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# CHRONOLOGICAL TREND OF CLIMATE IN THE LUMLE VILLAGE DEVELOPMENT COMMITTEE FROM KASKI DISTRICT, NEPAL

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**ABSTRACT**

*A study has been conducted to examine how the temperature and precipitation in the Lumle Village Development of Kaski district, Nepal has varied over the thirty years period of 1997-2008. Maximum and minimum temperature and precipitation data were collected from Narayani basin. Maximum and minimum-summer and winter temperatures and precipitation categorized as s pre-monsoon,, monsoon and post-monsoon were studied with duration of 10 years separately and average annual temperature and precipitation trends of each decade was examined. The trends of temporal variations of temperature and precipitation were analyzed using secular trend of time series analysis with simple linear regression. For almost all decades maximum temperatures were found to be increasing trend whereas most of the minimum temperatures for three decades were found to be decreasing trend except for two events. So, maximum and minimum temperatures were seen increasing trend with average value 0.033 Celsius per year. Extreme temperature event was seen in 2000-2005. Post monsoon precipitation was seen erratic pattern with increasing during first decade and decreasing second and third decades. Pre-monsoon precipitation is constant pattern and trend of precipitation in the first two decades are increasing where as present decade seen decreasing. But average precipitation is increasing trend with rate of 2.5346mm/year because increasing trend of previous two decades outweighs present rate. Extreme drought period was seen in 2005. Actually, it is concluded that Lumle has decreasing trend in total seasonal precipitation and an increasing trend in temperatures.*

**KEYWORDS:** *Chronological trend, temperature, seasonal precipitation, time series*

## INTRODUCTION

Climate is a statistical description of the mean and variability of surface variables such as temperature, precipitation and wind, over a period ranging from months to thousands of years. Climate change refers to a change in the state of the climate that can be identified statistically and that persists for an extended period, typically decades or longer. It is caused by the accumulation of greenhouse gasses in the lower atmosphere. This can be due to natural or anthropogenic causes. Currently, it is being caused by humans releasing greenhouse gasses (mainly carbon dioxide, methane, nitrous oxide and chlorofluorocarbons), many of which stem from the use of fossil fuels (LFP, 2009). Since climate influence everything on the earth, balance and regulation of climate is essential. However, due to anthropogenic and natural activates climate is changing day by day. We are experiencing extreme hot during summer and extreme cold during winter because of climate change. Global climate change is a change in the long-term weather pattern that characterizes the regions of the world (http://www.ijsrp.org).

Accelerated emission of green house gases is primary cause of unprecedented global warming bringing climate to change. Since the mid-1970s, the average air temperature measured at 49 stations of the Himalayan region raised by 10 C with high elevation sites warming the most (Hasnain, 2000). This is twice as fast as the 0.60 C averages warming for the mid-latitudinal northern hemisphere over the same time period (IPCC, 2001a) and illustrated the high sensitivity of mountain regions to climate change (WWF, 2006). Using current climate change trends, by 2100, the average global temperature may rise by 1.4-5.80C (IPCC, 2001b; Wigley, 2005). As through much of its history, the earth's climate is changing. Right now, it is getting warmer. Most of the warming in recent decades is very likely the result of human activities (IPCC, 2007).

Mountainous environments are considered sensitive indicators of climate change (Barry, 1990; Stone, 1992; Beniston, 1994). The Himalaya and Tibetan Plateau play an important role in regional climate, most particularly with respect to monsoon circulation. Links between the monsoon and other global-scale phenomena extend the implications of climatic variations in the Himalaya and in the Tibetan Plateau beyond the regional scale (Barnett et al., 2005). Climatic changes in the Himalayan region could be a reflection of large-scale climate changes, or they could even be driving them. A study of the long-term trend in surface air temperatures in India by Hingane et al. (1985) indicated an increase in mean annual temperature of 0.40C over the past century. Analyses of maximum temperature data from 49 stations in Nepal for the period 1971–94 reveal warming trends after 1977 ranging from 0.060to 0.120C yr-1 in most of the middle mountain and Himalayan regions, while the Siwalik and Terai (southern plains) regions show warming trends less than 0.030C yr-1. The subset of records (14 stations) extending back to the early 1960s suggests that the recent warming trends were preceded by similar widespread cooling trends. Distributions of seasonal and annual temperature trends show high rates of warming in the high-elevation regions of the country (middle mountains and Himalaya), while low warming or even cooling trends were found in the southern regions. This is attributed to the sensitivity of mountainous regions to climate changes. The seasonal temperature trends and spatial distribution of temperature trends also highlight the influence of monsoon circulation. Though the actual mechanisms are not well understood, monsoon circulation may play an important role in the distribution of seasonal temperatures as well as temperature trends (Shrestha et al., 1999).

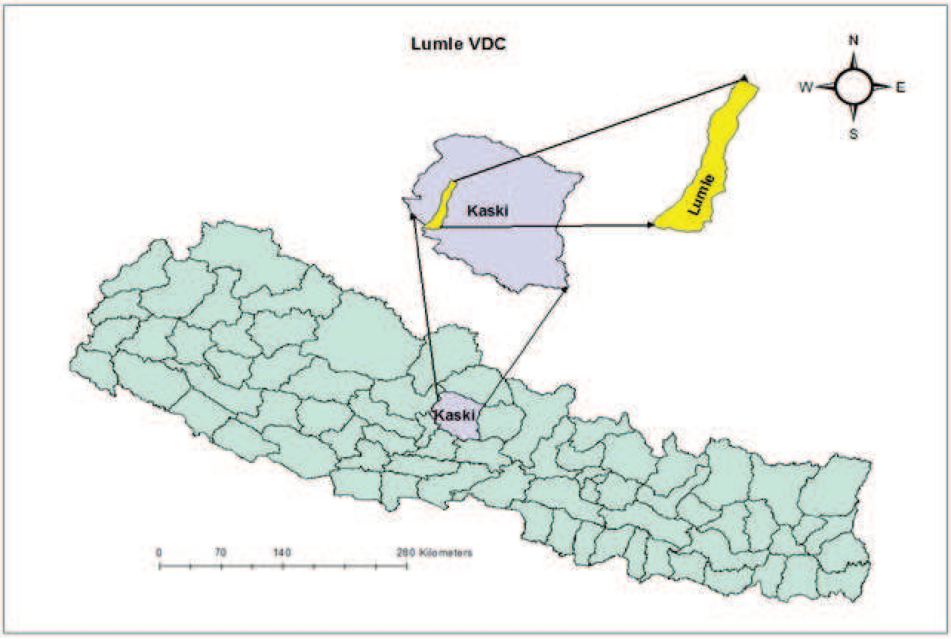
Various models have been developed to assess climate change impact at the global and regional level. Temperature and precipitation trends differ at the local level and have differing impact. Also, various studies have been done in different parts of the world for detecting climate trends and changes. Some of these have shown significant trends (Capodici et al., 2008; Feidas et al., 2007; Gemmer et al., 2004; Shakhatreh, 2010). However, very limited work has been conducted at the national level especially on time series analysis (Dankers et al, 2008). However, there is more general information available on climate change and its impacts. The information lacks at local and specific level regarding the extent and pattern of change in precipitation and temperature, the locations of high or low trend, and pattern of climate variables. These pieces of information are essential for implementing effective measures to help the poor communities to cope and adapt to impacts of climate change.

## MATERIALS AND METHODS

### Study Area

Lumle VDC is situated to just 32 K. M. west from Pokhara on Pokhara-Baglung Highway – about an hour drive from the headquarter of Kaski district. Laying in the subtropical region, it receives highest precipitation in Nepal. Lumle lies between 28°18’ N latitude and 83°48’ E longitude with an elevation of 1740 m above sea level (VDC profile, 2008). This study site falls under the Annapurna Conservation Area (ACAP) which was declared as conservation area and given authority of management to ACAP of National Trust for Nature Conservation (NTNC) by Government of Nepal in 1986.

*Figure 1: Location map of Lumle VDC, Kaski*




### Data Collection

Meteorological data dates from 1979 to 2008 (30 years) were collected from Narayani basin. To study climate (temperature and precipitation) trend, the data were extracted to MS Excel 2007 and trend lines were drawn. Maximum and minimum- summer and winter temperatures were studied with time period of 10 year and described separately. Jun, July and August are accounted as summer and December, January and February are accounted as winter. Finally, average annual temperature trend was examined.

The three precipitation seasons was categorized as pre- monsoon (March–May), monsoon (June–September), and post monsoon (October and November) excluding Winter (December, January and February) precipitation due to negligible rainfall season in this research. Also, finally, average annual precipitation trend was examined.

**Data Analysis**

The trends of temporal variations of temperature and precipitation were analyzed using secular trend of time series analysis with simple linear regression. Least square curve fitting technique was used to fit linear trend in the data. The linear trend between the time series of temperature or precipitation data (y) and time (t) is given by the equation as

$Y = \alpha + \beta_t + \varepsilon_i$ where, $Y$ = Temperature or precipitation data at time $t$ (year), $\alpha$ (intercept) i.e. amount of temperature or precipitation data at time zero and $\beta$ (regression coefficient) i.e. the rate of change of temperature and precipitation over the time t,εi is a random error which is out of control of the researcher. The best fit line of the above model is given by the following equation

$$\hat{Y} = \hat{\alpha} + \hat{\beta}\, t$$

Where, $\hat{\alpha}$ and $\hat{\beta}$ are estimated by the principle of least squares (Marahatta et al., 2009). Annual and seasonal averages were calculated for each year in all decades.

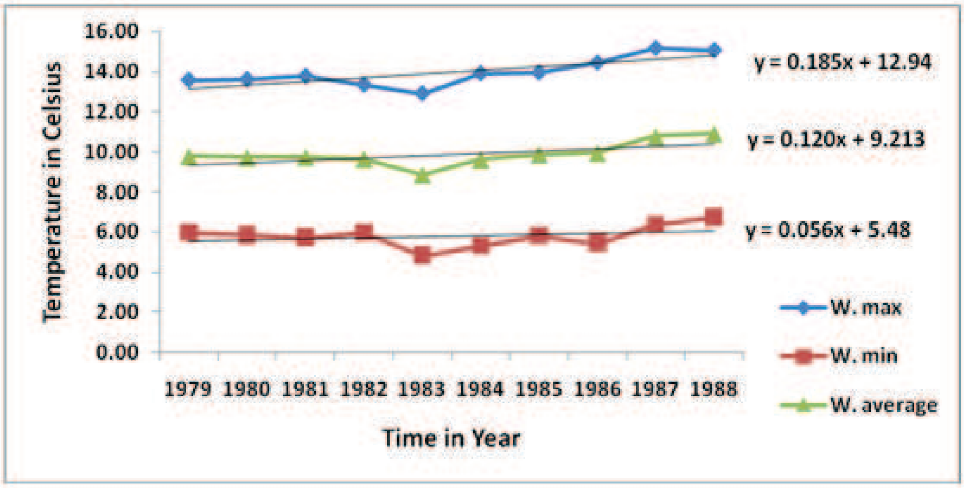
## RESULTS AND DISCUSSION

### Winter Temperature Trends in Three Decades with Respect to Seasons

### Winter temperature trend (1979-1988)

During this period, maximum and minimum temperature showed increasing trend and due to this same follows for the average temperature. But in 1983, decrease in temperature has been seen (Fig 2).

*Figure 2: Winter temperature trend (1979-1988)*

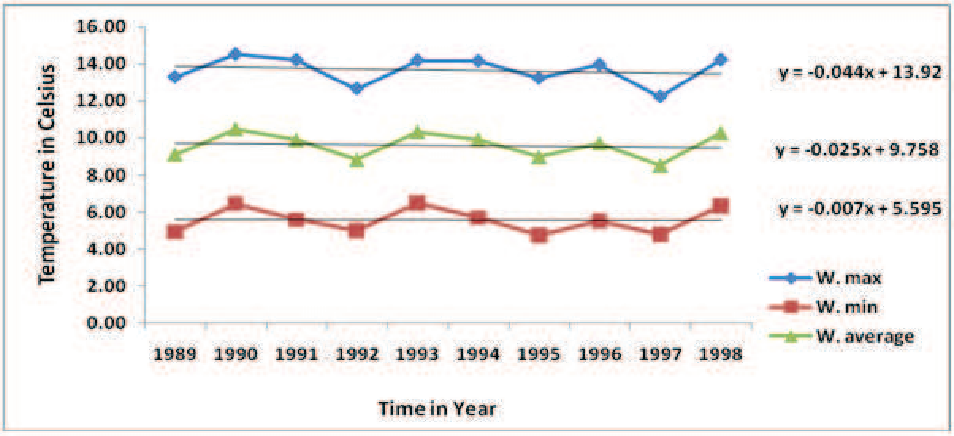



During the decade 1979-1989, the mean annual temperature of Lumle was increasing and has experienced the most increment of mean annual mean temperature at 0.1209oC/year. The annual average temperature was varies from 9 to more than 11oC. The mean annual maximum temperature of Lumle was also increasing at rate of 0.1855 oC/year. The mean annual maximum temperature varies from 13 to more than 15oC. The mean annual minimum temperature of Lumle was slightly increasing with rate of 0.056oC/year. The mean annual of minimum temperature varies from 6 to more than 7oC (Fig 2).

**Winter temperature trend (1989-1998)**

Both maximum and minimum trends were decreasing and average follows the same pattern of temperature but with very small degree of average rate of change of temperature per year. There was no any regular pattern of increase and decrease of temperature in each year during this decade.

*Figure 3: Winter temperature trend (1989-1998)*

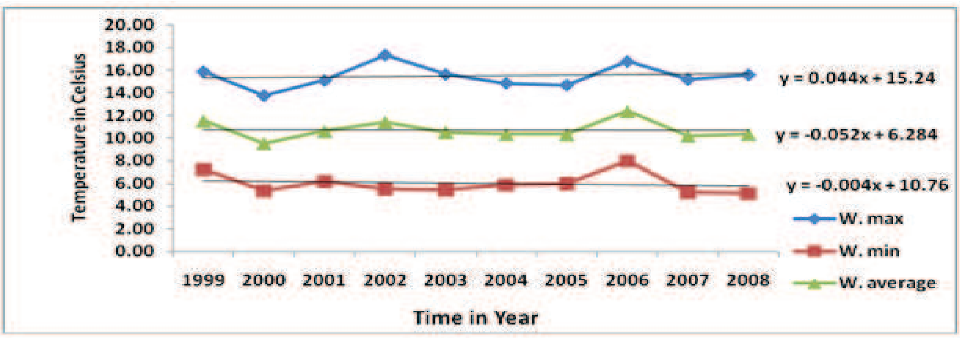



During the decade 1989-1998, the mean annual temperature of Lumle is slightly decreasing with value of 0.0259 oC/year.The mean annual maximumand minimum temperature of this areais slightly decreasing with rate of 0.0446 and 0.0071oC/year respectively (Fig 3).

**Winter temperature trend (1999-2008)**

Contrasting result seen in this period is that maximum temperature is at increasing trend with value of 0.0442oC/year where as minimum temperature is decreasing trend with value 0.0523oC/year and average temperature is also decreasing trend with value 0.004oC/year since minimum temperature outweighs maximum temperature. This is an indicator of extreme temperature pattern (Fig 4).

*Figure 4: Winter temperature trend (1999-2008)*

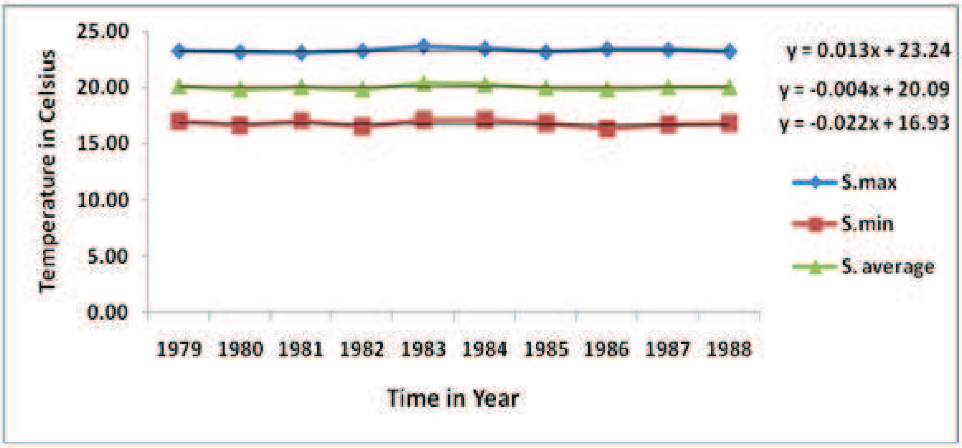


**Summer Temperature Trends in Three Decades**

**Summer temperature trend (1979-1988)**

Average summer temperature of this period showed decreasing trend with slight increasing maximum temperature and decreasing minimum temperature. Trend line depicted that temperatures events are constant (Fig 5) by smooth curves almost parallel to horizontal axis.

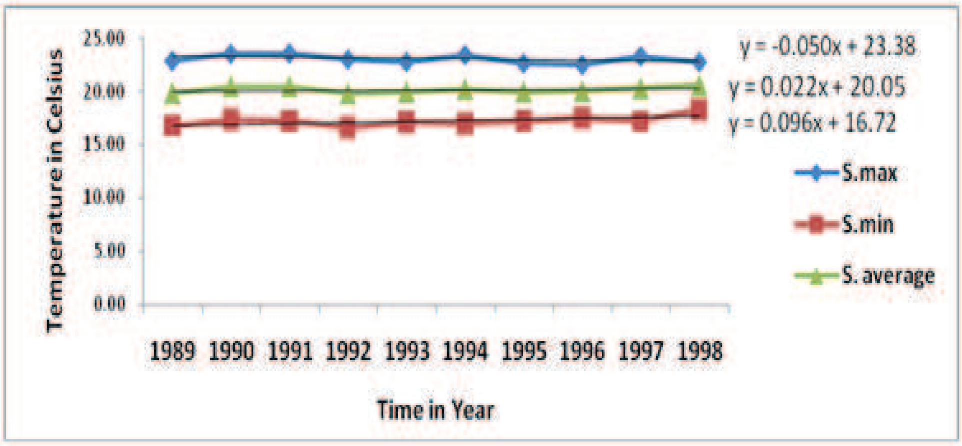
*Figure 5: Summer temperature trend (1979-1988)*




**Summer temperature trend (1989-1999)**

Maximum temperature is decreasing where as minimum temperature is increasing and average temperature showed increasing trend because coefficient of increasing trend is larger than decreasing trend.

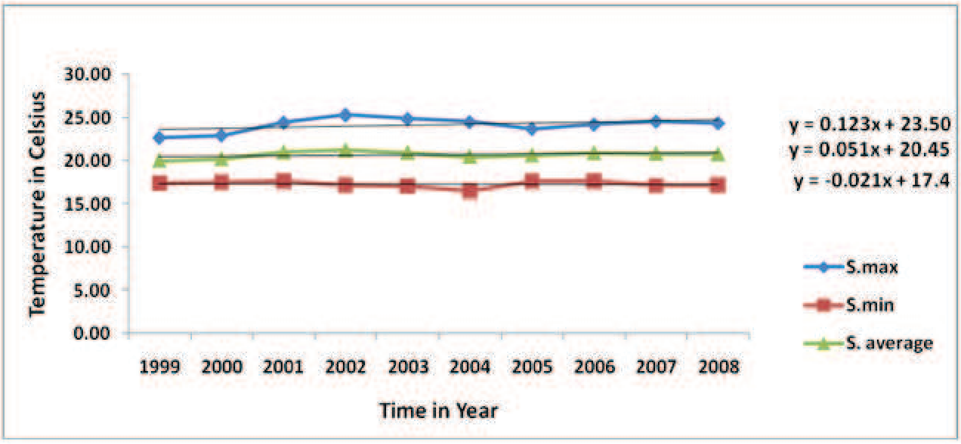
*Figure 6: Summer temperature trend (1989-1999)*




**Summer temperature trend (1999-2008)**

Maximum temperature is increasing at increasing trend and minimum temperature is decreasing trend where as average temperature in increasing trend with coefficient 0.0512 Celsius/year. Respective regression equations are presented with adjacent time series trend lines (Fig 7).

*Figure 7: Summer temperature trend (1999-2008)*



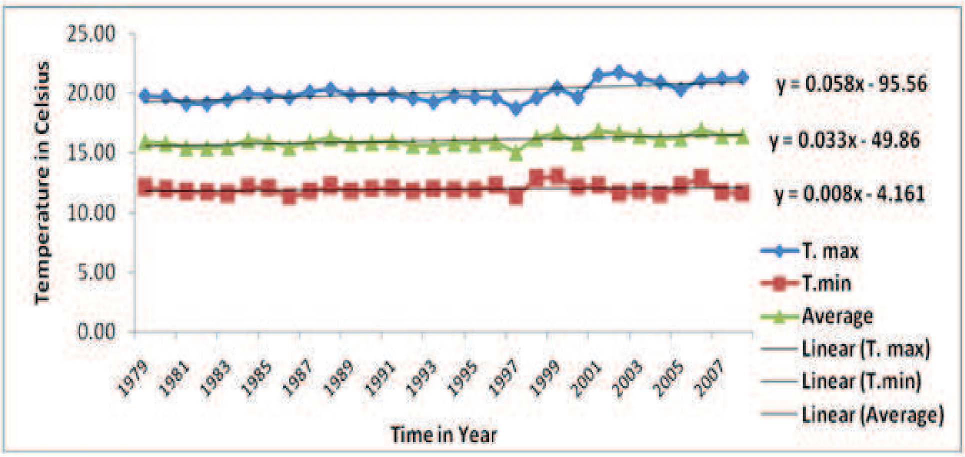

As such, winter temperature for 1979-1988 is decreasing where as increasing 1988 onward. Summer temperature (1979-1988) showed decreasing trend but increasing temperature trend 1988 onward is as an indicator of global warming.

**Average Annual Temperature Trend (1979-2008) for Thirty Years**

As shown in figure 8, averages annual temperature trends also seen decreasing initially but increasing trend from 1989. Overall trend of maximum and minimum temperature is increasing with coefficient 0.058 and 0.0081 Celsius per year respectively and average temperature too with the coefficient 0.0330C per year. Whereas, analyses of maximum temperature data from 49 stations in Nepal for the period 1971–94 reveal warming trends after 1977 ranging from 0.068 to 0.120C yr-1 in most of the middle mountain and Himalayan regions (Shrestha et al., 1999).

Extreme temperature event was seen in 2000-2005 during which maximum temperature was increased where as minimum temperature was decreased. According to MOPE (2004), Nepal's temperature is rising by about 0.41 degrees Celsius per decade.

*Figure 8: Average annual temperature trend (1979-2008)*

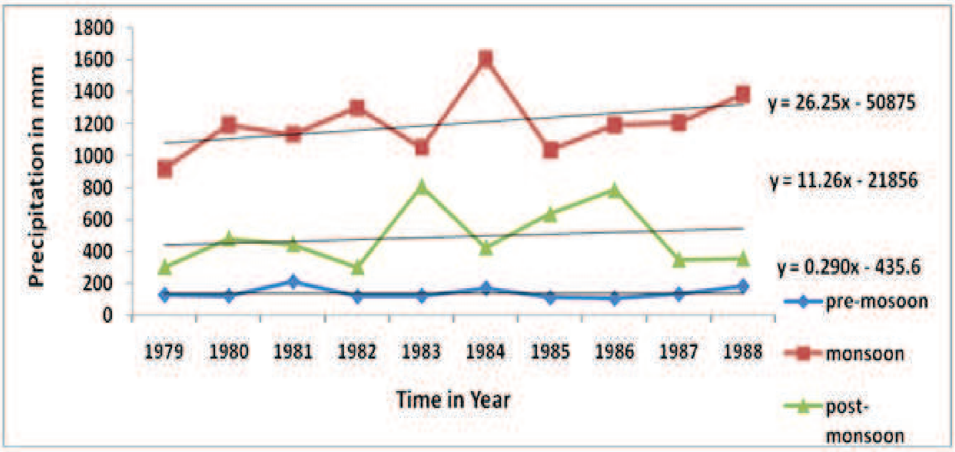


**Precipitation Trends in Three Decades with Respect to Seasons**

**Precipitation trends (1979-1988)**

Graphs show that all seasonal precipitations are increasing trend. Post-monsoon precipitation is seen erratic with two peaks in 1984 and 1986 where as pre-monsoon precipitation is almost constant. During this period highest monsoon precipitation received in 1984.

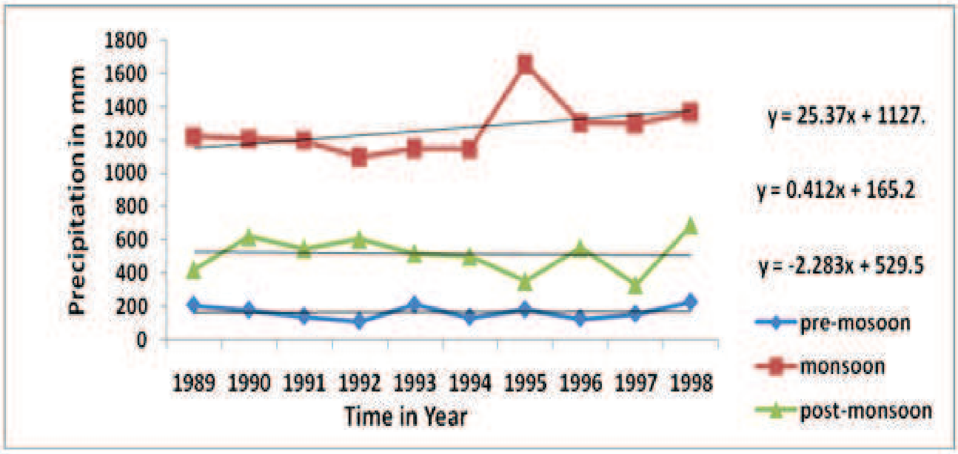
*Figure 9: Precipitation trend (1979-1988)*




**Precipitation trend (1989-1998)**

Pre-monsoon and monsoon precipitation are in increasing trend whereas post-monsoon precipitation is seen decreasing trend. Monsoon precipitation is peaked in 1995 and post-monsoon precipitation is decreased substantially in 1994 and 1997 and seen increased onwards.

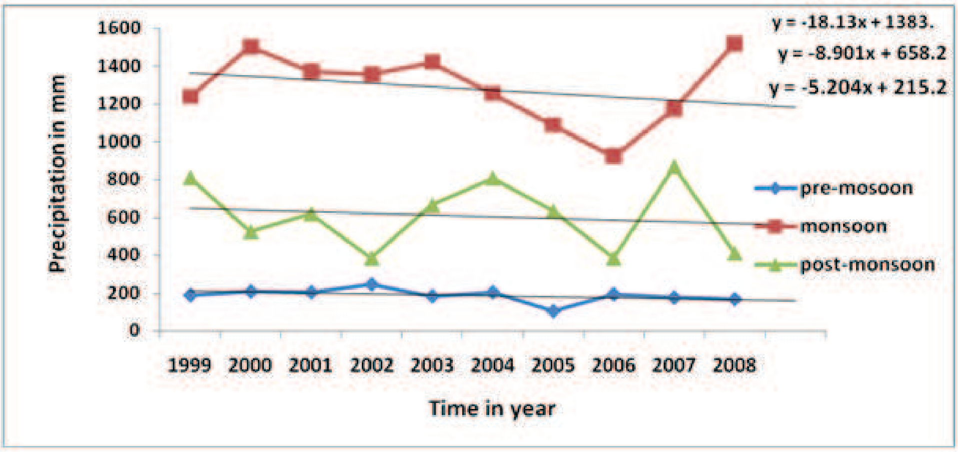
*Figure 10: Precipitation trend (1989-1998)*




**Precipitation trend (1999-2008)**

All precipitations in this period are seen decreasing trend. Pre-monsoon precipitation is decreasing constantly where as monsoon precipitation is decreased markedly in 2006 and increased onwards. As such, post-monsoon precipitation is erratic pattern.

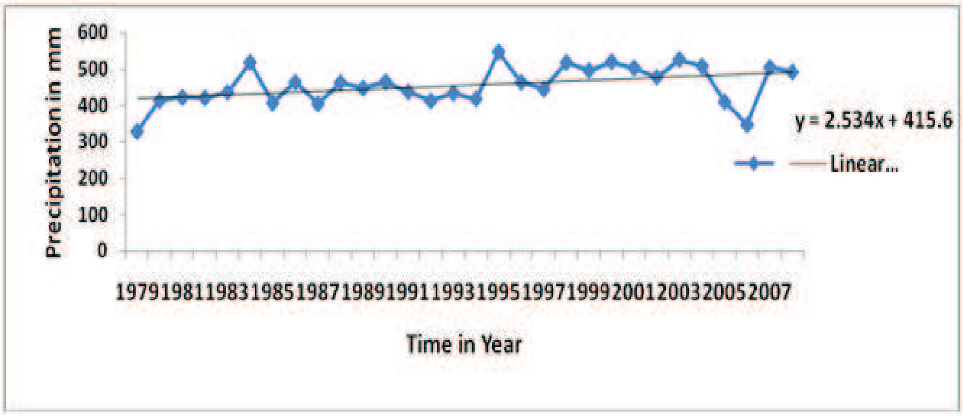
*Figure 11: Precipitation trend (1999-2008)*




**Average Annual Precipitation Trend (1979-2008) for Thirty Years**

Average annual precipitation is seen increasing trend with 2.5346mm/year as shown in figure 12. In 1979 precipitation was lowest and increased onwards and similarly, highest received precipitationsin 1984 and 1985. Remarkable reduction in precipitation was found during 2003-2007 and so, drought was seen in 2005. Though precipitation trend of 1999-2008 was decreasing average trend is increasing. This is because precipitation trend of the first two decades were increasing trend (Fig 9 and 10).

*Figure 12: Average annual precipitation trend (1979-2008)*




**Rate of Change of Temperature and Precipitation Per Year in Each Decade**

Summary statistics of the rate of change (yearly) in temperature and precipitation for three decades illustrated in table 1. Table 1 revealed that average summer temperature has been increased from first to third decade but average winter temperature has been decreased from first to last decade respectively. Regarding to summer, average rate of change in temperature from 1st to 2nd and 2nd to 3rd decade per year has been increased 0.026 0c and 0.029 0c respectively but in winter, average rate of change in temperature from 1st to 2nd and 2nd to 3rd decade per year has been decreased 0.1450c and 0.021 0c respectively.

*Table 1: Descriptive statistics of the temperature trend rate 0celcius per year in three decades w.r.t.seasons*

| Temperature | Temperature trend rate $^0$c/year in each decade w.r.t. season | | | | | |
|---|---|---|---|---|---|---|
| | 1979-1988 | | 1989-1998 | | 1999-2008 | |
| | Summer | Winter | Summer | Winter | Summer | Winter |
| Maximum | 0.013 | 0.185 | -0.05 | -0.044 | 0.123 | 0.044 |
| Average | -0.004 | 0.12 | 0.022 | -0.025 | 0.051 | -0.004 |
| Minimum | -0.022 | 0.056 | 0.096 | -0.007 | -0.021 | -0.052 |

Regarding to precipitation, rate of precipitation from 1st to last decade per year in all seasons has been decreased respectively. In monsoon, Average rate of change in precipitation from 1st to 2nd and 2nd to 3rd decade per year has been decreased 0.88mm and 43.5 mm respectively. Temperature observations in Nepal from 1977-1994 shows a general warming trend (Shrestha et al., 1999).

*Table 2: Descriptive statistics of the precipitation trend rate per year in three decades*

| Season | Precipitation trend rate mm/year w.r.t. decade and season | | | |
|---|---|---|---|---|
| | 1979-1988 | 1989-1998 | 1999-2008 | Simple average |
| Monsoon | 26.25 | 25.37 | -18.13 | 11.16 |
| Post monsoon | 11.26 | 0.412 | -8.901 | 0.923 |
| Pre-monsoon | 0.29 | -2.283 | -5.204 | -2.40 |
| Simple average | 12.6 | 7.833 | -10.745 | 3.23 |

Rate of change in precipitation for post-monsoon has been decreased by 10.848 mm and 9.313 mm from 1st to 2nd and 2nd to 3rd decade respectively and such rate of change for pre- monsoon has been decreased by 2.573 mm and 2.921 mm per year respectively.

Based on the above result, it is evident that Lumle has decrease in total seasonal precipitation and an increase in temperatures. These results are in agreement with those obtained by other workers (Capodici et al., 2008; Feidas et al., 2007; Gemmer et al., 2004) and with prediction in the IPC C reports.

## CONCLUSION

For almost all decades, maximum temperatures were found to be increasing trend whereas most of the minimum temperatures for three decades were found to be decreasing trend except for two events. So, maximum and minimum temperatures were seen increasing trend with average 0.033 Celsius per year. Extreme temperature event was seen in 2000-2005.

Post-monsoon precipitation was seen erratic pattern with increasing during first decade and decreasing second and third decades. Pre-monsoon precipitation is constant pattern and trend of precipitation in the first two decades are increasing whereas present decade seen as decreasing. But average precipitation is increasing trend with rate of 2.5346mm/year because increasing trend of previous two decades outweighs present rate. Extreme drought period was seen in 2005. The analysis showed a negative trend in average rainfall and positive trend in average temperatures. It is concluded that linear trend analysis was efficient for prediction and forecasting.

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