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Climate Change: Trends and People's Perception in Nepal

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Abstract

In the context of climate change, the frequency and intensity of extreme events such as floods and droughts will increase which could put tremendous challenges in water resources management in the coming days. While scientific knowledge on climate threats and changing climate patterns are essential, it is also important to consider the impacts in relation to how the threats are perceived and handled by local people. This paper intends to assess the trend and people's perception on temperature and precipitation. Three focus groups' discussion and a total number of 240 households were interviewed during field visit. The collected information was scaled from the least preferred-1 to the most preferred-5 based on their preferences. The trend of mean of annual average, maximum and minimum temperature indicates that the temperature has increased significantly and precipitation intensity and magnitude are also in increasing trend in the monsoon and post-monsoon seasons which may raise the extreme flood events. These facts were verified with the people's perception. This finding could be useful for formulation of effective flood management policy and plan in this river basin as well as very applicable for other similar areas.

Keywords

Climate Change; Trends; People's Perception

1. Introduction

Climate change is gradually becoming a major concern to mankind but most of the people, who are most vulnerable, are not aware of the real consequences of the global warming. It is recognized as a major threat to the communities in the rural areas who are more dependent on the natural resources [1]. Especially in developing countries, the impacts are more severe, but also those living in high risk areas in developed countries are greatly impacted. Temperature in Nepal is increasing at a high rate in recent years similar to the phenomenon observed

globally. The average temperature has increased consistently and continuously, at a rate of 0.05˚C/year from 1971 to 2005 [2]. Similarly, the maximum temperature increased by 0.06˚C and minimum temperature increased by 0.03˚C/year between 1975 to 2005 [3]. **Figure 1** shows the projected mean annual temperature anomaly for Nepal where the temperature and precipitation were gradually increased and it was estimated to rise in the coming future.

This seasonal variation is commonly observed all over the country as rainfall occurs due do the south-west monsoon which lasts from June to September. The humid monsoon air coming from the Bay of Bengal is forced to rise as it meets the high hills and mountains in Nepal [4]. The rate of increase in temperature is less in the lower altitude than that in the high altitude [4]-[6]. According to NCVST [7] the climate of Nepal is influenced by the Himalayan ranges and the South Asian monsoon. The result analysis from [2] showed that altitude affects annual temperature and precipitation patterns. Up to about 1500 m, annual rainfall increases with altitude; thereafter, annual rainfall decreases with increasing altitude [8]. The mean precipitation in Nepal is increasing annually by 13 mm, while the number of rainy days is decreasing by 0.8 days/year. High increase in summer river flow provides further evidence that high summer temperatures are leading to fast glacier melt/retreat [9]. A study of monsoon rainfall from period of 1971 to 2005 shows that there is linear increasing trend of about 2.08 mm/year with a large inter-annual variation [5]. There is also increase in the number of flood days in certain rivers in Nepal. The projections show an increase in the number of hot days and nights, with similar increases in the number of heavy rainfall events during the monsoon period. Likewise, for Western Nepal, the study identifies similar patterns of changing temperature and precipitation which shows the positive effects in country wide as well as Western Nepal (**Table 1**).

Climate risks including natural hazards such as floods and droughts affect the poor people's agriculture based subsistence livelihood. Changing climate mainly temperature and precipitation and the number of rainy days show a positive relationship with flood and extreme events where it damaged the physical infrastructures, loss of agricultural production and land and increase water borne diseases.

Studies showed that the adverse impacts of flood are more significant in developing countries like Nepal, making a weak economy even weaker [10]. It was manifested by the intense rainfall caused floods resulting in a huge loss of agriculture land and products in various parts of the country. The Koshi flood in 2008 in the eastern part and the West Rapti flood in 2012 in western part of Nepal are examples of such devastating flood events in Nepal [11]. Particularly, the mid-western regions of Nepal where West Rapti River Basin lies, are experiencing greater than expected floods, which resulted in immense damage to lives, properties and serious losses in production every year [3].

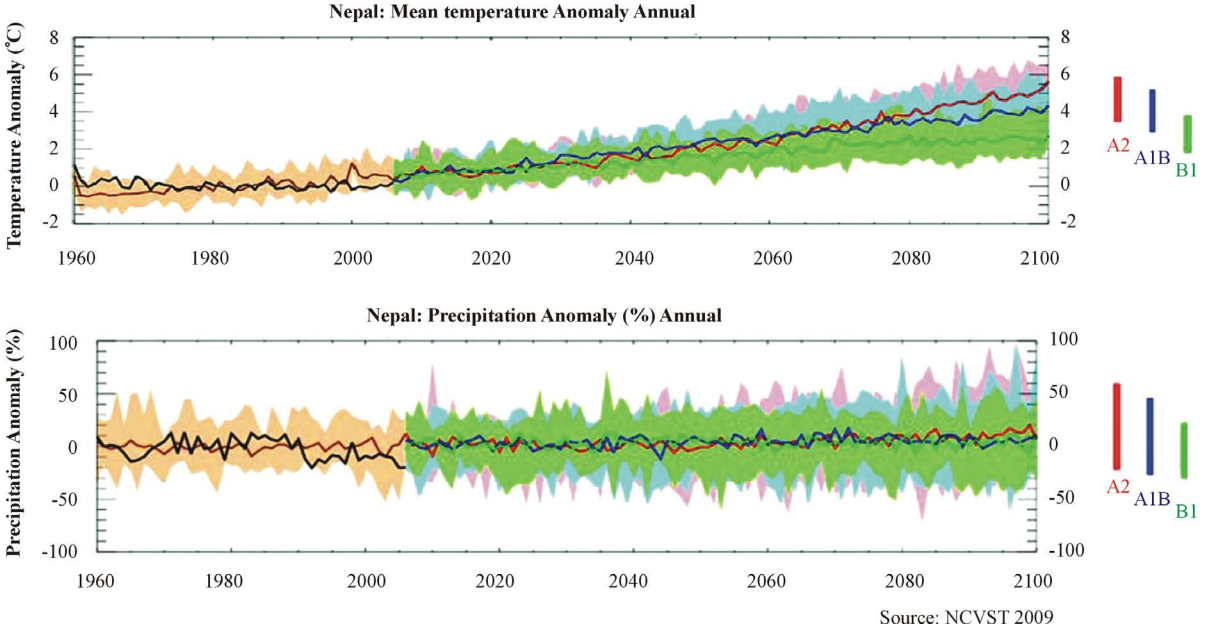

Figure 1. Mean annual temperature and precipitation anomaly.

Table 1. Projected multi-model GCM climate change variables for Nepal and Western Nepal.

	Nepal country wide			Western Nepal		
	2030	2060	2090	2030	2060	2090
Change in mean temperature: annual (˚C)	+1.4	+2.8	+4.7	+1.4	+2.8	+4.8
Change in frequency of "hot days" pre monsoon (%)	-	+2.5	+43	-	+26	+40
Change in monthly precipitation annual (%)	0	+4	+8	0	+4	+3
Change in precipitation as heavy events: monsoon (%)	+2	+7	+16	0	+2	+6

Changes are relative to the mean 1970-1999, run using the A2 scenario, hot days taken as hottest 5% days in the period of 1970-1999, and heavy events means high rainfall within the short time. (Sources: NCVST, 2009)

People have been facing flood problems on the banks of West Rapti River for the last few generations [12] but there has been little progress in developing the means of minimizing the impacts of floods, other than locally developed warning systems. The extent of damage due to flood in the basin will be increasingly severe due to the lack of information on climate change induced flood scenarios and lack of effective adaptation measures [13]. People have relied upon local knowledge for early warning, current and future flood adaptation strategies. Improvement of such activities with sound technical backup and integrating early warning system with proper community based flood management is seen to be very effective in saving lives and property due to floods [14]. Therefore, this paper argues that to identify the temperature trends of climate change and people's perception on those parameters.

2. General Features of the Study Area

The study was carried out in the West Rapti River Basin, covering both Banke and Dang districts of Nepal (**Figure 2**). The basin is located between 27˚40′ to 28˚36′ North and 82˚20′ to 83˚10′ East. The West Rapti River (WRR) originates in the Lesser Himalaya, flows through the Siwalik Hills and Terai plain of Nepal before joining the Ganga River in India. The main tributaries of the river are MadiKhola and JhimrukKhola. The average annual rainfall varies from 1151 mm to 2489 mm [15]. More than 80% of the rainfall occurs during the four months of monsoon season *i.e*. June to September. In this basin, more than 80% people are farmers. They are using indigenous methods in agricultural practices. Since the basin has long history of devastating flood, these people have been using their own flood adaptation strategies for their survival since time immemorial. However, such knowledge has been transferred to new generation verbally and through demonstration. This basin can, therefore, be considered one of the ideal basins and is chosen to do a research on the assessment of indigenous knowledge on flood management practices.

3. Methodology

The hydrological and meteorological data such as daily average temperature and rainfall data were obtained from the DHM Nepal and analysed using regression equation. The perceptions of the people on climatic variables and the results of rainfall analysis are compared based on seasons (early monsoon, monsoon and post monsoon seasons). Similarly, three focus group discussions (FGDs) were conducted in the flood prone areas; at Holiya Village Development Committee (VDC, the lowest administrative unit of the government of Nepal) and Kamdi VDC of Banke district and at Lalmatiya VDC of Dang district. People who have first-hand experience in early warning system such as farmers, foresters, VDC secretary, school teachers and local NGOs, were invited in the FGDs. In total, 39 people participated in the FGDs. In the beginning, they were asked to prepare a list of reliable media for information transformation that are reliable for local context. Then, they were further requested to select only those media that are most reliable. These most reliable media strategies were administered through household survey. Total 240 households were randomly selected for the interview. During the field visit (Feb-May 2012), the key person of the household was requested to rank selected early warning media against a 1 - 5 scale, where 1 is a least reliable option and 5 is most reliable option.

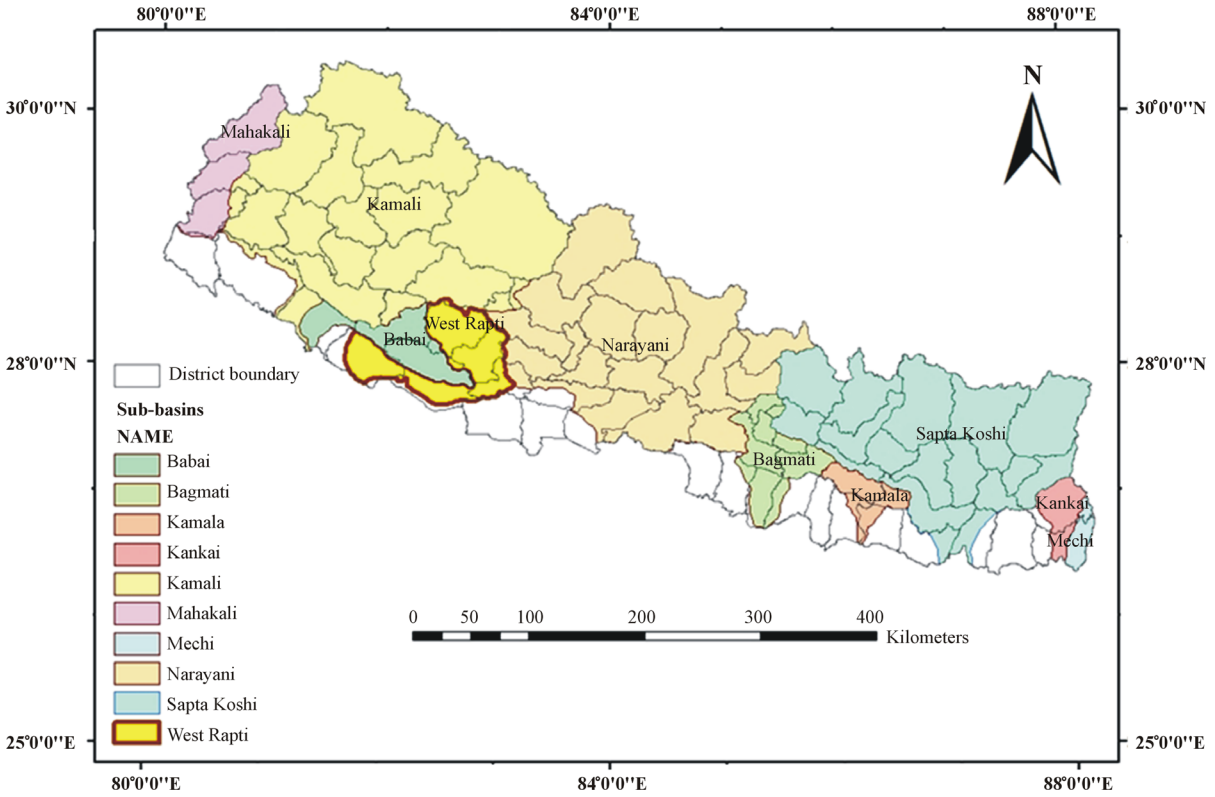

Figure 2. Location map of study area.

4. Results and Discussion

4.1. Temperature: Trends and People's Perception

4.1.1. Observed Trend

The temperature data of 35 years (1973 to 2008) was used for its trend analysis. The annual mean temperature for this period was found to be 25.4˚C. However, the highest and lowest annual mean temperature in the study area were respectively 26.7˚C in the year 2007 and 23.5˚C in 1983. The trend of mean temperature rise was +ve but slow in between 1970s to 2000. However, the rate of rise was remarkable after 2003 (**Figure 3**). It shows that the annual mean temperature rise was 0.025˚C/year for this period. It can be seen from the graph that there was greater fluctuation in mean temperature in 1970s than in 1980s and 1990s.

Figure 4 shows the trend of mean annual maximum temperature of the study area. It shows that there was slow rise in the maximum temperature until 2000. After 2000 the mean annual temperature showed a very strong rise. It is noted here that the mean maximum temperature was 43.9˚C for the whole period from 1973 to 2008 with the highest value of 46.8˚C in the year 2008 and the lowest value of 39.9˚C in the year 1990. The annual mean maximum temperature rise was 0.045˚C/year between 1973 and 2008.

The trend of mean minimum temperature rise was +ve (**Figure 5**). There were some fluctuations in annual minimum temperature in 1970s and 1980s but there was smooth rising trend since 1990s. There was also a very smooth rise in mean annual minimum temperature in the last 5 years. The average of the minimum mean temperature was found to be 3.3˚C for the years 1973 to 2008 with the highest minimum mean temperature of 7˚C in the year 1977 and lowest of 0.9˚C in the year 1976. The graph shows that the annual mean minimum temperature has a positive increasing trend. It is 0.043˚C/year.

4.1.2. People's Perception

People's perception on the temperature change over the past two decade is presented in **Figure 6**. Majority of the respondents mentioned that there was an increase in both the summer (63.7%) and winter (52.7%) tempera-

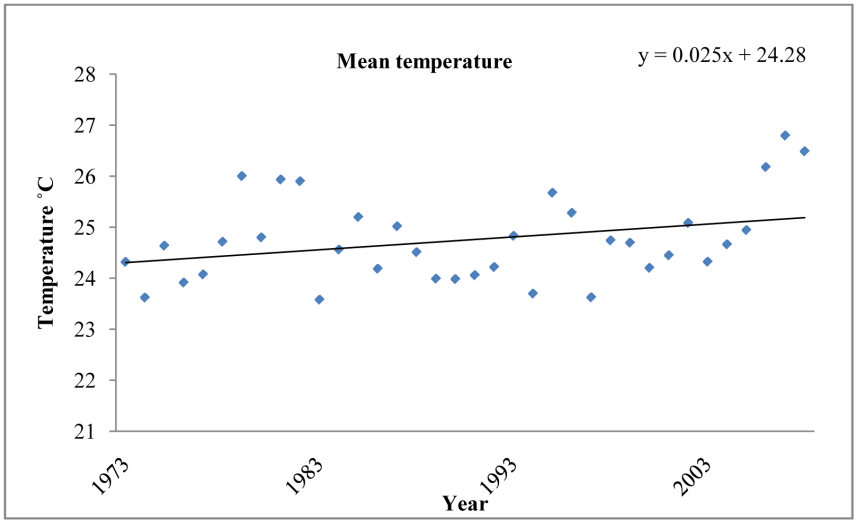

Figure 3. Trend of annual mean temperature.

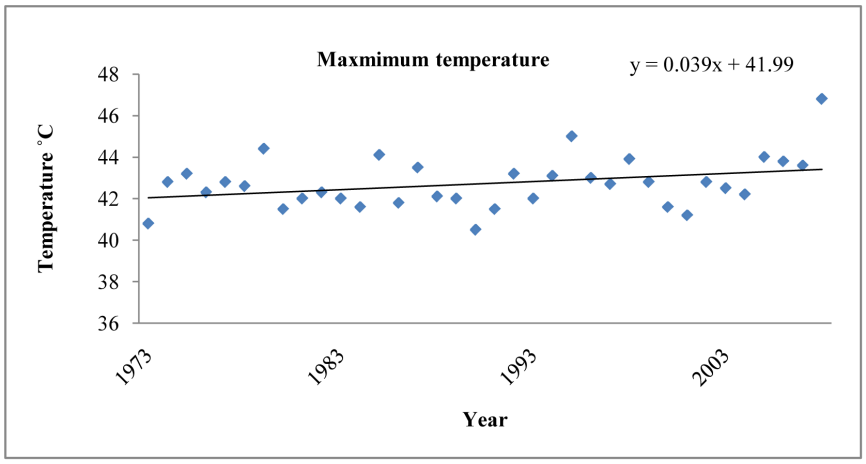

Figure 4. Trend of annual maximum mean temperature.

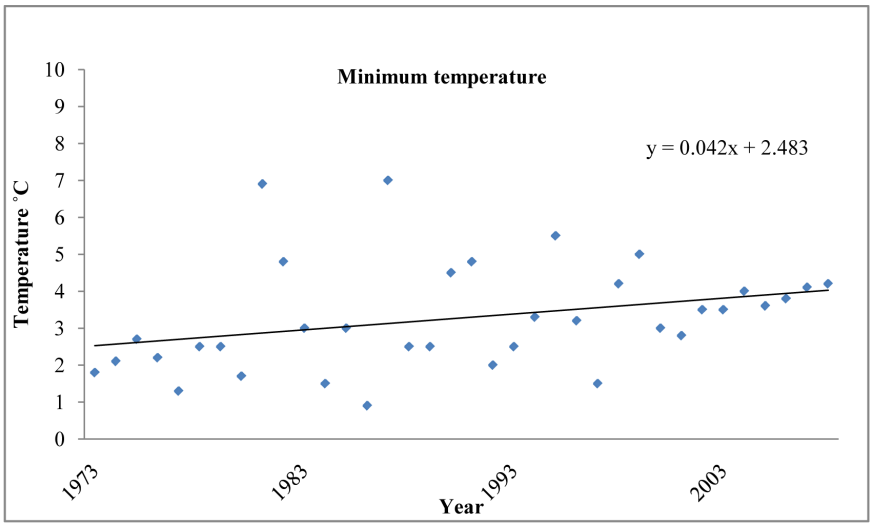

Figure 5. Trend of annual minimum mean temperature.

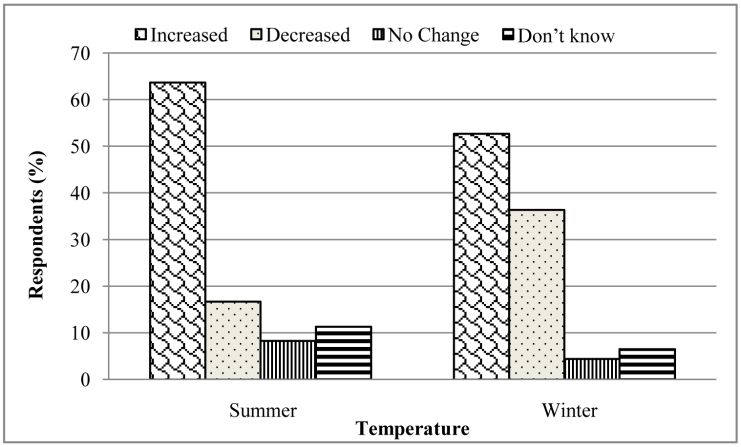

Figure 6. Perception of respondents (N = 240) of the recent temperature compared to 20 years ago.

ture. However, some of respondents (16.7%) mentioned that there was a decrease in temperature in summer and sizable number of people (36.4%) said that winter temperature was decreasing when compared to past temperature. Similarly, 8.3% and 4.4% of the respondents perceived that there was no change in temperature during summer and winter. Moreover 11.3% and 6.5% of the respondents had no idea about change in temperature.

4.2. Discussion on Temperature: Trends and People's Perception

The annual average maximum temperature is 46.9˚C in 2008 and annual average minimum temperature is 0.9˚C in the year 1976 with the highest minimum of 7˚C in the year 1977. The trend analysis of temperature showed the increasing trend of both the annual average minimum temperature and maximum temperature. The trend of maximum mean temperature was +0.044˚C/year and that of minimum mean temperature was +0.042˚C. Average temperature of the study area has increased by 0.043˚C/year which was similar to the findings of previous studies [16] [17] which have mentioned that the temperature rise in Nepal is within a range of 0.2˚C - 0.6˚C per decade.

Other studies [18], [13] have also indicated that average annual temperature has risen by 0.06˚C per year and also reported temperature increase of 0.06˚C to 0.12˚C/year in most of Middle Mountain and Himalayan regions while less than 0.03˚C/year for Siwalik and Terai region from 1971 to 1994. Baidya *et al.* [6] analysed both annual mean minimum and maximum temperature for the years 1981 to 1998 and found that annual mean maximum temperature has increased at a higher rate (0.057˚C/year) than annual mean minimum temperature (0.025˚C/year). Similar trends were also found on the other side of the Himalayas on the Tibetan Plateau where the temperature trend was less than 0.005˚C/year at elevations lower than 500 m whereas it was more than 0.03˚C/year at elevations higher than 4000 m [19]. This value was also most similar with the annual average land-surface temperature trends for the globe (*i.e.* 0.011 - 0.022˚C/year) and for the Northern Hemisphere (*i.e.* 0.018 - 0.031˚C/year) form the period of 1976-2000 as reported by [20]. In the context of Nepal, projected temperature increases are lower in Eastern Nepal than in Western and Central Nepal; by the 2090s with the difference of about 0.7˚C [21].

The finding of temperature rise was consistent with the people's perception. As compared to 20 years ago, people perceived increase in both the summer and winter temperatures. Similar result was found by other scholars [22]-[24] in the mid part of the country. Local people have perceived that cooler days are decreasing and extreme hot days are more pronounced than 20 - 30 years back [25]. In conclusion, the temperatures in Nepal are increasing at a faster rate than the global average.

4.3. Precipitation: Trends and People's Perception

4.3.1. Observed Trend

The pre-monsoon (March-May) rainfall also was decreasing by 0.08 mm annually from 1971 to 2008 (**Figure 7**). **Figure 8** shows that the trend of monsoon (June-September) rainfall averaged over all four stations of West

Rapti Basin. The general trend was +ve, increasing by 0.004 mm annually from 1971 to 2008. **Figure 9** shows that the trend of post-monsoon (October-February) rainfall of all four stations. There is very clear positive trend of post-monsoon rainfall with annual increase by 0.212 mm from 1971 to 2006. This is the biggest shift in rainfall and has significant impact on cropping time of several crops.

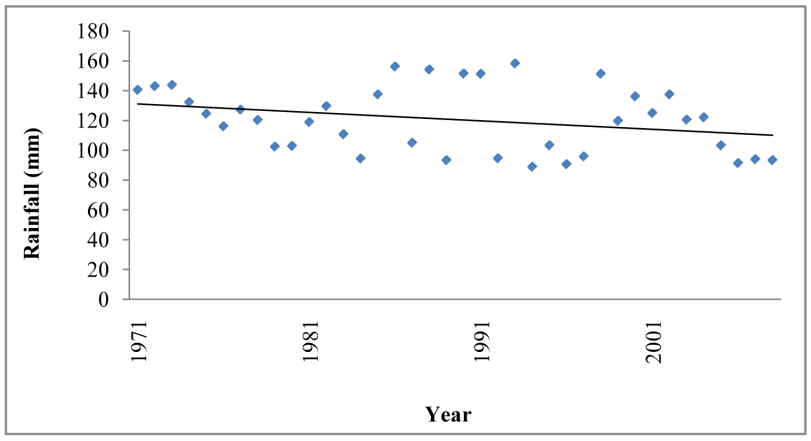

Figure 7. Trend of pre-monsoon rainfall.

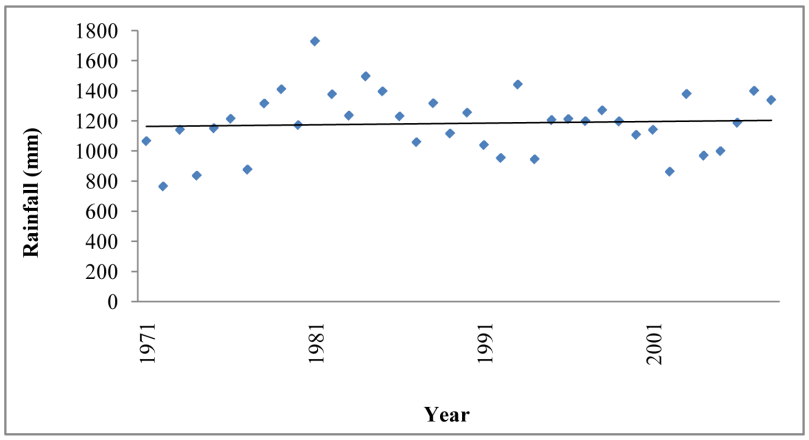

Figure 8. Trend of monsoon rainfall.

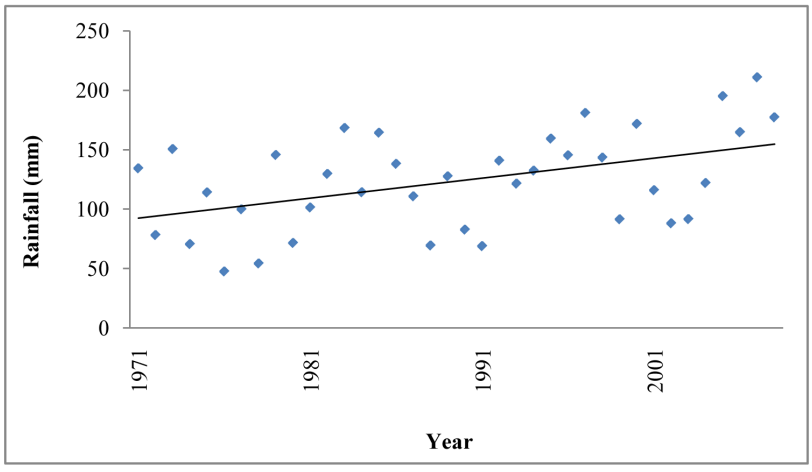

Figure 9. Trend of post-monsoon rainfall.

4.3.2. People's Perception on the Change in Monsoon Season

Even in the scientific community the onset of monsoon and end of it is under debate. About 88% of the respondents stated that there was a change in beginning and ending time of monsoon season when compared to last 20 years rainfall. Out of the total respondents, about 20% (6.7% strongly agreed and 14.7% agreed) believed that there is some earlier shifting of monsoon *i.e.* increase in pre-monsoon rain, in recent years as compared to past whereas more than this percentage (30%) did not believe (18.4% and 10.4% of the respondents disagreed and strongly disagreed) such change (**Figure 10**). Majority of the people (49.8% of the respondents) told that they could not say anything on it as onset of monsoon is early in some years and late in some other years.

More than two third of the respondents (strongly agreed: 20% and agreed: 47.5%) felt that the amount of monsoon rain has been increasing in the last two decades. Only 10.8% of the people of the study area said that they did not feel that there is any increase in monsoon rainfall. About one fifth of the people (21%) are neutral on this issue. Similarly, majority of the respondents (86.4%) either strongly agreed (54.3%) or agreed (32.1%) that monsoons has been pushed further and post-monsoon rainfall has been increased. This situation may force climatologists and meteorologists to redefine the monsoon season.

4.4. Discussion on Precipitation: Trends and People's Perception

The observed precipitation trend was analysed for pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-February). The precipitation was significantly increasing for post-monsoon season; however pre-monsoon precipitation was decreasing in the recent years. This result was supported by the previous studied [5] [7]. The post-monsoon trend illustrated an increasing trend in rainfall up to over 4 mm/year for most of the mid-western development region and the southern parts of eastern, central and western development regions. This study found that, the unexpected rainfall was increasing in post-monsoon season affecting hydrological cycle considerably, which influence the river flooding, drought and low flows.

People's perception on climate change revealed that most of the people believe that there is a change in the temperature and rainfall pattern. However, there were many respondents having no idea. More than 88% of the respondents mentioned that the monsoon season was shifting. The starting time of monsoon becoming late and ending of rainfall also late. It means that the timing of rainfall was changing. It is noticeable that people's perception on rainfall time and trend observed were similar. Other researcher also argued that monsoon time was shifting and also agreed variability in rainfall with untimely rainfall events, late monsoon start, and high intensity pattern in off monsoon season [3] [6].

Similarly, the rainfall pattern compared to 20 years ago, the beginning of monsoon rainfall time is late and

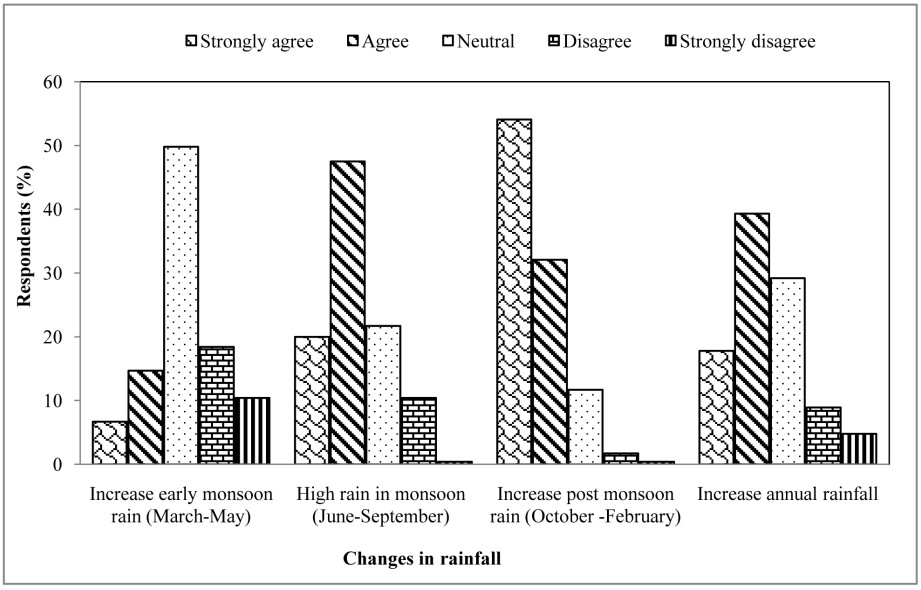

Figure 10. Perception of respondents (N = 240) of the recent rainfall pattern compared to 20 years ago.

post monsoon time is late in recent years. The respondents strongly agreed and mentioned (**Figure 10**) that total precipitation and duration of post-monsoon season is increasing, however, in the case of early monsoon season, majority of the respondents strongly disagreed and disagreed. Majority of the respondent were strongly agreed and agreed with the increased in the monsoon rainfall and total annual rainfall. It also verified and comparable with the observed trend, which were similar to each other. It is noted that the observed trend and people's perception on starting monsoon season was similar which open the area to redefine the monsoon season from this study.

Not only in this study, heavy rainfall is projected to increase slightly in the monsoon and post-monsoon seasons, and decrease slightly in the pre-monsoon seasons [7]. Similarly, rainfall magnitude has increased the linear trend of monsoon rainfall for the years 1971 to 2005 as analyzed by Baidya *et al*. [6] showed slight positive tendency. Sharma [26] concluded in his study that the number of monsoon days, with early onset and late withdrawal as well as the intensity of monsoon rain has an increasing trend. Also, Shrestha *et al*. [27] concluded that the associated effects of climate change have already been observed such as increase in dry period, intense rainfall, flood, landslides, forest fires, glacial retreat etc.

The increasing temperature generally results in an increase in water holding capacity of the atmosphere that lead to change in precipitation pattern and increase in atmospheric moisture [28]. Botzen *et al*. [29] found that heavy rain with high wind velocity correlates with high minimum temperature. Therefore, increase in minimum temperature in the study area can be expected to cause increase in unusual rainfall (with high wind velocity) and damages caused due to this.

The overall rainfall trend in monsoon season showed that the rainfall was mainly increasing in eastern, central, western and far western development regions reaching up to over 30 mm/year [3] [30]. In mountains, the monsoon rainfall is mainly of an orographic nature, resulting in distinct variations in rainfall with elevation [27]. On the meso-scale, the impact of climate is mainly due to local topographic characteristics [31]; with dry inner valleys receiving much less rainfall than the adjacent mountain slopes as a result of the lee effect. Thus the amount of rainfall received in each decade varied which may be due to the fluctuation in the temperature. Similarly, projected mean annual precipitation does not show a clear trend and it is projected that it will changes by −34 to +22% by the 2030s. Similarly, the changes in mean precipitation will be from −36 to +67% and −43 to +80% by the year 2060s and 2090s [21]. In south Asia continent, the number of rainy days with daily precipitation of more than 50 mm was increasing by 2%/year. The IPCC [20] pointed out that there was some evidence of increases in the intensity and frequency of extreme weather events like intense rainfall, prolonged dry spells etc. in Asia throughout the 20th century. Precipitation has increased from 5% to 10% during 20th century over mid and high latitudes of northern hemisphere continents, but has decreased by 3% on average in much of sub-tropical land areas [20]. Trends from 1900 to 2005 indicated that precipitation has increased significantly in eastern parts of North and South America, Northern Europe and Northern and Central Asia. Predictions of climate change and its impacts are highly uncertain at regional and local levels [32].

It is very difficult to identify specific causes of climate change induced flood risk but these events were the results of climate factors [33] [34]. Therefore, the actual trend shown by the recorded data and the perceptions of the local people are in good agreement to each other which has increased the reliability of the findings. The implication of this finding of this research is mainly on climate change policy, National adaptation programme of action and Local adaptation programme of action for their implementation modalities in Nepal.

5. Conclusion

The changing climate is a challenge for both current and future generations. Its impacts are increasing the vulnerability of societies around the world. Finally, the temperature is increasing at a faster rate in West Rapti River basin than the average of Nepal and global. Similarly, rainfall intensity and magnitude are increased in the monsoon and post-monsoon seasons rather than in the pre-monsoon season which may raise the extreme events such as floods. Furthermore, the actual trend shown by the recorded data was justified by the perceptions of the local people resembling with the findings of the study. The devastating floods and incessant rains affect this basin in that: causing extensive damage to standing crops, physical and social infrastructure, environment, people's lives and livelihood and weakening the capacity of rural poor. The analysis provided herein shows that combining with scientific facts and figure and local people's opinions provides more reliant and relevant investigations of climate change and allows for better planned adaptations. The findings of this study can be useful for making

effective flood management strategy, policy and plan.

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