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Periodical Deviation in Climate and its Impact on Agriculture in High Hill of Nepal, Jumla

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ABSTRACTS
Meterological data on temperature and rainfall for the period of 30 years was analysed using statistical tools to see the periodical deviation of climate. The impact of changing climate on mountain agriculture has been reviewed. Gradual increase in minimum and maximum temperature was observed whereas magnitude of increase in maximum temperature is more than minimum. There has not been steady increase in rainfall indicating higher variability. The increased temperature and irregular rainfall pattern has resulted in occurrence of diseases/pest in mountain ecosystem having adverse effect on agricultural production. Increase in temperature has opened revenue for introduction of new agro-biodiversity, whereas negatively resulted in loss of existing diversity.

Keywords
Deviation, period, temperature and rainfall

JEL Codes
Q54, Q55, Q58

INTRODUCTION

In recent decades, climate change is a real issue of affecting almost all lives and activities on earth rather than just limiting in theory (Sharma, 2009). Broadly, it is defined as change in climatic parameters over time (Back and Bretherton, 2005). It indicates climate change is more than just a change in temperature, but a change in overall weather which has led to increase in temperature, declined and more unpredictable rainfall pattern, occurrence of extreme weather events and higher severity of pest and disease (Parry *et al.,* 2007; Kotschi, 2007; Morton, 2007; Brown and Funk, 2008; Lobell *et al,* 2008).

Since 1880 to 2012, global average temperature has hiked by 0.85°C (IPCC, *2013*) and is projected to increase 2-4°C by 2100 (NCSU, 2013).Similarly, total precipitation during the last 100 years has increased nearly by 2 per cent (EPA, 2014). However, it was found that changing behavior of climatic parameters is unequivocal across the regions, though some places are getting more precipitation than they used to get, while others are getting less. Precipitation is expected to increase in higher latitudes and decrease in areas closer to the Equator (EPA, 2014).

Projections made by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007) for South-Asia as a whole show that warming is likely to be above the global mean. Rainfall in the summer season is likely to increase and it is very likely that there will be an increase in the frequency of intense precipitation events in parts of South-Asia. Extreme rainfall and winds associated with tropical cyclones are also likely to increase (ABD, 2014).

Over the year, surface air temperature of Nepal is increasing while rainfall has become more variable (Shrestha *et al*., 1999). Climate change in no time has become a major concern to both Nepal and Nepalese. According to IPCC 2007, the temperature trend of Nepal during 1906 to 2005 and 1956 to 2005 are high as compared to global temperature rise of 0.74p C and 0.13p

C, respectively. Nepal has been ranked as the 14th most vulnerable country to climate change worldwide (USAID, 2014). Climate change is responsible for erratic rainfall, decreased water availbility and higher temperatures in Nepal, resulting in lower crop production and increased problems with disease and pests (USAID, 2013). It has been noted that even 1 °C rise in temperature tends to lower the yield by upto 10 per cent (Lobell *et al.,* 2011).

Among plain, mid-hills and mountain regions of Nepal, mountain regions are found more vulnerable to climate change and its impact because both the warming trend and its affect get magnified due to the rapid changes in altitude even over small distances (Karki *et al.,* 2009; Pathak, 2010; Shrestha *et al*, 1999; Shrestha and Devkota 2010). Likewise, with the increase in temperature and $CO_{2,}$ there is chance for shift of diseases and pests of plain ecosystem to hills and mountains which may affect higher altitude agricultural production (Malla, 2008; Khanal, 2009; NAPA, 2010; Pokhrel, 2011; and Karki 2012). More vulnerable and increasing effects of climate change are being noted in higher altitude where the studies have been conducted to analyze the trend on annual basis. Thus, present study is a systematic attempt to analyze the change in a periodical monthly basis.

The main objectives of this study are to analyze the pattern and trend of change in monthly average temperature and to study the changing rainfall pattern over time in Jumla District. Furthermore, present study attempted to review various literature to dig out the impact of climate change on diversity and production of mountain crops.

METHODOLOGY

Present study was conducted in Jumla district of Nepal which has extended in an area of 254,365 ha and has total population of 108,921 (CBS, 2011). The study district is situated at a latitude of 18^{0}05'08" to 29^{0}16'31" N and a longitude of 81^{0}05'10"E to 82^{0}11'00" E and at an elevation of 915 m to 4679 m above sea level. Daily weather data of Jumla district was collected from the Department of Hydrology and Meteorology, Government of Nepal, pertaining to the period of 1981-2010. The study period (1981-2010) was divided into different period i.e. Period-I (1981-1990), Period-II (1991-2000), Period-III (2001-2010) and overall Period-IV (1981-2010). Guhathakurta and Rajeevan (2006) used 10 year as one period while studying trends in the rainfall pattern. Daily data on each climatic parameters were averaged out on monthly basis. Descriptive statistics such as mean, standard deviation (SD), coefficient of variation (CV) etc., were estimated for each period. Further, independent two samples t-test was employed to study the significant between two sample mean. The data analysis has been done by using SPSS. The methodology adopted under this study has already been used by Upadhya and Grover (2012) and Grover and Upadhya (2014). Furthermore, various reports, publications, flyers, brochure and several other literatures were reviewed to gather necessary information on climate change and its impact in agriculture.

RESULTS AND DISCUSSION

Period Wise Change in Temperature and Rainfall

There has been slight increase in both the minimum and maximum temperatures in all the months of recent years as compared to the base period resulting in increase of minimum and maximum temperature at current decade (Table 1). But when comparing the average rainfall of current period with the base period there has not been consistent pattern in the amount of rainfall in the current period. Inconsistent pattern of rainfall has been experienced, where there is higher rainfall intensity but lesser no. of rainy days resulting in excessive dryness during the drought (Sapkota *et al.,* 2010).

Table 1: Periodical variation of rainfall, minimum and maximum temperature over time

Parameters	Period I	Period II	Period III
Min Temp (0 C)	4.68	4.57	5.24
Max Temp (0 C)	20.46	20.47	21.47
Total Rainfall (mm)	834.70	811.68	780.59

TEMPERATURE

Minimum Temperature

Shift in the minimum temperature for the period of 30 years has been studied and presented in Table 2. Result shows that the minimum temperature of Period-III is distinctly above the Period-IV, and turned out significant for the month of January (0.5^{0}C), February (0.56^{0}C), March (0.6^{0}C), April (0.78^{0}C) and July (0.41^{0}C). There has also been slight increase in minimum temperature in the period II as compared to Period-I but none of them were found to be significant. Similarly, considerable increase in mean minimum temperature of Period-III over Period-II was observed indicating significant increment only in the month of January (0.98^{0}C) and April (1.38^{0}C).

The deviation in minimum temperature of Period-III clearly shows there has been increase in the minimum temperature during this period but indicating the significant increment only in the month of March, April and July with the value of 0.67°C, 0.95°C and 0.56°C respectively. It can be inferred that there has been consistent rise in average minimum temperature throughout all months during Period-III as compared to Period-I and II.

It has been found that the value of SD is lower in all months in Period-III as compared to Period-I except for the month of November and December (Table 3). Likewise, the SD is minimum for all months in Period-

Table 2: Periodical Deviation in monthly minimum average temperature

Month	Difference (°C)			
	Period II over I	Period III over II	Period III over I	Period III over IV
January	-0.46^{NS}	0.98*	0.52^{NS}	0.50*
February	-0.20^{NS}	0.94^{NS}	0.74^{NS}	0.56*
March	-0.44^{NS}	1.10 ^{NS}	0.67**	0.60***
April	-0.43^{NS}	1.38**	0.95**	0.78***
May	-0.08^{NS}	0.96^{NS}	0.88^{NS}	0.61^{NS}
June	0.35^{NS}	0.39^{NS}	0.74^{NS}	0.39^{NS}
July	-0.10^{NS}	0.66^{NS}	0.56***	0.41***
August	0.04^{NS}	0.23^{NS}	0.28^{NS}	0.16^{NS}
September	0.13^{NS}	0.37^{NS}	0.50^{NS}	0.28^{NS}
October	-0.15^{NS}	0.62^{NS}	0.47^{NS}	0.36^{NS}
November	0.46^{NS}	-0.11^{NS}	0.35^{NS}	0.84^{NS}
December	-0.40^{NS}	0.48^{NS}	0.08^{NS}	0.18^{NS}

******, ** and * significant at 1, 5, 10 per cent level***
NS: Non-significant.

III as compared to Period-IV except for the month of September and December. It clearly indicates the increase of minimum temperature in Period-III over Period-I and IV is consistent for almost all months.

Table 3: Deviation in monthly minimum average temperature in Jumla District, 1981-2010

Month	Period I	Period II	Period III	Period IV
January	0.97	1.34	0.81	1.11
February	1.18	2.24	0.99	1.57
March	0.76	2.08	0.53	1.35
April	0.86	1.44	0.76	1.18
May	1.28	1.64	1.26	1.43
June	1.67	1.61	0.91	1.42
July	0.34	1.64	0.32	1
August	0.43	0.46	0.33	0.41
September	1.06	0.94	1.03	1
October	1.08	2.16	0.74	1.43
November	0.71	0.93	0.88	0.84
December	0.8	0.74	1.02	0.86

Maximum Temperature

Assessment of periodical deviation of monthly average maximum temperature for the period of 1981-2010 brings out that the average maximum temperature of III period is above the IV in all the month whereas it came out significant in the month of March (1.11^{0}C), April (0.85^{0}C), August (0.43^{0}C), October (0.65^{0}C), November (0.93^{0}C) and December (0.74^{0}C) (Table 4). Similarly, there has been slight increase in the maximum temperature in the II period as compared to I in the month of April, May, July, September, October, November and December where increase in the maximum temperature of July has been found significant at 5 per cent. While assessing the deviation of maximum temperature of Period-III over II, there has been increase in the maximum temperature in all the months except for May. Among the months where there has been increase in temperature has increased significantly only in January, February, March, August and December. The maximum temperature in Period-III has increased as compared to Period-I in all the months but increase is significant only in March, April, July, August, September, October and December with the magnitude of 1.51°C, 1.36°C, 0.86°C, 0.50°C, 1.08°C, 1.42°C and 1.12°C respectively.

The value of SD is lower across months in Period-III as compared to period I except for months February, April, June and October. Similarly, SD is minimum in all months in Period-III as compared to period IV except for January, February, June and September. This indicates that the increase of maximum temperature in Period-III over Period-I and IV is not so consistent.

Rainfall

Result shows that there is neither steady increase nor the increased amount of rainfall is significant in different months (Table 5). While looking monthly rainfall of Period-III over Period-IV, rainfall in Period-III period is lower than that of IV in the month of January, February, March, July, September, October, November and December. The deviation in rainfall of Period-II over Period-I, it can be inferred that there is neither significant nor continuous rise in the rainfall over the period except for the month of January. The periodic variation of rainfall in both Period-III over Period-II and Period-III over Period-I shows increase in rainfall only in some of the months but none of them is significant in both the periods.

While assessing the rainfall variation of Period-I, three digit value has been observed in October (111.8 per

Table 4: Periodical Deviation in monthly maximum average temperature

Month	Difference (°C)			
	Period II over I	Period III over II	Period III over I	Period III over IV
January	-0.79^{NS}	1.90**	1.10^{NS}	1.00^{NS}
February	-0.54^{NS}	2.00**	1.46^{NS}	1.15^{NS}
March	-0.30^{NS}	1.82*	1.51*	1.11*
April	0.17^{NS}	1.20^{NS}	1.36**	0.85*
May	0.83^{NS}	-0.22^{NS}	0.61^{NS}	0.13^{NS}
June	-0.29^{NS}	0.78^{NS}	0.49^{NS}	0.42^{NS}
July	0.86**	0.002^{NS}	0.86**	0.29^{NS}
August	-0.29^{NS}	0.79***	0.50**	0.43***
September	0.17^{NS}	0.40^{NS}	0.57^{NS}	0.31^{NS}
October	0.18^{NS}	0.90^{NS}	1.08**	0.65*
November	0.06^{NS}	1.36***	1.42**	0.93**
December	0.01^{NS}	1.11^{NS}	1.12*	0.74**

******, ** and * significant at 1, 5, 10 percent level***
NS indicates Non-significant.

cent) and November (211.5 per cent) which indicates higher variation. In case of Period-II and III period higher variation has been found in October, November and December. In Period-I period lowest value of variation in Jumla was found in August (26.7 per cent) followed by July (41.0 per cent). In Period-II period also, August has the lowest variation (28.4 per cent) followed by July (37.5 per cent). But in the case of Period-III, it has been found that September (34.3 per cent) has got the minimum variation followed by August (38.3 per cent).

Perception and Impact of climate change on diversity and production of mountain crops

In this section, study synthesis information from various studies on perception and impact of climate change on diversity and production of mountain crops. Before entering in the perception and impact on mountain region, study presented people perception on climate change in Nepal. Nepalese people have perceived increase temperature, delay on onset of monsoon, great variability in the amount of rainfall, increase in extreme hot days, high intensity pattern in off monsoon season, increase in precipitation and duration of post monsoon (Bhusal 2009, Regmi *et al.,* 2010, Tiwari et al 2010, Piya *et al.,* 2012 and Devkota 2014). Similarly, Meldrum *et al.,* 2015 studied Jumla's people perception on climate change and reported that very few of the respondents were not aware about the change. Majority of the respondents expressed the experience of hotter days than as it used to be in the past. People has experienced declining, unpredictable and late onset of rainfall. Farmers said that there has been decrease in the no. of rainy days but it rains more heavily when it comes. With the increase in temperature and shift in the rainfall pattern, farmers are now facing prolonged drought than in the past which is ultimately affecting the

Table 5: Deviation in monthly maximum average temperature in Jumla District, 1981-2010

Month	Period-I	Period-II	Period-III	Period-IV
January	2.23	1.29	2.22	2.06
February	1.52	1.73	2.22	1.98
March	2.03	2.05	1.82	2.06
April	0.92	1.81	1.37	1.5
May	1.55	1.14	0.45	1.16
June	1.07	1.09	1.15	1.11
July	0.82	0.69	0.71	0.83
August	0.52	0.36	0.39	0.53
September	1.11	0.81	1.08	1.00
October	0.93	1.37	0.95	1.17
November	1.2	0.95	1.06	1.23
December	1.45	1.91	0.98	1.54

Table 6 Periodical Deviation in monthly rainfall in Jumla District, 1981-2010

Month	Difference (mm)			
	Period II over I	Period III over II	Period III over I	Period III over IV
January	19.9**	-16.1NS	3.8NS	-4.08NS
February	-4.6NS	-1.6NS	-6.2NS	-2.61NS
March	-7.9NS	-13.5NS	-21.4NS	-11.64NS
April	-8.9NS	6.7NS	-2.2NS	1.48NS
May	-16.8NS	17.0NS	0.2NS	5.73NS
June	15.9NS	-4.8NS	11.0NS	2.08NS
July	-25.3NS	1.8NS	-23.5NS	-7.23NS
August	18.4NS	11.0NS	29.4NS	13.45NS
September	3.4NS	-12.5NS	-9.2NS	-7.23NS
October	-16.3NS	0.4NS	-15.9NS	-5.17NS
November	10.9NS	-11.2NS	-0.3NS	-3.85NS
December	-11.6NS	-8.2NS	-19.8NS	-9.33***

***, ** and * significant at 1, 5, 10 percent level*
NS indicates Non-significant.

agricultural production. With the changing temperature, declining and unpredictable nature of rainfall, new pests and disease are evolving in recent years (Meldrum et al. 2015).

In order to cope with the effects of changing climate, people are now looking for different way outs that include switching to other crops and even varieties of same crops (Meldrum *et al.,* 2015). So climate change has impact both ways positive and negative in agricultural biodiversity and production of local mountain crops which are the source of food for the people residing in mountains. Positive in the sense that people are introducing new varieties to cope up with the changing environment inorder to increase agricultural production for the sake of food security by replacing the old ones which are local and giving low yield which is creating a risk of genetic erosion is a negative impact.

DISCUSSION

Meteorological data for the period between 1981 and 2010 of Jumla district were collected from Department of Hydrology and Meteorology, Government of Nepal. To study climate trend and variation, the data was divided into different time period of 10 year periods. Analysis of monthly maximum, monthly minimum temperatures and monthly rainfall were studied and described separately.

Present study brings out that minimum temperature in recent decade has increased at different level across 12 months where as it comes out to be significant from January to July only which is corroborated with the findings of the previous researchers who have found that monthly minimum temperature has been increased significantly during the winter season (Upadhya and Grover 2012 and Hasan and Rahman 2013).

Table 7: Variation in Monthly Rainfall in Jumla District, 1981-2010

Month	Variation in Monthly Rainfall (Coefficient of Variation %)			
	I (1981-1990)	II (1991-2000)	III (2000-2010)	IV (1981-2010)
January	81.2	60.5	97.5	80.5
February	97.3	78.8	71.9	82.3
March	79.9	93.9	79.9	84.9
April	56.5	63.8	63.8	59.8
May	63.9	54.3	39.8	53.9
June	53.2	53.8	90.2	67.2
July	41	37.5	41.1	39.2
August	26.7	28.4	38.3	31.9
September	51.7	44.1	34.3	43.2
October	111.8	119.5	159.8	126.5
November	211.5	146	156.1	176.7
December	87.7	238.4	121.4	162.7

A high value of standard deviation in monthly minimum average temperature is because of abrupt change in the temperature during 2000 which is also resemble with the study carried out by Kafle (2014). His results shows that the average temperature of Jumla was found to be between 12°C to 13°C except for year 2000 which has got the lowest temperature and after 2001 the temperature has got increasing trend.

Like minimum temperature, maximum temperature has also increased in recent decade but at various levels across 12 months where it comes out to be significant during March, April, August, October, November and December. A study carried out by Hasan and Rahman (2013) found positive and increasing trend of monthly maximum temperature at the rate of 0.5°C/year where maximum increase was observed in the month of November at the rate of 2.05°C per year.

This study also found that though both maximum and minimum temperature of Jumla are increasing, maximum temperature has increased at higher rate or magnitude as compared to minimum temperature. Though maximum temperature has increased, it has more value of standard deviation at recent decade which is similar to the study carried out by Kattel and Yao (2013) where they found that maximum temperature has increased with higher magnitude and minimum temperature shows large variability like positive, negative or no change. But in a study carried out by Krishna (2014) in Saudi Arabia, Makokha and Shisanya (2010) in Kenya found that the minimum temperature was generally found to be increased at a higher rate compared to the maximum temperature.

There was neither continuous increase nor any pattern in the rainfall over the time period. Rainfall of majority of the months shows negative magnitude indicating there has been decrease in the intensity of the rainfall leading to more drought condition which is similar to the study done by Lamichhane and Awasthi (2009), where they found uncertain pattern and high fluctuation in the annual rainfall increasing the dry periods. And another study carried out by Timilsina (2015) found that there has been decrease in the rate of precipitation during all the seasons over decades.

CONCLUSIONS

Present study found increase of both minimum and maximum average monthly temperature in the recent decade. The magnitude of increase of maximum temperature is higher than that of minimum temperature. No any smooth pattern and continuous rise was seen in the rainfall pattern of study site. Rainfall of majority of the months at recent decade showed negative magnitude which depicts that there has been decrease in the intensity of the rain increasing prolonged drought in Jumla.

This attempt brings out that there is rise in both maximum and minimum temperature across different months. Increase in temperature might have two effect on crop performance. Positive, with the rise in temperature there might be increase in the possibility of introducing new and diverse crop varieties in the new domain of higher altitude. Negative, with rise in temperature existing crop in the higher altitude might not be able to adapt and provide the optimum level of yield that it should have because every single crop has got certain different climatic requirement suitable for its proper growth and development. This will create a threat of loosing the existing genetic diversity from that place.

Findings of this study has created a further scope to make a study and analysis of weekly data. There are certain critical stages in the crop cycle of different crops, an abrupt change in the climatic condition during this period may adversely affect the growth and development which may decrease the crop yield and the level of variation in weeks' time can be known by doing the analysis and study of the weekly data.

Another scope that has been seen after making an attempt of this study is that the combined impact of the climate change along with technological inputs that has been used in the production of the crop which is also the vital component to be considered. Similarly, present findings could be utilized to identify the climate analogues sites of Jumla. This would help to assess the possibility of material exchange between the Jumla and analogues sites in future days.

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