Trend and Forecasting Analysis on Climate Variability: A case of Nepal

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Trend and Forecasting Analysis on Climate Variability in Nepal: Economic Implication

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Abstract

Climate variability in Nepal has become a big environmental issue. This paper investigates empirically and analytically whether climate variability exists or not in different altitude, whether its direction moves and what will be its future direction. We use time series model based on the secondary data of hydrology and metrology collected from Department of Hydrology and Metrology, the Government of Nepal. This paper finds climate variability in the different parts of Nepal in which all months have variability of temperature and rainfall precipitation. From 1975 to 2010, temperature raises annually by 2^0 C. However, rainfall is declining. It is forecasted change of temperature by 6^0c over next 40 years. In case of rainfall forecast, it is constant and results drought in high altitude and flood in low altitude. Climate variability may be a big threat in the different parts of Nepal. It may be valuable inputs to the policy makers and farmers for economics as usual.

Key words: *climate variability, environment, altitude, temperature, rainfall, economics, Nepal,* etc.

Introduction

Climate change is one of the most critical environmental issues (Daniel, et.al 2005). This is scientific outcome and well established fact. The world scientific community after a long discussion and examination on it explained as warming trend (temperature of natural variation, volcanic activity, changes in solar activity, urban heat effects and more), despite the historical records of observed data of climate change and discovered the Greenhouse effect as its cause in 1824 and first measured in 1859 (IPCC, AR4, 2007). IPCC (2001) and UNFCC (2008) established scientifically and empirically measurement of climate change to the variation of temperature, precipitation and rainfall, wind etc. and to the adverse effects such as flooding, drought, landslides, soil erosion etc. Further, IPCC (2007) specify the variation of mean temperature, precipitation and wind over 30 year's period.

Climate change is human induced (UNFCC, 2007). The growth of human activity changes the composition of the global atmosphere by discharging greenhouse gases and aerosols and then climate change. Similarly, climate change enforces to change human activity (http://unfccc.int). Climate variability on the other hand is used in reference to naturally occurring changes in global climate, that is, changes caused without human activity. Thus, climate change has become critical environmental issue.

Effects of climate change are Trans boundary. Stern (2006) argues its vertical and horizontal distribution all over the World. Its impact depends on the variation of adaptation capacity and behavior as well as mitigation activities among countries. In almost literatures (Stern (2006) and IPCC (2001a)), developing countries are more vulnerable socio economically than developed countries based on adaptive capacity and behavior. Furthermore, its adversities fall in human activity: production, consumption and development activities. Hassan R (2008), Hanif et al (2010), Joshi, et al.(2010), Kurukulasuriya and Ajwad (2004), Mendelsohn et al.(1994), Mirza and Schmitz(2011), Seo et al (2009), Seo and Mendelsohn(2008), Shrestha et al.(2012) and Zainal, et. al (2013) measured their adversities in different sectors. Most of literatures in agriculture (Kurukulasuriya and Ajwad (2004), K.C.(2013), Seo and Mendelsohn(2008) and Zainal, et. al (2013)) empirically examined on the effect of climate change in agriculture based on three popular approaches: a) Agricultural processing approach, b) Ricardian

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approach and c) Profit function approach. Thus, climate change is a global issue having global effects. Therefore, the world argues the need of collective responsibility for responding this issue and its vertical and horizontal distribution in the world, although developed and developing countries have the variation of adaptive and mitigation capacity and behavior(Stern, 2006). Developed countries have a strong adaptive capacity because of their available resources, advance technology and knowledge, infrastructure, institution and highly smart human resource, meanwhile its reverse situation is in developing countries. It means weak adaptive capacity with traditional and indigenous knowledge and technology, non-specialized human capacity, poor infrastructure, weak institution etc. In simple, those countries could not minimize risk of climate change vulnerability more than developed countries. Almost developing countries are more socio economically vulnerable than developed countries (Stern (2006) and IPCC (2001a)). Its examples are African and Asian countries, where the household studies indicated that the poor households are more vulnerable than the rich households are from climate change because of different assets, literacy, money, information, mobility, physical access etc. Therefore, climate change vulnerability has become massive impactful issue in developing countries.

Nepal is one of vulnerable developing country in accordance with the ample of relevant literatures, IPCC (2001) and UNFCC (2008). Climate change and its vulnerability are being complicated issues having adverse effects. Scientifically, the climate change approach of IPCC and UNFCC has provided sufficient evidence of the variation of temperature and rainfall over 30 years period and its extremes. Landslides and flood disasters and their physical and economic losses and deaths supplemented to it (MOH, 2018). Thus, climate change and its vulnerability are wider outcome scientifically and empirically in the country.

2. Climatic Variables

2.1. Temperature

Climate variables as parameters are temperatures and rainfall. Temperature, a climatic variable, is a quantitative measure of hot and cold. Its measurement are scale, centigrade, Fahrenheit etc. (www.dicitionary.com). Specifically, Oliver and Hidone(1984) supplements it with as measurement of intensity or degrees of hotness in body. Similarly, Basnet (1989) describes it as measure of the warmth or coldness of an object or substance with reference to some standard value. Its variation reflects warming of the country. Therefore, it is an indicator of warming.

Temperature varies in the variation of altitude, location and topography. Basnet(1989) notes that temperature is influenced by factors such as altitude, aspect, topography, proactive winds, distances from sea and the snow fields etc. In Nepal, variation of temperature is influenced by heterogeneous altitude. For example, mountain areas, which are high altitude, have below zero temperature all over a year. In terai areas (lower altitude) have above zero temperature. Further Hau, 1953) finds that the normal lapse rate of temperature is 0.68 c /100m. Since the atmosphere is mainly heated from below, it is clear that temperature should be highest at low altitude and should decrease with height. Upto 665.6 m altitude, the temperature increases by 0.02c /100m. This is the highest turning point. The temperature decreases slowly at the beginning and is followed by increasing rate of decrement.

2.2. Rainfall

Rainfall is another climatic variable as source of water recharging to all physical forms of water including river, spring, sea, well etc. in the world. This natural variable has natural mechanism of water cycle and recharging within a year. This climatic variable is an input of production and of human life and biodiversity.

In Nepal, rainfall ranges from 50mm to 5000 mm all over Nepal in the different weathers in accordance with rainfall recorded by Department of Metrology and Hydrology. The mean annual rainfall of Nepal that is reference to measure warming is estimated at 1857.6 mm. Rain fall is controlled by altitude and

topography. In the variation of altitude and topography, there are identified three pocket areas including southern slope of Makalu range in eastern development region, Jugal range in central development region and south of Annapurna range in western development region for highest rain fall. In these sites, rainfall was recorded above 5000 mm. Similarly, there are identified two pocket areas including Manang and Mustang for lowest rain fall. In these sites, there were recorded below 143 mm.

Similarly, coverage and pattern of rainfall is coiled with weathers. In the structure of annual rainfall, the study found share of pre monsoon, monsoon and post monsoon as 12.68 percent, 79.58 percent and 4.25 percent respectively.

3. Characteristics and Status of Climatic Variables

3.1. Seasonal Characteristics and Status

Traditionally and scientifically, season is important system of climate in the world. It is comprised of four seasons: spring, summer, autumn and winter. Nepal has too (Nayava, 1990 and Subedi, 2013) but differently into pre-monsoon, monsoon, post monsoon and winter, although traditional six seasons are practiced as follows spring, summer, rainy, autumn, pre winter and winter. In practice, four and six seasons are narrowed into three: summer (pre monsoon), monsoon and winter (post monsoon).

Seasonal characteristics influence movement and variation of the observed variables such as temperature, rainfall and precipitation. In Nepal, the weather system has three seasons, although traditional practices of weather have six seasons. They are summer, monsoon and winter. In summer season, the observed data of temperature is extremely higher all over the country but is extremely lower in winter season. Differently, monsoon season is known as mild temperature under the influence of rainfall. In accordance with historical database of rainfall, rainfall in pre (March- May) and post (October-November) monsoon is below mean annual rainfall but is above mean annual rainfall in monsoon (June-September). Monsoon with heavy rainfall comes from the bye of Bengal to the east and then west of Nepal. It is a source of irrigation in Nepal. It is a best for hilly terrain agriculture. If it is on time, its positive contribution falls on paddy production. If not, paddy production will fall. Terrain land will be barren. The small farmers are in the problem. Thus, the monsoon rainfall is lifeline of Nepalese agriculture. In winter, monsoon cycle comes cold and snow fall from west of Nepal. It makes lower temperature.

Ecological variables control climatic variables: rainfall and temperature. Nepal has Variation of altitudes from sea level to mountain range into three ecological belts: Mountain (High Altitude), Hill (Medium Altitude) and Terai(Lower Altitude). Rainfall and temperature have negative correlation with altitudes. Climate variation affects differently on all ecological belts. Its details are in Table -1.

Table 1: Climate Variables across Ecological Belts

Ecological Belts	climate	Rainfall(mm)		Temperature(^{0} C)
Mountain	Arctic /Alpine	Snow falling	150-200	< 3-10
Hill	Mixed (cool/warm)	No	275-2300	10-20
Terai	Tropical/Sub Tropical	No	1100-3000	20-25

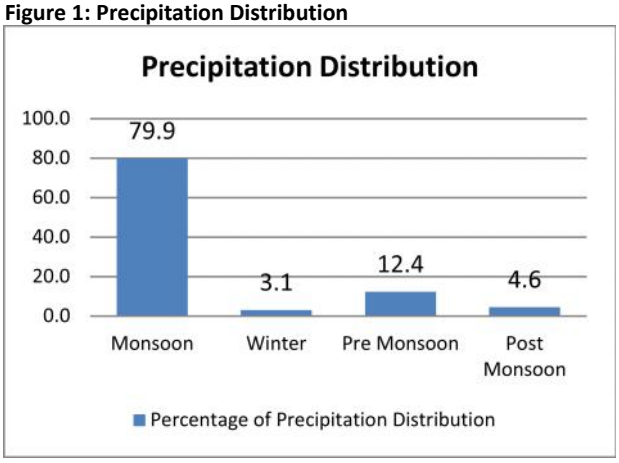
Source: CST, 1997

Monthly pattern of Temperature from 1980 to 2012 provides interesting facts of Temperature. Except zero degree temperature of 1981, 1982, 1984, 1991, 1997 and 1999, maximum temperature was approximately 25^{0c} meanwhile minimum temperature was approximately 12^{0c} (Figure-1).

Precipitation

Precipitation is another climatic variable. Seasonally, precipitation concentrates at 80 percent in monsoon. In three seasons, it distributes as follows: 3.1 percent in winter, 4.6 percent in post monsoon and 12.4 percent in pre monsoon (Figure-1).

Figure 1: Precipitation Distribution



3.2. Variation of Temperature and Rainfall

Temperature and rainfall pattern and trend are in variation globally and locally as climate change. Scientifically, their variations are heterogeneous across the heterogeneity of location, altitude, distance etc. in Nepal (Acharya (2012), Basnet(1989) and Malla(2008)). There are very relevant literatures reviewed to capture variation of these climatic variables.

Temperature variation in maximum annual in Nepal is 0.06^{o}C a year (see its details in DOM, (2012), ICIMOD (2011), MOS (2010) and Shrestha et al. (1999). Shrestha et.al (1999) in their econometric study on temperature data collected from 49 meteorological stations all over Nepal provided empirical evidence of increasing temperature in the higher altitude region of Nepal than the lower altitude regions, and higher increased rates in the winter season compared to other seasons in the year. Practical Action (2007) supplemented 0.09°C / year increase in Himalayan region and 0.04°C per year increase in temperature in Terai belt. Relatively, the rate of temperature variation is higher in the Himalayan region than the Terai region. Similarly, Shrestha(2012) in his thesis on Study of Temperature Variation over Nepal and its different topographic regions between 1989 and 2010 noted that regionally, Middle Mountain and Himalayan Region have experienced the highest increase in mean temperature especially during the spring season followed by winter season. Spring season in the higher region of Nepal will experience warmer temperature in the future. Likewise, the glaciers will most likely to melt at faster rate during the spring season and flash floods can be expected during this time of the year also. Furthermore, the warming is significantly greater at higher elevations, i.e. mountainous region, in the northern part of the country than at lower elevations, i.e. Terai in the south (Agrawala and Berg 2002).

Shrestha(2012) analyzed trend and structure of temperature using time series data from 1989 to 2010 and found increasing maximum temperature by 0.4^{0}C, minimum temperature by 0.2°C and the mean temperature by 0.7°C. Thus, maximum temperature in Nepal increases more significantly than minimum temperature.

Differently, Malla(2008) found 1.8^{0}c average per year in the study on climate change and impact on Nepalese Agriculture by using time series data from 1975 to 2006. It is also three times higher than National average. Similarly, it does not reflect the western Nepal, where Acharya (2012) in his study based on time series data (1975-2010) on the impact of climate change on agriculture in Nepal found temperature rise with 2.0^{0}c average in the western Nepal. It is relatively three times higher than lower temperature within the country and significantly higher in the comparison of global trend of temperature variation. Average temperature rise within the last 36 years (1975-2010) in western Nepal also is 1.2°C, which is two times high of the global average. Furthermore, Hills and high hills are more vulnerable to climate change.

Rainfall

Like as temperature, rainfall cycle, pattern and trend varies globally and locally. Bhandari (2013) in the study on the effect of precipitation and temperature variation on the yield of major cereals in Dadeldhura Districts found adverse effects of two climate variables (namely, high temperature and low rainfall) on the rice and maize yield. However, some variety of wheat, millet and barley can even tolerate high temperature and low rainfall to give substantial yield. Similarly, Joshi et.al.(2011) in the study on the effect of observed climate variables on yield of major food crops in Nepal, namely rice, wheat, maize, millet, barely and potato based on regression model for historical (1978-2008) climate data and yield data for the food crops found increasing temperature and rainfall in summer but decreasing temperature and rainfall in winter.

4. Methods and Materials

Large literatures show the use of time series model to analyze the trend line of climatic variables including rainfall and temperature in Nepal. The paper employed this model further to understand the trend of temperature and rainfall in Sot Khola river basin and its forecasting. The econometric model was simple regression to capture trend of rainfall and temperature over time variables. In the model, Y (dependent variable) is temperature or rainfall and X (independent variable) is time (t). For it, least square curve fitting technique is applied. Let's fit regression model to find linear trend between the time series data(Y) and time (t) is given in the equation below.

$$y_t = a_0 + a_n t^n$$

Where,

y_t = temperature or rainfall over time

$t^n = n^{th}$ time (year)

"a_0" and "a_n" are unknown parameters

If a_n is greater than "0", then "y" increases at a constant rate (=dy/dt). The trend line of y will be positive. If a_n is lower than "0", then "y" decreases at a constant rate. The trend line of y will be negative.

The data set of rainfall, precipitation and temperature is the published time series data of the country from 1980 to 2012 of Metrology Department and Environmental Statistics, Centre Bureau of Statistics (CBS), Nepal government. Its data sources were nine metrological stations of the country(Taplejung, Biratnagar, Hetuda, Pokhara, Bhirawa, Jomsom, Surkhet, Jumla and Dhanghadi. The data covers 12 months (January to December). The data was recorded for information and forecasting of these climatic variables for agricultural production and sale, disasters as well as travel plan.

Table 2: Descriptive Statistics of Temperature and Rainfall from 1980 to 2012

Indicator	Mean temp(0c)	Mean rainfall(mm)
Mean	18.85	160.35
Std. Deviation	2.33	19.5
Variance	5.46	383.26
Minimum	12	120.7
Maximum	21	214.4

Source: *DHM, 2015*

5. Results and Discussion

Time series data of Climatic variables –temperature and rainfall from 1980 to 2012 that is 30 years long data sets are observed its nature and characteristics for understanding characteristics and nature of climate change in Nepal. Such outcomes are in Table 2 .

5.1. Descriptive Statistics of Temperature and Rainfall

Table-2 is outcome of descriptive statistics including mean, median, standard deviation, and variance, range (minimum and maximum).

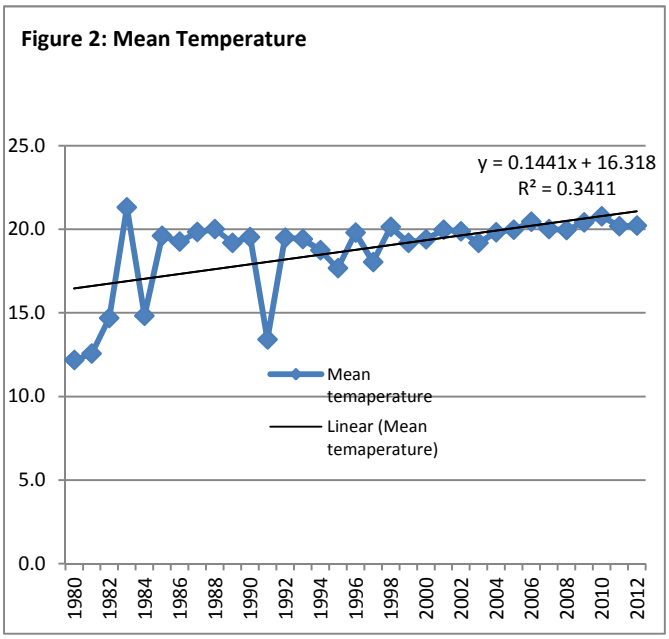
Mean temperature of Nepal from 1980 to 2012 is only 18^{0}c in the range between minimum temperatures 12.2^{0}c and maximum temperature 21.3^{0}c. There is variance of temperature at 5.949^{0}c. Similarly, mean rainfall of Nepal from 1980 to 2009 is 1926.9 mm.

Table 3: Descriptive Statistics of Annual Temperature across Stations

Stations	N	Range	Min	Max.	Mean	Std. Deviation	Variance
Taplejung	32	41	-23	18	15.10	7.03	49.44
Biratnager	33	10	15	25	24.30	1.75	3.06
Hetauda	33	22	22	43	23.68	3.58	12.81
Pokhara	33	2	20	22	21.09	.51	.266
Bhirahawa	33	10	15	25	24.52	1.69	2.86
Jomsom	32	56	-44	12	8.40	10.41	108.50
Surkhet	33	6	17	23	21.64	.92	.852
Jumla	33	3	11	14	12.81	.59	.352
Dhading	33	54	-30	24	18.11	12.10	146.53

Source: *Field Survey, 2015*

By Station, there is selected only 9 stations in Nepal. Table-3 shows its descriptive statistics. There are hetrogeneous mean with respect to districts. Mean temperature of Jomsom is 8.07^{0}c that is lowest among districts but the highest mean of temperature is 24.46^{0}c recorded in Bhairawa.

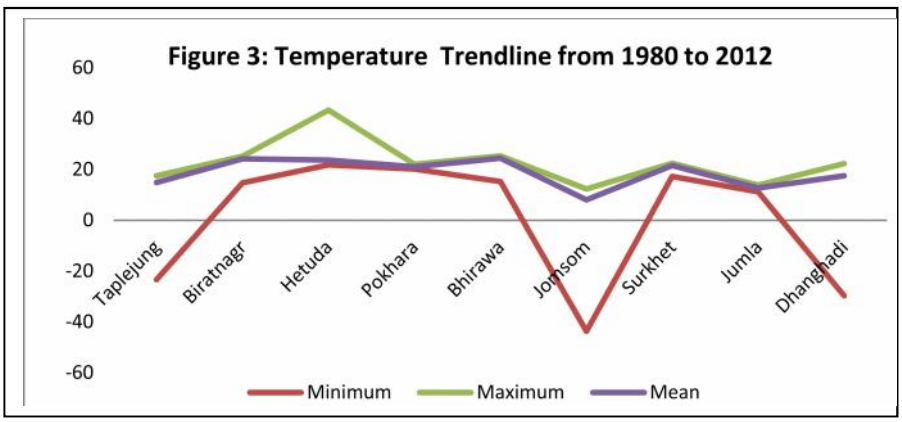


By minimum temperature distribution, there are -43.70c as the lowest minimum temperature relatively with Taplejung(-23.3^{0}c) and Dhanghadi(-29.6^{0}c). Highest minimum temperature is recorded at 21.8^{0}c in Hetuda.

By maximum temperature distribution, there is highest maximum temperature at 43.4^{0}c recorded in Hetuda. Lowest maximum temperature is 12.4^{0}c recorded at Jomsom. It shows that highest altitude has lowest temperature and lowest altitude has highest temperature. Thus, temperature is found heterogeneous pattern depending on altitude and other variables.

5.2. Climate Variables: Trend and Pattern

5.2.1. Temperature Trend and Status: Figure-2 shows mean temperature of Nepal movement from 1980 to 2012. It shows the movement is slightly fluctuating, except big variance of 1982, 1984 and 1991.



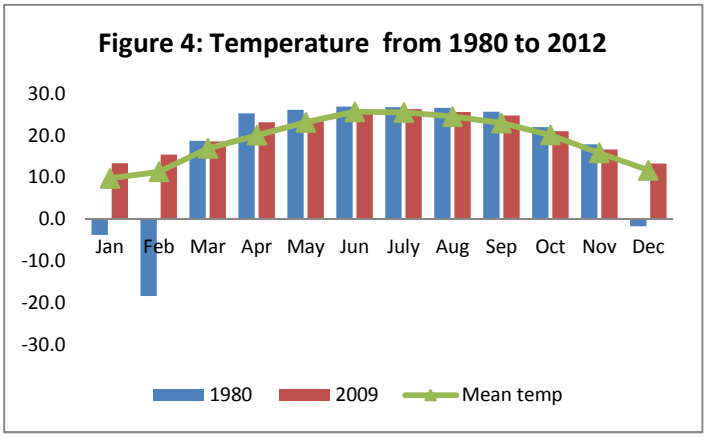
Mean temperature of Nepal recorded at 12.2^{0}c in 1980. Till 2012, it is recorded at 20.4^{0}c. Trend line of the temperature from 1980 to 2012 is inclining with 8.2^{0}c.

Temperature by minimum and maximum

In figure-3, Minimum and maximum temperatures Trend line shows that minimum temperature from 1980 to 2012 is declining trend but maximum temperature from 1980 to 2012 is inclining trend.

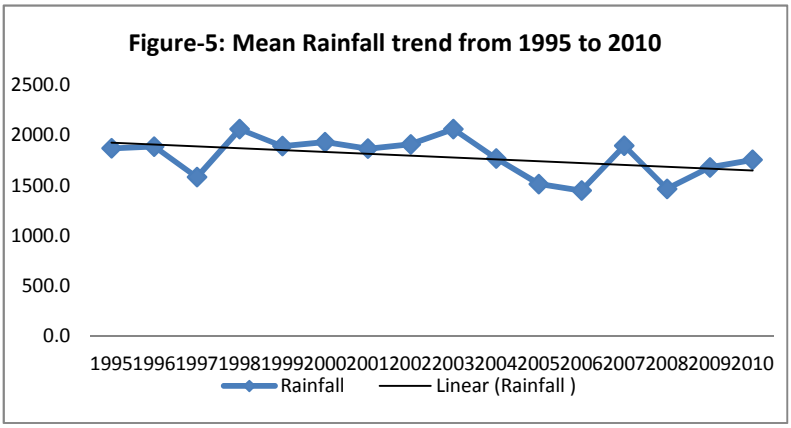
It shows winter season is colder than before and summer is hotter than before. Thus, temperature variation can be seen in winter and also in summer.

In figure-4, there are selected monthly temperature data sets of 1980 and then of 2009 and mean temperature as reference line to understanding change of temperature.



In 1980, temperature in three months including January, February and December was below 0^{0}c. Temperature of January and December were -1^{0}c to-3^{0}c but in February, it was nearly -20^{0}c. After 30 years long period, temperature in those three months was 10 ^{0}c to 15^{0}c. Thus, sharp temperature rising was recorded in those three months in temperature pattern.

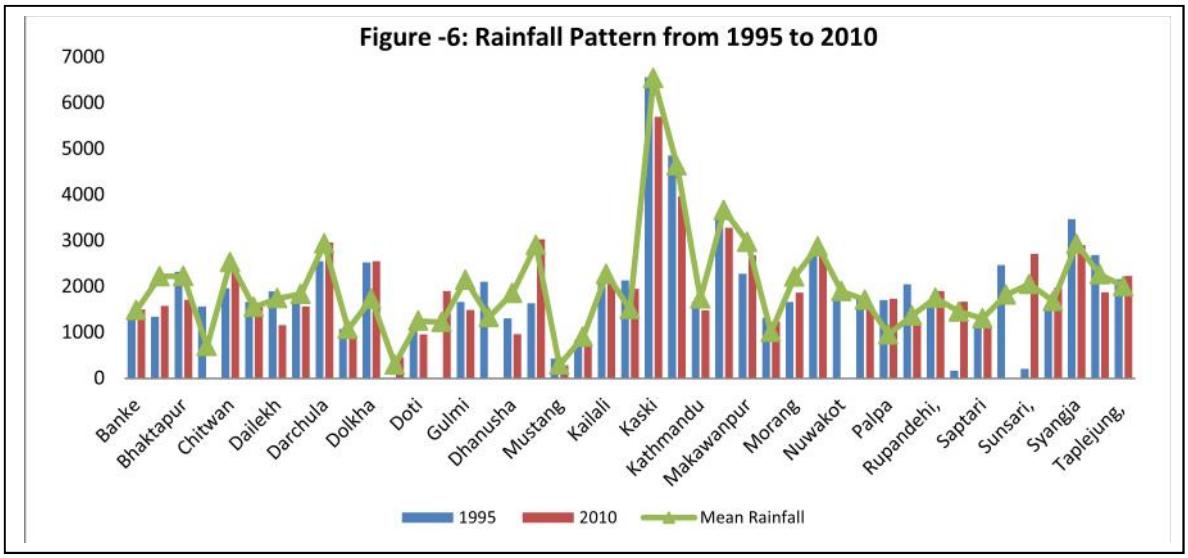
In 1980, temperature in the months of March, April, May, June, July, August, September, October and November was in the range between 15^{0}c and 25^{0}c. When we observe 2012 in those months, temperature was slightly lowered than 1980's temperature. Thus, temperature pattern of all months was changing in Nepal.



5.2.2. Rainfall Trend line and Status

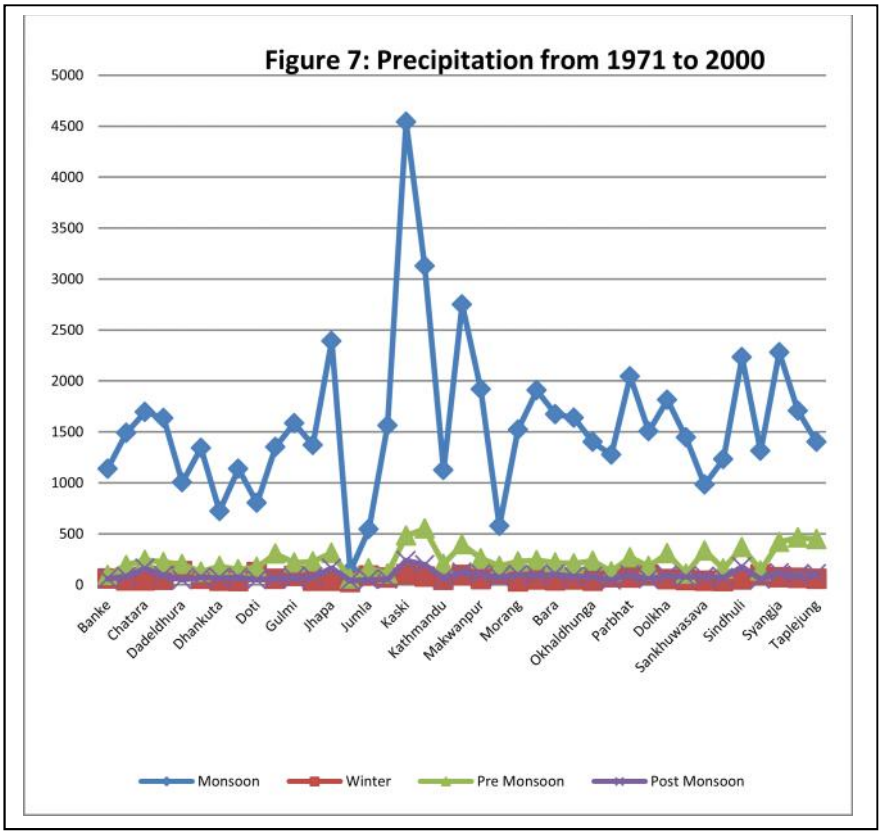
Figure-5 Rainfall data from 1995 to 2010 were collected and run to understand its trend line and status. Rainfall moves with fluctuation. In trend line, rainfall is declining in Nepal, although districts and monthly figures of rainfall may be either inclining or declining.

In 1995, rain fall was recorded higher than rainfall recorded in 2010. In Rupendehi and Sunsari, rainfall was



recorded very lower in Nepal. However, those stations recorded more than mean rainfall that is 1500 mm in Rupendehi and 2500mm in Sunsari. Similarly, in 1995, rainfall was lower than mean rainfall in Bhaktapur. Rainfall was 1200 mm in 1995. In 2010, it was 1400 mm. It was inclining figure 6. Furthermore, there were inclining trend of rainfall in Darchula, Morang and Tapeljung.

Except those six rainfall stations, rainfall of almost stations have shown declining rainfall.



Precipitation

Figure-7 shows seasons precipitation four including monsoon, winter, pre- and post-monsoon. The trend line of precipitation in monsoon season is highly fluctuating. Mustang was lowest precipitated and was followed by Manang. Meanwhile, Kaski was highest precipitated district and then Ilam and Lamjung. The remaining districts had in average precipitation. In totality, precipitation in monsoon was highest among other seasons.

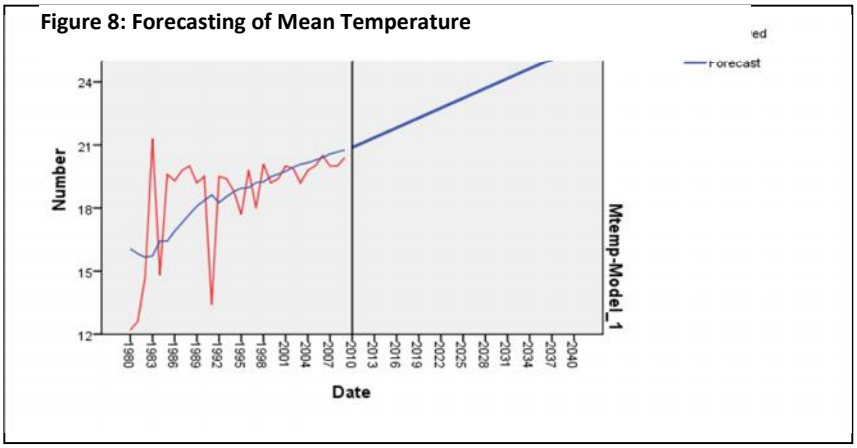
In winter, pre and post monsoon, precipitation's distribution was in total 20 percent. In winter and post monsoon, precipitation's trend line was slightly fluctuating against location and altitude, like as in monsoon.

5.3. Forecasting about Temperature and Rainfall

5.3.1. Temperature

Figure-8 shows temperature trend line based on observed data and fit line from 1980 to 2009. In addition, the figure shows forecast of temperature trend line based on the past data sets of temperature from 1980 to 2009 for next 30 years. Like as the period from 1980 to 2009, the trend line of temperature for next 30 years from 2010 to 2040 will be inclining by annual growth rate of 0.4^0c-0.6^0c. As inclining trend of temperature, climate change will follow and its consequences will follow.

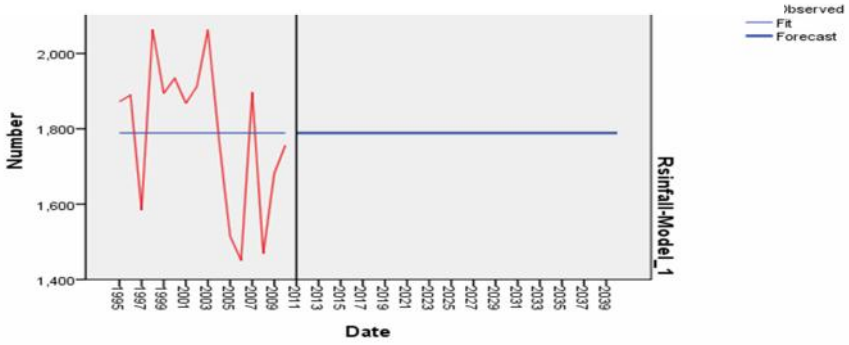
Figure 8: Forecasting of Mean Temperature



5.3.2. Rainfall

Figure-9 shows Rainfall trend line based on observed data sets of rainfall and fit line from 1995 to 2010. In addition, in figure, there was forecasting of temperature based on rainfall data sets of the period from 1995 to 2010 for next 29 years long from 2011 to 2040. The trend line of rainfall from 1995 to 2010 was consistently constant. Its reflection can be found in forecasting. For next 29 years long period, rainfall trend line will be constant like as the past trend line.

Figure 9: Forecasting Mean Rainfall



6. Conclusion

Above empirical results leads to conclude climate variability in Nepal. Its range per annum in temperature and rainfall over 30 years is 0.5^0c but slightly declining but seemingly constant. The result validates the previous empirical literatures. The model shows temperature will grows with the range from 0.4^0c to 0.6^0c in next 29 years. In this developing country, Nepal not only in the low altitude land but also in the high altitude, the weather the weather will be hotter than today meanwhile rainfall pattern and intensity will have shorter than today in next 29 years. Almost rural households have bad experiences of climate change. Out of total households, about 60 percent have bad experiences and about 40 percent have information. They have new threats and higher damage cost with new diseases in rice, wheat, maize, tomato, green vegetables, beans, potato etc. They have avoidance cost. They have lower incentive and higher vulnerability. They are worry about its negative impact on their present income, saving, food security and livelihood. There is a higher probability of incremental poverty due to new threats, higher avoidance cost and lower productivity. Experimentally, they have preferred crop insurance and climate resistance seeds and technology. They said that they started tunnel vegetable farming in raining season and drop irrigation system in dry season. However, its coverage is limited, although the government of Nepal has allocated 80 percent budget on adaptive activities, preparation and resilience. However, climate change is a transnational issue. In this context, whatever Nepal's effort on climate stability will be

negligible, until and unless without the global effort. If the climate change is not business as usual in the world, climate change following the temperature rising prediction of the model will have devastating economic effects on agriculture, industry, water resources, wildlife and biodiversity, human health and life, food and water security, energy in both altitudes. Its fast effect will fall on the low land more than the high land. Thus, climate change will produce more food insecurity and livelihood insecurity and then poor people in Nepal. Therefore, climate variability across ecological belt, its disasters and economic implication may be a good area for further scientific and empirical study.

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