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Analyzing the Relationship between Climatic Variability and Vegetables Yield: A Study in Syangja District, Nepal

N. Regmi[1*], B. Ghimire[1], S. Baral[2] and S. Dhakal[3]

[1]Ministry of Agricultural Development (MoAD), Government of Nepal, Nepal.
[2]Ministry of Livestock Development (MoLD), Government of Nepal, Nepal.
[3]Agriculture and Forestry University, Rampur, Chitwan, Nepal.

Authors' contributions

This work was carried out in collaboration between all authors. Author NR designed the overall study, performed survey, data entry and the statistical analysis and wrote the protocol. Author BG managed the analysis, made interpretations and wrote the first draft of the manuscript. Authors SB and SD managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Vegetable production is highly dependent on climatic variability. Several studies have concluded that Syangja district (latitude 28°4'60 North and lo ngitude 83°52'0 East) of Nepal is more vulnerable to climate change; thus, a changing climate should have a significant impact on vegetable crop yields. In this paper, the relationship between climate variation and vegetable output in Syangja district for the period 2005 to 2014 was analyzed. This work aims to explore the impact of climate change on major vegetable crop yields and to determine their relationships based on a regression model between historical climatic data and yield data for vegetable crops. Tomato (Solanum lycopersicum) was ranked as the most affected vegetable crop in the study area. An analytical analysis of the last 20 years of climatic data from meteorological stations of Syangja district was

**Corresponding author: E-mail: binodghim@gmail.com, regminirmal5@gmail.com;*

done. Microsoft excels and STATA12 have been used for the trend analysis and quantification of climatic data. Trend analysis of area under vegetable and productivity shows increasing trend over last 10 years in the study district. Both maximum and minimum temperature shows the increasing trends over the last 15years. The mean maximum temperature was increasing significantly ($P<0.1$) at the rate of 0.029℃ per year, while the average minimum temperature was increasing significantly ($P<0.01$) at the rate of 0.044℃ per year. Rainfall shows decreasing trend by 11 mm per year and relative humidity in the morning and evening shows increasing trend by 0.009 and 0.27% per year respectively. Logistic regression analysis was used to determine the role of climatic variables in productivity of Vegetable crops. The logit regression analysis of vegetable production with climatic variables revealed a coefficient of determination of 0.94 indicating 94% of vegetable production variance is explained by climatic variables. Results showed positive significant relationship with area under vegetable cultivation ($P<0.1$) and negative significant relationship with average minimum temperature ($P<0.5$).

Keywords: Climate; vegetable; temperature; rainfall; regression; Nepal.

1. INTRODUCTION

Climate change has significantly affected global agriculture in 21st century and Intergovernmental panel on climate change assessment report indicates that most countries will experience an increase in average temperature, more frequent heat waves, more stressed water resources, desertification and periods' of heavy precipitation. IPCC [1] reported that the global mean surface air temperature has increased by 0.6±0.2℃ cover 20th century. Climatic variability and change has always presented a threat to food security in Nepal through their effect on rainfall, soil moisture and production. MoE/NAPA [2] indicated the rise in Nepal temperature is 0.04-0.06ºC. Tiwari [3] showed that average temperature of Nepal has increased from 0.06 to 0.098℃ cover last 30 years. The projected figures for Nepal further show that average increase in temperatures of 1.2℃ for the year 2030, 1.7℃ for 2050 and 3.0℃ for 2100. Literature on economics of climate change suggests that although global crop production may be boosted slightly by global warming in the short term before 2030, it will ultimately turn negative over the longer term, IPCC [4].

A number of studies have attempted to assess/predict the potential effect of climate change on agricultural production. Analysis of the last 30 years of climatic data from Lamjung district using Mann-Kendall and Sen's Slope showed an increase in temperature of approximately 0.02˝C to 0.07˝C per year in different seasons and a mixed trend in precipitation. Although there was no significant impact of the climate variables on the yields of all crops, the regression analysis revealed negative relationships between maize yield and summer precipitation and between wheat yield and winter minimum temperature, and a positive relationship between millet yield and summer maximum temperature (Poudel et al. [5]).

Climate change affects agriculture in a variety of ways. The interaction of temperature increase and changing precipitation patterns determines the availability of soil moisture. With rising temperatures, both evaporation and precipitation are expected to increase. The resulting net effect on water availability makes agriculture and livelihood of the people more vulnerable. The agriculture in Nepal is vulnerable for two reasons. First, the existing system of food production is highly climate sensitive because of its low level of capital investment and adoption of modern technological options. Second, agriculture is the main source of livelihoods and thus climate change will put greater number of people at risk when agriculture is impacted due to climate variability and uncertainty (Dahal et al. [6]).

1.1 Objectives

The main objective of the research was to identify the relationships between climate variability and vegetable yield in Syangja district of Nepal.

To achieve the main objective, specific objectives were:

- To measure the impacts of climate change on vegetable crops (Cabbage; Brassica Oleraceae var. Capatita, Tomato; Lycopersicum esculentum and Cauliflower; Brassica Oleracea var. Botrytis) of the study area.

- To analyze trend of climatic data (precipitation, relative humidity and temperature) of study area.
- To analyze the farmer's perceptions on climatic variability.

2. METHODOLOGY

2.1 Primary Data

Primary data was collected through the means of household interview using interview schedule with semi structured questionnaires. Information on various aspects of climate change as perceived by the farmers was collected. 100 respondents were selected to collect primary information for this study using random sampling techniques.

2.2 Secondary Data

Secondary data were extracted from published and unpublished documents, newsletter, journal, bulletins, annual reports and relevant articles from different agencies including Ministry of Agriculture Development (MoAD), District Agricultural Development Office (DADO) and local agencies. Rainfall and temperature (1995-2014) data were collected from Department of Hydrology and meteorology (DHM) of the Syangja station. Agricultural data sets on vegetables area and production was obtained from District Agriculture Development Office Syangja. The vegetable cultivation in rainfed system was further analyzed with climatic variables.

2.3 Data Analysis Procedures

Primary data were interpreted using secondary data to authenticate the finding of primary data. The data and information collected were tabulated in the MS-Excel-2007, SPSS 16.0 and MS-Word-2007 and was used for data processing, data analysis and interpretation of information collected. The data were analyzed by using different statistical tools. Regression analysis was done to see the trends in temperature, rainfall and productivity. Also, the vegetable productivity trend was analyzed using regression combining the data of rainfall, area under vegetables and temperature. Five points scaling techniques was applied to rank the most affected vegetable crop due to changed climate. The results thus obtained were presented pictorially in charts, diagram, graphs etc.

2.4 Multivariate Regression Analysis

Multivariate regression analysis of climate anomalies and vegetable yield anomalies has been performed to confirm the percentage of the response variable variation from the predictor variable that is explained by a linear model in equation below.

$$\text{Ln } YH_t = a + b_1T + b_2\ln PRC_t + b_3\ln TMP_t$$

Where,

YH= yield for 't' years

T= Time trend

PRC_t = Rainfall measured in millimetres for 't' years

TMP_t = Temperature measured in degree Celsius for 't' years

a, b1, b2 ,b3= intercept and slope of the estimated regression line, where YH is the observed change in the yield due to temperature and precipitation in the same season as crop growth and b_1, b_2 and b_3 are coefficients of the time, precipitation, temperature during the season, respectively. Similarly ln PRC_t and ln TMP_t are the observed changes in precipitation and temperatures of the seasons respectively, during the study period.

3. RESULTS AND DISCUSSION

3.1 Trend of Climatic Variables

3.1.1 Area and productivity of vegetables over the time in Syangja district

The secondary data were taken for analysis and interpretations were made accordingly. The study revealed that the area of vegetable in the Syangja district was in increasing trend during 2005 to 2014. The positive value of slope indicates the increasing trend on area allocation over the time. Similarly there was slight increase with some wide fluctuations in vegetable productivity during the same period of time. The area for vegetable was increasing at the rate of 23.24 hac per year and the productivity was increasing at the rate of 0.101 mt/hac in Syangja district over last 10 years as shown in Fig. 1.

3.1.2 Trend of productivity and rainfall in Syangja district

The study revealed that productivity of vegetables in Syangja district was increasing at the rate of 0.101 mt/hac annually. Maximum productivity has been observed in year 2011 and 2012 at rainfall of 375mm annually (Fig. 2).

3.1.3 Trend of maximum temperature and productivity at Syangja district

The trend analysis of productivity versus maximum temperature showed that productivity of vegetables was maximum in year 2011 and 2012 when the temperature range was in between 23.5 to 24 degree Celsius (Fig. 3). The result also revealed that maximum temperature is increasing at the rate of 0.029 degree Celsius annually and productivity is also increasing at the rate of 0.101 mt /hac annually. According to Vants Hoffs law for every 10 degree rise in temperature the rate of dry matter production doubles which is applicable up to temperature range of 5-35 degree Celsius. Sato et al. [8] demonstrated that moderate elevations of daytime and/or night-time temperatures can have negative impact on tomato yield.

3.1.4 Trend of average temperature and productivity at Syangja station

Analysis of average temperature and productivity of last 10 years of Syangja district showed that productivity was increasing with increase in average temperature. The highest productivity was noticed in the year 2011 and 2012 when average temperature was in the range of 25 to 26 degree celcius (Fig. 4). The increase in productivity with increase in average temperature will be for certain limit after which productivity will be decreased due to effect of high temperature on pollen set, fruit set and flower initiation.

3.1.5 Trend analysis of productivity and relative humidity at Syangja station

Relative humidity is the amount of water vapor present in the air as percentage which could be held at saturation at same temperature and air pressure. It has influence on transpiration as low humidity tends to increase transpiration and high humidity has opposite effect. However higher humidity for longer time favors incidence of diseases and pests attack on vegetables. While analyzing the morning and evening relative humidity of last 20 years of Syangja station, it is clear that both morning and evening relative humidity increased significantly over the time. The trend analysis showed that morning and evening relative humidity increased by 0.009% and 0.270% per year.

3.1.6 Trend of temperature at Syangja station

While analyzing the maximum and minimum temperature of last 20 years, it is clear that both minimum and maximum temperature increased significantly over time period. The trend analysis showed that maximum temperature and minimum temperature increased by 0.029 and 0.044 degree per year respectively (Fig. 6). Mean maximum temperature was increased in less than average of Nepal (0.042 degree Celsius per year)(Baidya and Karmacharya, [9]). The R^2 value is significant at 0.5 % level of significance.

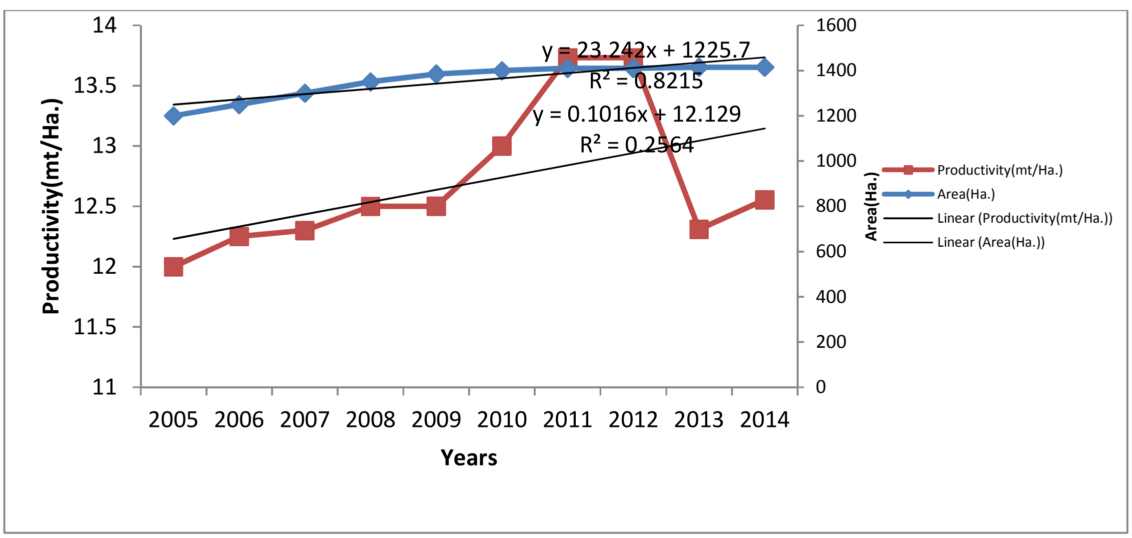

Fig. 1. Area and productivity of vegetables over the time in Syangja district (2005-2014)
Source: DADO, Syangja [7]

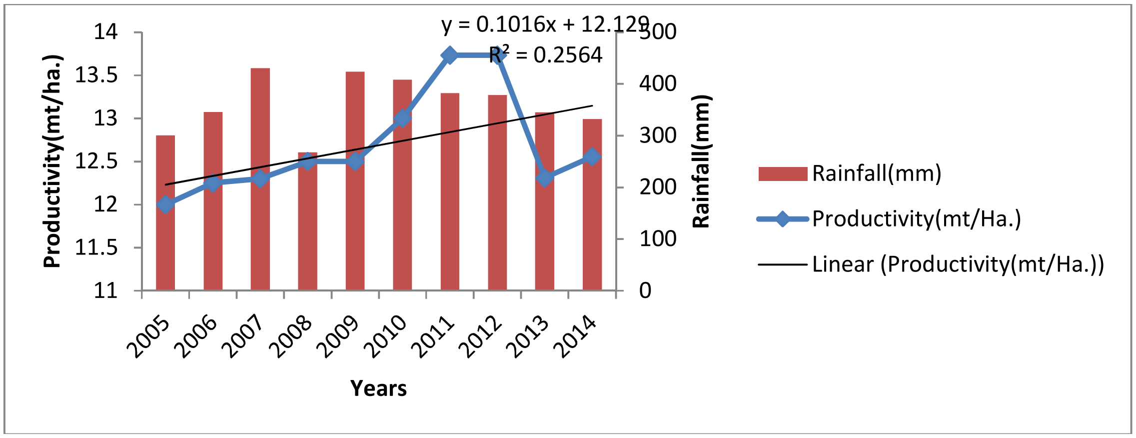

Fig. 2. The productivity of vegetables as influenced by rainfall in Syangja district (2005-2014)

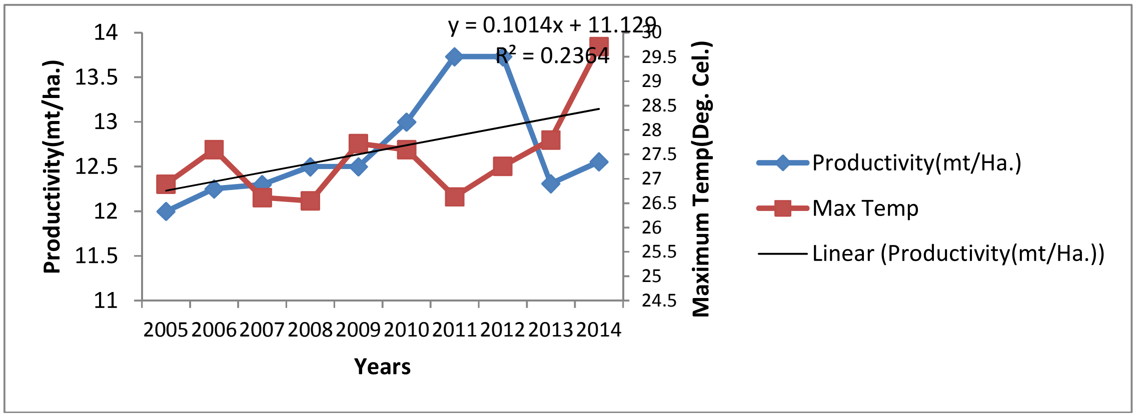

Fig. 3. The productivity of vegetables as influenced maximum temperature in Syangja district (2005-2014)

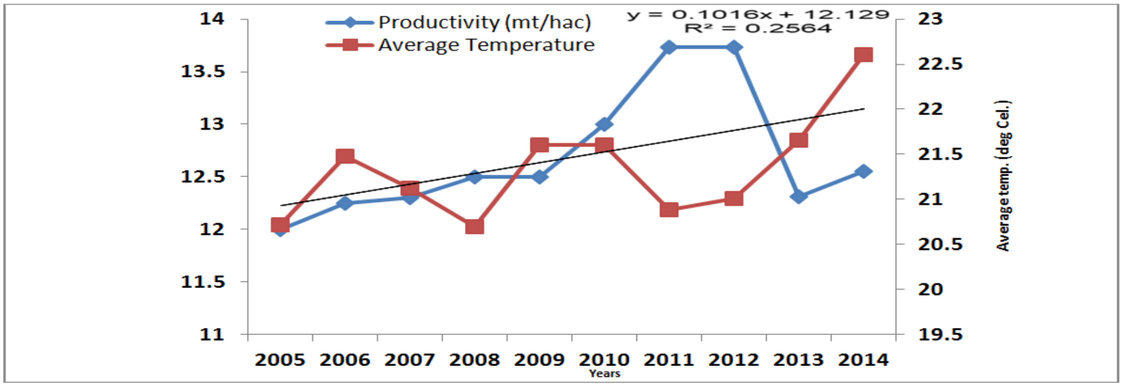

Fig. 4. The productivity of vegetables as influenced mean temperature in Syangja District (2005-2014)

3.1.7 Trend of rainfall at Syangja station

Analyzing the rainfall data of last 20 years, irregular pattern of rainfall was observed with highest recorded (546.83 mm) in 2002 and lowest (267.293 mm) in 2008. Perusal of rainfall trend in Fig. 1 clearly showed that, the variability in rainfall over the period of 20 years between the years was distinct. It was ranged from 267mm (2008) to 547 mm (2002).

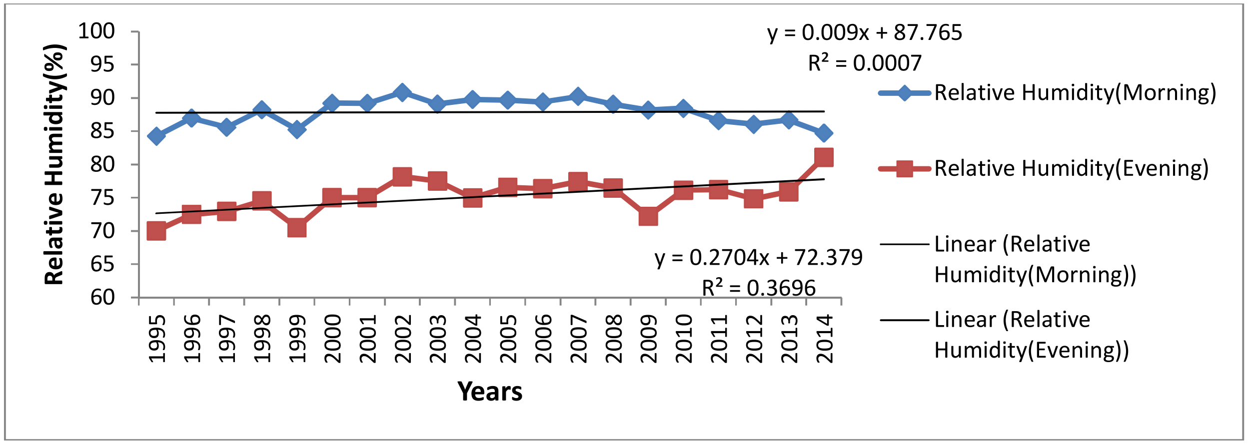

Fig. 5. Relative humidity vs productivity in Syangja district, (1995-2014)

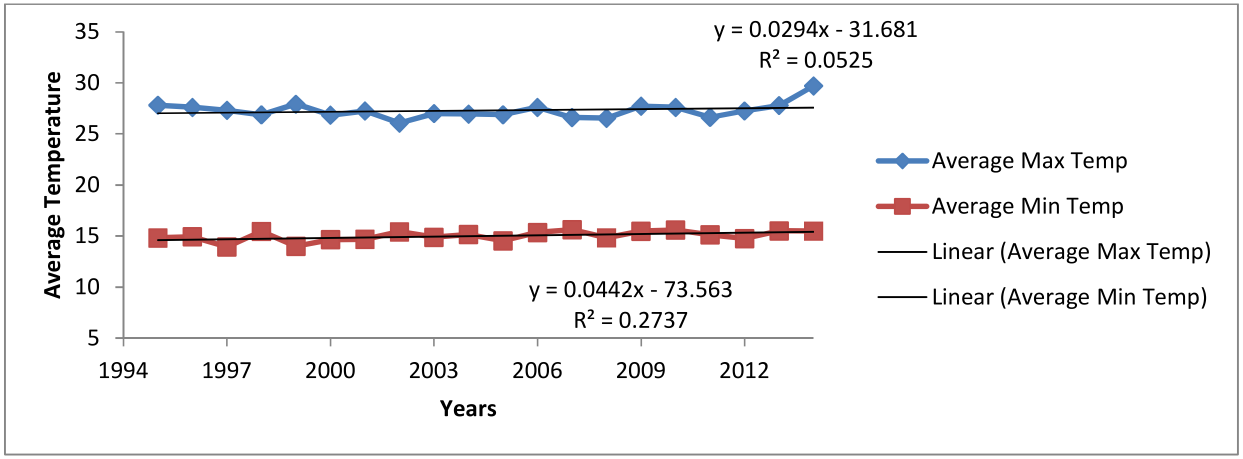

Fig. 6. Trend of maximum and minimum temperature at Syangja station (1995-2014)

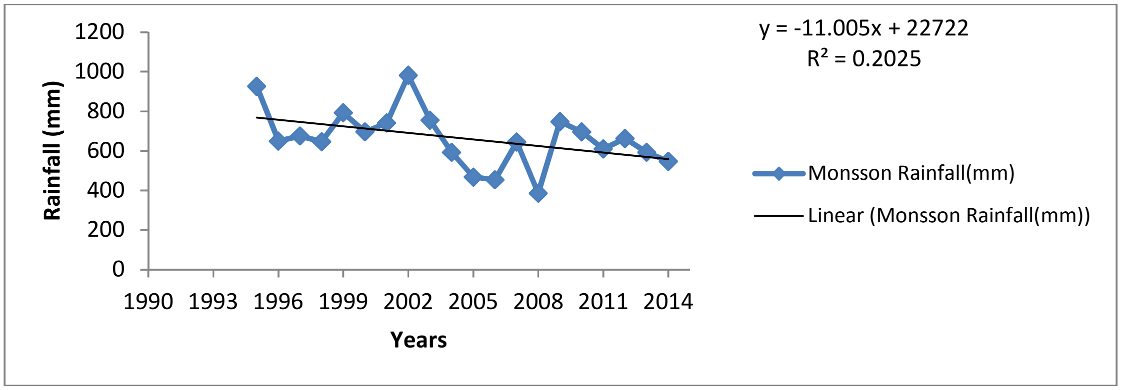

Fig. 7. Trend of rainfall (mm) at Syangja station (1995-2014)

The trend showed that the rainfall pattern was decreasing. The trend analysis showed that total rainfall was decreased with rate of 11 mm per year. Using cross-sectional household survey data and the Ricardian model, Kabubo-Mariara and Karanja [10]. Estimated the economic impact of expected adverse changes in climate on crop farming in Kenya. Their estimates show that increase in summer temperatures have a negative effect of crop revenue of farmers while increase in winter temperatures has a positive relationship with crop revenues. Following approach similar to Kabubo-Mariara and Karanja [10], Benhin [11]. Estimates of the potential impact of climate change on revenue of South African farmers found that a 1 percent increase in temperature would increase the farmers' net crop revenue while a 1mm/month fall in precipitation would lead to a fall in net crop revenue.

3.2 Impact of Climatic Variables in Vegetable Production

3.2.1 Impact of climate change on major vegetable crops

This section includes the impact of climate change on tomato, cauliflower and cabbage crops. Among all respondents perceiving changes in crop performance, 9.33% of respondents perceived increased in yield, 44.67% perceived decreased in yield and 46% of respondents perceived no change in yield of vegetable crops. The decreased in yield of crops may be due to attack of insect pest and diseases in the changing climate.

3.2.2 Ranking of perception of farmers for most affected vegetable crop

Tomato, cauliflower, potato, cabbage and leafy vegetables were the major vegetable crops in the study site. The value obtained from preference ranking scale result showed that tomato (index value 0.77) was the most affected vegetable crop by climate change followed by cauliflower (0.67), potato (0.65), cauliflower (0.47) and leafy vegetables (0.38) respectively.

3.2.3 Production of vegetables in relation to climatic variables

The regression analysis computed for the vegetable revealed that coefficient of determination of 0.94. This indicates that 94% of the variance in vegetable production can be explained by climatic parameters under study. The climatic variables show significant as well as non-significant relations with vegetable production as shown in Table 3.

Table 1. Yield responses of vegetable crop to climate change (2015)

Categories	Yield response of different vegetable crops			
	Tomato	Cauliflower	Cabbage	Total
Increased	9(9)	13(13)	6(6)	(9.33)
Decreased	54(54)	41(41)	39(39)	(44.6)
No change	37(37)	46(46)	55(55)	(46)
Total	100(100)	100(100)	100(100)	(100)

Figures in parentheses indicate percent

Table 2. Ranking of farmers perception for most affected vegetable crop (2015)

Vegetable	Index value	Rank
Tomato	0.77	I
Cauliflower	0.67	II
Potato	0.65	III
Cabbage	0.47	IV
Leafy vegetables	0.38	V

Table 3. Productivity of vegetables in relation to climatic variables

Crop	Variables	S.E	Regression coefficient	p-value
Vegetables	Maximum Temperature	.35841	-.1515008	.690
	Minimum Temperature	.55623	-1.2785061	.070
	Area	0.1869	1.6168	.000
	Rainfall	.08767	.1638529	.121

*R^2=.94 *Significant at 10% level (p<0.1), and S.E indicates standard error*

The results revealed that area is positively significant (p<0.05) with production and minimum temperature is negatively significant (p<0.05) with production. This indicates that with increase in area by 1 hectare production of vegetables would increase by 1.616 mt. Similarly with increase in minimum temperature by 1 degree Celsius the production of vegetable would decrease by 1.378 metric ton. This might be due to freezing injury or due to intolerability of vegetable to cold stress and frost for longer period of time. Similar result had been found by Moore et al. [12]. In European agriculture where it has imposed a cost in terms of profitability or yields lost as a result of management practices that turn out to be, ex post, imperfectly adjusted to the actual weather. Also in line with the result, Adams et al. [13] stated that tomato grows under high temperature produced lower fruit yield.

4. CONCLUSION

This paper presents the effects of climatic variability and change on production of vegetables in farmers of Syangja district. We focus on vegetable since they play an important role in livelihood of farmers. Overall the results show that climate change has potential to significantly affect farmer's livelihood by either increasing or decreasing production. Farmers in the study area had perceived impact of climate change on vegetable production. Trend analysis of area under vegetable and productivity shows increasing trend over last 10 years in study district. Both maximum and minimum temperature shows the increasing trends over the last 15 years. The average maximum temperature was increasing significantly (P<0.1) at the rate of 0.029℃ per year, while the average minimum temperature was increasing significantly (P<0.01) at the rate of 0.044^0c per year. Rainfall shows decreasing trend by 11mm per year. Logit regression analysis of vegetable production with climatic variables showed positive significant relationship with area under vegetable cultivation (P<0.1) and negative significant relationship with average minimum temperature (P<0.5).

Thus, it is recommended that any programs that are working to minimize the adverse impact of climate change on vegetable crops production should first consider the crop, such as tomato and cauliflower that is being most affected by the lower temperatures. Moreover, these two are important vegetables crops in Nepal, especially in the mountainous and hill regions that are also exposed to higher degrees of vulnerability to climate change. The main shortcoming of this study is the examination of the entire district as one unit, despite the huge diversity existing within it. Therefore, further investigation with better spatial and temporal resolution is highly recommended to better understand the patterns and consequences of extreme weather affecting vegetable production in mountainous regions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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