Pang, 2009; McCarl*et al.*, 2008 and Lobell and Field, 2007). The regression model using observed data of crop yield and climate variables is based on time series. In this study, a multivariate time series regression model, a common approach (Joshi *et al.*, 2011and Tao *et al.*, 2008) based on the first difference time series (difference in values from one year to the next) for yield and climate variables is used. It is assumed that crop yield responds to year-to-year changes of climate variables, and use of the first difference time series of the crop yield helps to remove the non-climatic influences such as adoption of new varieties and changes in crop management practices (Lobell and Field, 2007).

Crop specific growing seasonal averages are used to make the regression results realistic. Consideration of the growing seasonal average for each climate variable for each crop produces the best-fit model R^2 (Lobell and Field, 2007). This study considers the total growing seasonal rainfall, average growing seasonal maximum and minimum temperatures, and standard deviations of monthly rainfall and temperature within the growing season. The standard deviations of rainfall and temperature are included in the regression model to assess the intra-seasonal effects of climate variables on crop yield. The standard deviations of monthly rainfall and temperature within a growing season are considered on the basis that sub-seasonal variations are critical to crop growth.

Analysis is done for estimating the effects of rainfall and temperature on food production in Kaski district using multivariate regression analysis. The ordinary least square method is used to estimate the contribution of climate variables to crop yield. The STATA tool is used to run the regression model. The multiple regression function estimated in the study is expressed as (Joshi *et al.,* 2011):

$\Delta Yield = m + r_y \Delta Climate + \varepsilon$……………………………………………………………………………………………………(1)

Here, ΔYield is the observed trend in yield, m is the average yield change due to management and other non-climatic factors or intercept, ΔClimate is the observed trend in temperature and rainfall, $r_y$is the yield response to this trend, and ε is the residual error. Detrending of the yield and climate variables and using the residuals to calculate quantitative relationships between variation in climate and yield can remove non-climatic influences such as adoption of new cultivars and changes in crop management practices (Lobell*et al.*, 2005). Due to consistency in the availability of climate data from the Kaski district, the period from 1977 to 2012 collected from Department of Hydrology and Meteorology, Nepal. A period of more than 30 years is qualified for study of the impact of climate variables on yield of the food crops as response to climate change (IPCC, 2007). District average yields of the food-crops from 1980 to 2015 were collected from different publications of the Ministry of Agriculture Development.

Change in crops yields due to climate variables is calculated using coefficient of theclimate variables for the respective crops and observed change in the climate variablesduring the study period i.e., $\Delta Y_i=(\beta_{1i}*\Delta R)+(\beta_{2i}*\Delta T_{min})+(\beta_{3i}+\Delta T_{max})$. Here, ΔY_i is observed change in yield of i^{th} crop due to climate variable, and β_{1i}, β_{2i}, and β_{3i}, are coefficient of rainfall, maximum summer temperature, and minimum summer temperature respectively for i^{th} crop. Similarly, ΔR, ΔT_{min}, and

¤T_{max} are observed changes in rainfall, summer minimum temperature, and summer maximum temperature, respectively, during the study period.

RESULTS AND DISCUSSIONS

CROPS' YIELD TREND

The yield trend of the food-crops based on the regression coefficient against time shows that time has significant (P-value <0.00) effect on yield of all the food-crops. However, the yield trend shows very different patterns (Figure 1). Potato has the highest regression coefficient against time variable. Potato yield has increased from 7.5 to 14.9 ton/ha from 1980 to 2015 contributing the yield growth rate of 2.16%. Except for the year 1985, during which the yield of potato declined, potato yield has been continuously increasing. Wheat also shows better performance in terms of yield growth. With the regression coefficient of 0.029 against time variable, yield growth rate of wheat is 1.91%. Yield growth rate of paddy is 2.37% during 1980-2015. Yield growth rate of only these three crops is higher compared to population growth rate (1.35%) of the country. Maize yield is also increasing but the growth rate is well below the population growth rate. Sharp decline in the yield of paddy and maize in 1982 and 2006 can be linked to sharp decline in summer rain in the same year (Figure 1 and 2). Yield growth of barley and millet, which are also a minor crops are relatively stagnant, growing at the rate of less than 1%.

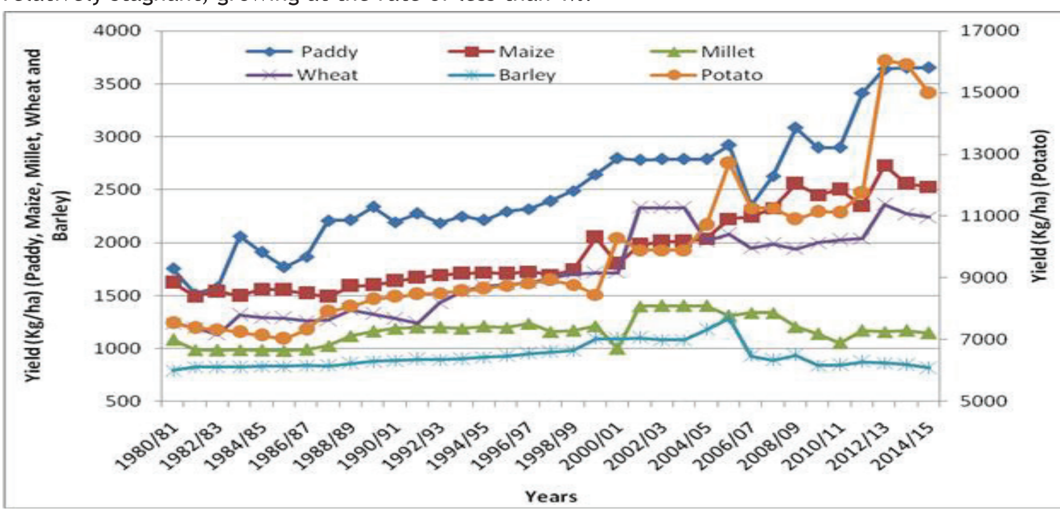

Figure 1 : Yield trend of major food crops in Kaski district

Source : Ministry of Agriculture Development, 2014

1.1 TREND OF CLIMATE VARIABLES

Trend of minimum temperature, maximum temperature,and rainfall for summer and winter is presented in Figure 2 and 3, respectively. Only maximum temperature for winter and summer season shows significant (P-value <0.00) increase over time, whereas minimum temperature and rainfall for both seasons show non-significant association with time variable.

Rainfall fluctuates over the years with less degree of predictability. However, it is inincreasing trend in summer season, but in decreasing for winter. The coefficients suggest that summer rainfall trend is increasing by 2.32 mm every year whereas winter rainfall is in decreasing trend by 0.59 mm every year. Rainfall in Nepal is concentrated during summer (around 75%) season. The positive coefficient for summer rainfall and negative coefficient for winter rainfall indicates that rain in summer is becoming more intense, which could hamper yield of summer food-crops due to water borne disaster like flood and landslides. However, still the relationship between rainfall and yield show positive correlation, i.e. yield will grow with increased rainfall and decrease with decreased rainfall. There was no rain during winter and the lowest during summer in 2008 which coincides with the low crop yield.

Coefficients of temperature for both seasons are positive except for winter minimum temperature. Winter maximum temperature is increasing at higher rate compared to summer maximum temperature. Summer and winter maximum temperature trend is increasing at the rate of 0.028^{0}C and 0.045^{0}C each year between 1977 and 2012, respectively. Summer minimum temperature is also in increasing trend every year by 0.01^{0}C. However, winter minimum temperature is decreasing trend each year but at very low rate 0.001^{0}C. Increase intemperature up to 2^{0}C will increase the food-crops yield in Nepal (Malla, 2008).

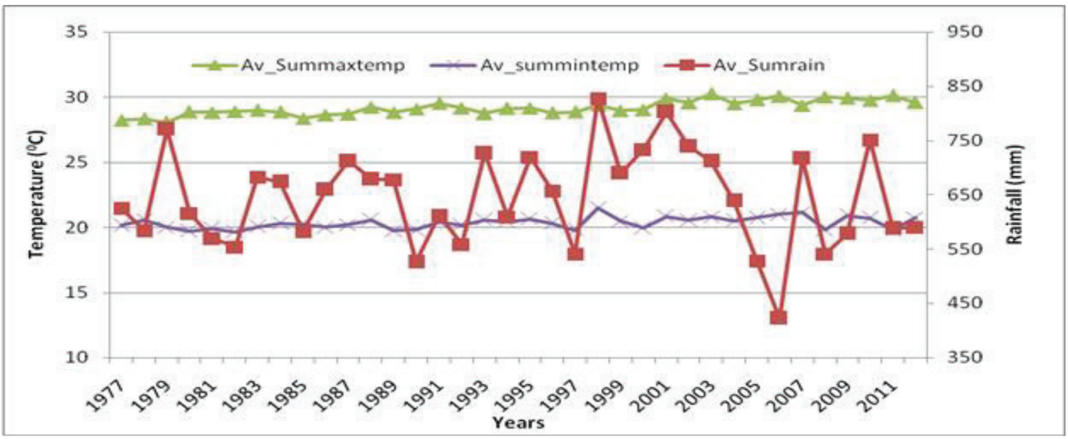

Figure 2 : Trend of average summer rainfall, summer maximum and minimum temperature of Kaski

Source : Department of Hydrology and Meteorology, Nepal

Therefore, the increase in temperature during the period i.e. below 20^{0}C would be favorable for growth in yield of food-crops. However, decline in minimum winter temperature could hamper the yield of winter crops as frost frequency caused by decline in minimum winter temperature which influence wheat yield adversely (Nicholls, 1997).

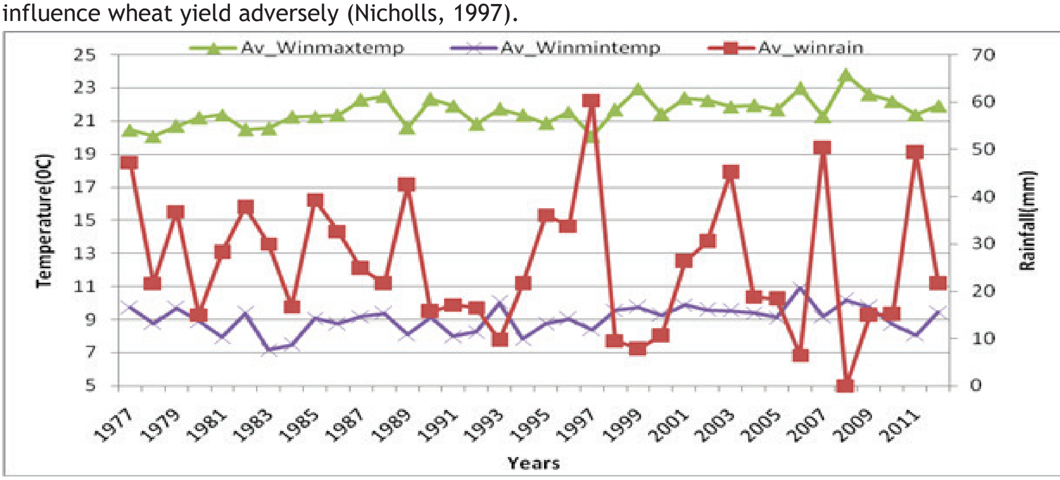

Figure 3 : Trend of average winter rainfall, maximum and minimum temperature of Kaski district

1.2 CLIMATE VARIABLES AND CROP YIELD RELATIONSHIP

The results from multivariate regression analysis are presented separately for both summer and winter crops in Table 1, and 2, respectively.

Table 1 : Relationship of summer food crops and summer climate variables

Variable	Paddy		Maize		Millet		Potato	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Sumrain	0.012*** (0.004)	0.01	-0.002	0.43	-0.001 (0.001)	0.56	0.003 (0.013)	0.79
Summintemp	-0.15(0.12)	0.25	0.07(0.006)	0.32	0.02(0.03)	0.55	0.21(0.38)	0.58
Summaxtemp	0.06(0.11)	0.61	-0.13**	0.04	-0.04(0.03)	0.19	-0.02(0.35)	0.95
R^2	0.24		0.12		0.03		0.11	

Note *** Significant at the 0.01 level, and ** significant at the 0.05 level, Sumrain-Summer rainfall, Summintemp-Summer minimum temperature, Summaxtemp-Summer maximum temperature, figures in parentheses indicates standard error

The results suggest that the model is able to describe a variation in food-crops yield rangingfrom 25% in paddy to only 1% in the case of barley. Though, the regression results show very few significant relationships between yield and climate variables, such coefficient can be used to assess real effect of climate variables in change of yield of food-crops (Nicholls, 1997). In addition, sign of coefficients give direction of movement of yield against change in climate variable. Climate variables show significant relations with paddy and maize only. The coefficient indicates that paddy yield increase significantly with increase in summer rainfall. Maize yield shows negative relation with summer maximum temperature, i.e., if summer maximum temperature increases yield of maize will decline sharply.

Table 2 : Relationship between winter food crops and winter climate variables

Variable	**Wheat**		**Barley**	
	Coefficient	P-Value	Coefficient	P-value
Winrain	0.003(0.004)	0.52	0.001(0.002)	0.69
Winmintemp	0.04(0.03)	0.15	-0.002(0.02)	0.87
Winmaxtemp	0.008(0.03)	0.78	0.01(0.02)	0.54
R^2	0.13		0.01	

Note :Winrain-Winter rainfall, Winmintemp-Winter minimum temperature, Winmaxtemp-Winter maximum temperature

The current trend in climate variables has contributed positively to yield of both wintercrops namely wheat and barley. In the case of wheat, there is 581 kg increase of yieldduring the study period, out of which 28.1 kg is contributed by the current climate trend. Decreasing winter rain and winter minimum temperature offset the positive effect ofincreased winter maximum temperature. For barley, the current climate trend contributed around 28% of the yield increase. Such increase can be attributed to increased winter maximum temperature and decreased winter minimum temperature. In the case of summer crops, only paddy is favored by the current climate trend. It has contributed 34 kg increase in paddy yield. An increase in summer rain and summer maximum temperature has contributed highly in such increase in paddy yield. Other crops especially maize is adversely affected by the current climate trend in Kaski. The adverse impact of increased summer maximum temperature and summer rain are the main factors which caused suppression of yield by 69 and 23 kg/ha for maize and millet, respectively. In the case of potato, the adverse impact caused by increase in summer maximum temperature offsets positive impact of increased summer rain and summer minimum temperature. The current climate trend suppress the yield of potato by 72 kg/ha.

CONCLUSION

This paper analyzed the impact of current trend of climate variables on yield of six main food-crops of summer and winter season crops. Yield of potato, wheat, paddy, and maize is in growing trend, but fluctuates over the years, whereas yield of millet and barley, two minorcereal crops, is growing very steadily. In summer, each of the climate variables is in increasing trend, whereas in winter, rainfall and minimum temperature is in decreasing trend. Insummer, increase in rain and maximum temperature has contributed positively to yield growth of paddy. Similarly, increase in wheat and barley yield is contributed by current climate trends. However, increased summer rain and maximum temperature suppressed the yield growth of maize and millet, whereas negative impact of increase in summer maximum temperature outweighed positive impact of increased summer rain and summer minimum temperature in case of potato.

The indicated that food-crops grown in summer are adversely affected by the current trend of climate variables in Kaski district except for paddy Maize and millet crops are adversely affected by increase in rainfalland maximum temperature. On the other hand, though rainfall is at declining trend in winter, increase in temperature has positively contributed to the yield growth of both wintercrops. With this, it can be 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. Moreover, these two crops are important staple food in case of Nepal, especially in mountain and hills that are also exposed to higher degree of vulnerability to climate change. The main short coming of this study is treating the mid hills of western development region as one basket despite the huge diversity existing within. Therefore, it is also recommended to conduct similar studies considering the variation caused by ecological and administrative division of the country. The empirical analysis does not capture the details of crop physiology, but it does capture the net effect of the processes by which climate variables affect yield. Besides climate variables, other factors such as crop management practices also play a significant role in determining crop yield and coping the adverse impact of climate change. The estimates of rainfall and temperature, therefore, donot represent the correct determinants of crop yield. The findings are useful for estimating climate change impacts on crop yield and determining the most vulnerable crops for prioritizing adaptation strategies for climate change.

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