Review Article
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Climate variability, disasters and their impacts assessment in Manahari, rural municipality of Makwanpur, Nepal

Abstract

Nepal is climatically very sensitive country because of long drought, heavy floods, landslides and soil erosion caused by changing pattern of rainfall and temperature. However, there are very limited studies related to these issues, thus this research was objectively carried out to analyze temperature and precipitation trend of study area, examine the climate pattern and assess the impacts of climate change hazards on different sectors. Ward number 7 and 8 Manahari Rural Municipality of Makwanpur district was selected as the study site. Total 40 households survey, 15 Key informants interview and two focus group discussions were conducted involving the affected local to collect the primary data. Moreover, secondary data specifically monthly maximum and minimum temperature and rainfall for thirty one years between 1985–2015 were gathered from nearest meteorological station i.e. NFI Hetauda Station (Station No. 906) and Manahari Station (Station No. 920). The drought trend was calculated using the ratio of Precipitation<2Temperatures. The theoretical distribution i.e. Gumbel, Log-Pearson and Log Normal models were applied to predict the flood peaks and maximum rainfalls. The mean annual temperature was increasing at the rate of 0.0226°C per year. The highest mean annual temperature was 24.1°C in 2015. It was found that, the number of days exceeding the maximum average temperature in the period of 31 years. However, the trend of total annual precipitation in Hetauda was decreasing at the rate of 5.6607 mm per year. The highest rainfall was recorded about 3323.1 mm in year 2002 and it was the least only 1626.2 mm in 2012. The January, February, March, November and December were the driest months. Flood frequency using Log Pearson showed the highest flood in 1000 years return period. The mean rank was the highest of drought having value 5 while it was the lowest only 1.4 of flood. The slope failure at the edges of the rural roads also causes landslides which also fills the agriculture land. The locals responded that the drainage systems were poor and there were no protection structure and/or biological component to reduce landslide risk during construction periods. Major five disasters were recorded in Manahari during from March to June whereas, wildlife attack throughout the year and so on.

Keywords: climatic variability, impact, disaster, temperature, precipitation, Manahari, Makwanpur

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Introduction

Climate change and global warming is the most significant threat to the living beings in this planet at the twenty-first century. The change has accelerated due to anthropogenic emissions of greenhouse gases (GHGs) over the last 160 years. According to IPCC, the adverse effects of changing weather patterns and climate have extended beyond crop cultivation and influence livelihoods of peoples. Water is the most important resource of a country, and of the entire society as a whole, since no life is possible without water.[1] It has this unique position among other natural resources, like minerals, fuels, forests, live-stock etc. because a country can survive in the absence of any other resources, except this but extreme is the problem.

Flood and landslides are the leading cause of losses among the most devastating natural disasters in the world, claiming more than 20.000 lives per year and adversely affecting about 75 million people worldwide, mostly through homelessness.[2] The trends of flood events are increasing more in Asian countries and decreasing in African countries.[3] South Asian countries have a long history of floods, among these Nepal is one of the highly affected country.[4] The country's social context characterizes with low level of development as well as low level of institutional capacity consequent to intensify the impact of disasters. Also, low-income and lower middle-income countries are more vulnerable to climate variability than high-income countries[5] due to their ability to adapt and their geographical location. Nepal is one of the most water-abundant countries in the world with its 6.000 rivers and rivulets, with total mean annual runoff of 224 billion cubic meters (BCM) and per capita water availability of 9.000m^3.[6] Nepal is exposed to a variety of natural hazards and human induced disasters. More than 80 percent of the total population of Nepal is at risk of natural hazards such as floods, landslides, windstorms, hailstorms, fires, earthquakes and Glacial Lake Outburst Floods (GLOFs). Globally, Nepal ranks 4th and 11th in terms of its relative vulnerability to climate change and earthquakes, respectively.[7]

Nepal ranked 23rd in the world in terms of the natural hazard related deaths in two decades from 1988 to 2007 with total deaths reaching above 7000[8] It is in 7th position for deaths resulting as a consequence of floods, landslides and avalanches; in 8th position for flood related deaths alone. A UN Report shows that out of 75 districts in the country, 49 districts are prone to floods and/or landslides, 23 districts to wild fires and one to wind storms. A total of 64 out of 75 districts are prone to disaster of some types.[9] The research on climatic parameters, discharge and its frequency analysis, adaptation strategies will help to provide sustainable resources management planning, but such research is not so far done in Makwanpur, Nepal. Thus, this research is objectively carried out to analyze temperature and precipitation trend of study area, examine the climate pattern and assess the impacts of climate change on different sectors.

Materials and methods

Research site

Makwanpur district is located in Province 3 and it covers an area of 2418 square kilometer within latitude 27°10' N to 27°40'N and longitude 84°41'E to 85°31'E. Makwanpur district is surrounded by the borders of Bara, Parsa and Rautahat districts to the South, Lalitpur, Kavre and Sindhuli to the East, Chitwan district to the West and Kathmandu and Dhading districts to the north.[10] Subsistence agriculture farming, mainly traditional agriculture is the main source of occupation and livelihood of the majority of the population. The shape of the district is like a military boot and represents different agro-climate zone comprising of valley, flat land to middle hills and high hills. Makwanpur district is well known for religious, historical, tourism, rafting (Indrasarobar), trekking and expedition. The district rises from 166 m to 2.584 m above sea level, making up 1.65 percent of the total land area of Nepal. Towards the north a 66 km wide Mahabharata range makes up 41% of the district area whereas the southern part of the district has 92 km wide Chure (Silwalik) hills that makes up for 59% of the district area.[11] The study is conducted in Manahari Rural Municipality. There are a number of rivers running through the district, the main ones being the Rapti, Bagmati, Bakaiya, Manahari and Lothar; in addition there are many smaller streams. The major hill ranges in the district are Chandragiri Range (Phakhel to Tistung), Mahabharata Range (Betini to Khaireni) and Chure Range (Rai Gaun to Manahari).[12]

The meteorological data from Hetauda station 1975-2005 periods, experiences average minimum temperature between 15°C and 17°C. Annual mean maximum temperature lies between 28°C and 30.5°C excluding some exceptions (such as in 1993). Most of Siwalik region and Bhawar like flood plains of the region fall in the sub-tropical climate zone up to altitude of about 1.200 meters and covers about 59% area of the district. Manahari Rural Municipality lies in Makwanpur district of Province 3. The rural municipality ranges from 84°42'35'' to 85°57' 36'' E Longitude and 27°23'34'' to 27°36' 37'' N Latitude. The study area is surrounded by Hetauda Sub-metropolitan city and Raksirang RM in East, Chitwan National Park in West, Raksirang RM in North and Parsa District in South with an area of 199.52 km^2.[13] The study area lies at a range from 390 m to 760 m.asl in ward no.7 and 8 of Manahari Rural Municipality as shown in Figure 1 below.

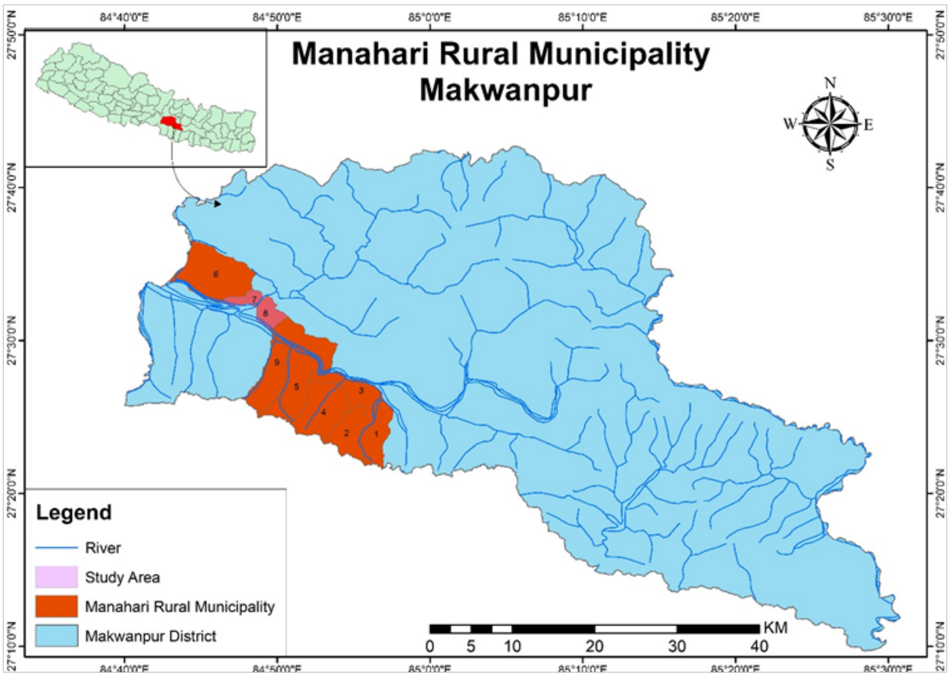

Figure 1 Location map of study area.

Data collection

Prior to field study, individual consultation was carried out with personnel of development organization of the district. The study area was finalized upon consultation with personnel of district, officer, district lead support agency etc. Primary data were collected using some Participatory Rural Appraisal (PRA) methods.

Household survey

The study area was focused on the area where the river invades the villages and causes damages and destruction. Altogether40 survey was done in ward number 7 and 8 of the rural municipality gets hit hard by the river during the time of summer monsoon.

Key informant interview

Informal interviews were carried out for the documentation of major climate disasters and their impacts. Teachers, Agriculture Office, Local NGO and Community Leaders etc. were interviewed. Total 15 experts were asked the about the climate disaster.

Focus Group Discussion (FGD)

Discussion was carried out with locals who had been residing in the study area for last 30 years. The community's response and coping strategies and the institutional support that was available at the time were identified. Two focus group discussions were done in both wards.

Field observation

Field observation was carried out to collect observed information was noted and any noticeable changes were marked.

Secondary data sources

Relevant literatures from different publication, reports, books, journals were consulted from different sources SchEMS library, Division Forest Office, online sources, Department of Hydrology and Meteorology and from internet. Climatic data such as temperature and rainfall obtained is of Hetauda NFI Station and Manahari Station from time interval 1985 to 2015.

Data analysis

Drought trend analysis

It is done by combining the monthly values of precipitation expressed in millimeters (P) and temperatures in centigrade degree (T). The biologically dry month is defined by ratio the P<2T, theory.[14]

Flood frequency analysis

Flood frequency analysis is a technique used by hydrologists to predict flow values corresponding to specific return periods or probabilities along a river. Frequency analysis makes uses of the observed data in the past to predict the future flood events along with their probabilities or return periods. It plays a vital role in providing estimates of recurrence of floods which is used in designing structures such as dams, bridges, culverts, levees, highways, sewage disposal plants etc.[15] The estimation of flood frequency helps in designing safe structures and also in protection against economic losses due to maintenance of structures. The flood frequency curve is used to relate flood discharge values to return periods to provide an estimate of the intensity of a flood event. The discharges are plotted against return periods using either a linear or a logarithmic scale and to provide an estimate of return period for a given discharge, the observed data is fitted with a theoretical distribution i.e. Gumbel, Log-Pearson and Log Normal, using a cumulative density function (CDF). This helps the users in analyzing the flood frequency curve.[16]

The Gumbel's method

The Gumbel's Method (Gumbel Distribution) is the most widely used probability distribution function for extreme values in hydrologic and meteorological studies for prediction of flood peaks and maximum rainfalls.[15] In this method the variate X (flood peak discharge) with a recurrence interval T is given by;

$$x_T = \bar{x} + K\sigma_x$$

$$where, K = \frac{\left(y_T - \overline{y_n}\right)}{\sigma_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

x_T = discharge of return period T.

$\bar{x}$ = mean discharge

y_T = reduced variate,

$\overline{y_n}$ = mean of reduced variate (it is table value)

σ_x = standard deviation of reduced variate (it is table value)

σ_x = standard deviation of sample size N

The log-pearson type III (LPT-III) method

In this method extrapolation can be made of the values for events with return periods well beyond the observed flood events. In this method the variate is first transformed into logarithmic form (base of 10) and the transformed data is then analyzed.[15] If X is the variate of a random hydrologic series, then the series of Z variate

where $Z = \log X$ are first obtained for this z series, for any recurrence interval T.

$$Z_T = Z_{ayg} + K_z S_z$$

Where Z_{ave} =arithmetic mean of Z values K_z is a frequency factor which is a function of recurrence interval T and the coefficient of skew Cs, For N=number of sample=n number of years of record. $S_{Z=}$ Standard deviation of Z variate sample $\sqrt{\frac{\Sigma(Z - Zave)^2}{N-1}}$

C_s = coefficient of skew of variate $Z = N\Sigma\frac{(Z - Zave)^3}{(N-1)(N-2)\sigma_s^3}$

Corresponding value of X=antilog (Z_T) 3.2

The log normal method

The method is basically same as the Log Pearson Type III method except the skewness coefficient C_s is taken as zero. The log normal distribution plots as a straight line on logarithmic probability paper.[15]

Results

The results of this study are presented in accordance to the objective in different sections below.

Mean annual temperature trend

According to a recent study, the temperature of Nepal is increasing by about 0.056°C/yr.[17] Most of flood plains and adjoining Siwalik and Bhawar regions in Makwanpur experiences sub-tropical climate. Remaining areas 1.200 meters above msl, which is about 40% of the district, fall on temperate climate zone. Annual mean maximum temperature lies between 26°C and 37°C excluding some exceptions. Thirty one year data of monthly maximum and minimum temperature from 1985 to 2015 was collected from nearest meteorological station i.e. NFI Hetauda Station (Station No. 906) and Manahari Station (Station No. 920) nearest station of same range. The mean annual temperature is increasing at the rate of 0.0226°C per year. The mean annual temperature for the thirty one year is found to be 23.0°C. The temperature of Makwanpur has been increasing till 1996 from 1985 and then sharp declining trend reaching 21.6°C in 2002, again increasing till 2015. This is why overall mean temperature trend appears to be increasing. The highest mean annual temperature recorded was 24.1°C in 2015 (Figure 2).

Days exceeding maximum average temperature

The maximum temperature from the Figure 3 shows the increasing trend. The average maximum temperature of 31 years is found to be 32.9°C. So, a plot is made with average maximum temperature and the temperature above average maximum. It shows that the days with maximum temperature is increasing year by year with the maximum being in 2009 AD. The following figure shows the number of days exceeding the maximum average temperature in the period of 31 years.

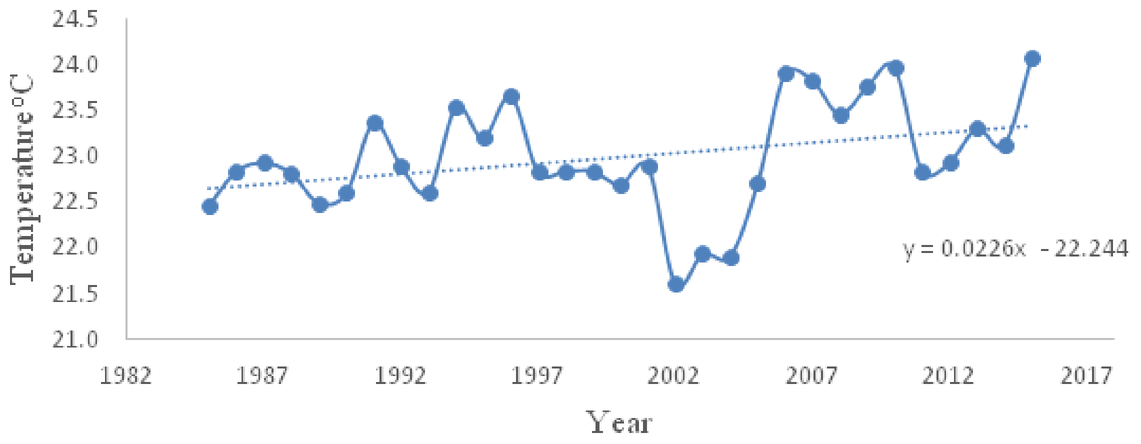

Figure 2 Mean annual temperature trend of Hetauda.

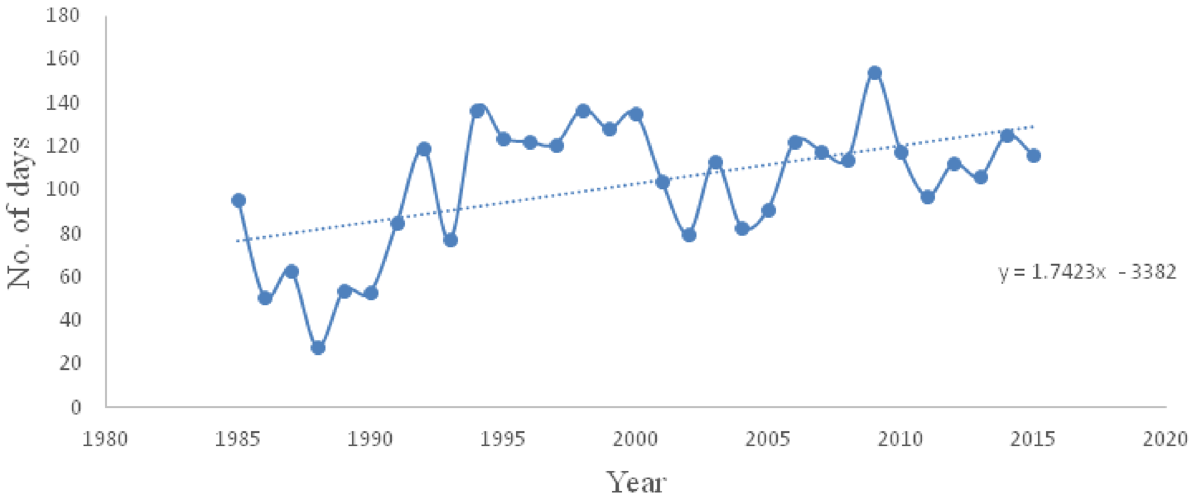

Figure 3 Days exceeding maximum average temperature.

Annual rainfall trend

Figure shows the decreasing trend of total annual precipitation in Hetauda at the rate of 5.6607 mm per year. Annual rainfall fluctuates regularly in last 31 years. The highest rainfall recorded is about 3323.1 mm in year 2002 and least amount rainfall i.e. 1626.2 mm was recorded in year 2012. Even though it fluctuated regularly throughout 31 years the rainfall has decreased a bit. The Variance in annual rainfall can be elaborated deeply as we study it in partially (Figure 4). The total annual precipitation shows the increasing trend in Manahari (Figure 5) at the rate of 11.148 mm per year. Annual rainfall fluctuates regularly in last 31 years. The highest rainfall recorded is about 2824.3 mm in year 2001 and least amount rainfall i.e. 1295.8 mm in year 1988.

Trend analysis of drought

The biologically dry month is defined by ratio the P<2T[18] theory. Analyzing 31 years monthly data of precipitation and temperature shows that January, February, March, November and December are driest months. Since, these months temperature when assumed double, the value exceeds the total precipitation received on these months. Out of these five months March is the driest month. The overall scenarios of precipitation and temperature are given in table below (Table 1).

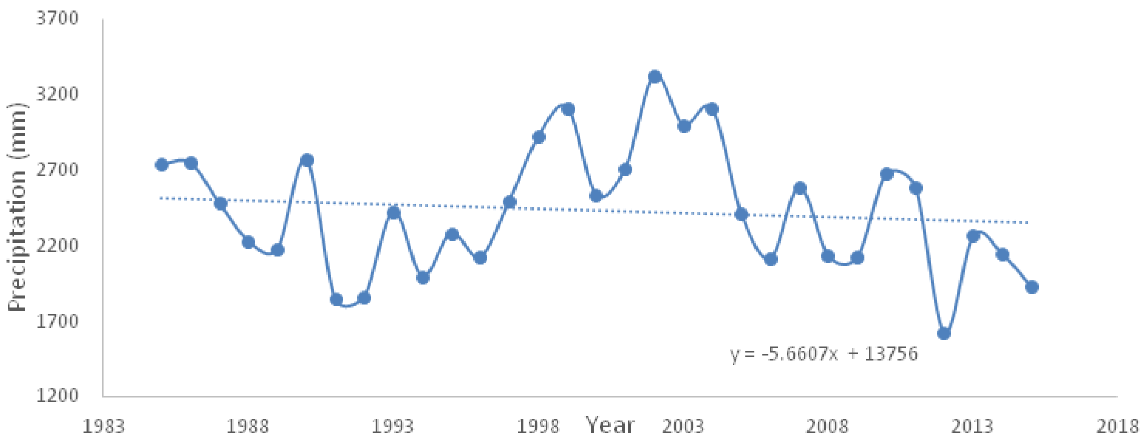

Figure 4 Total annual rainfall trend of NFI Station Hetauda.

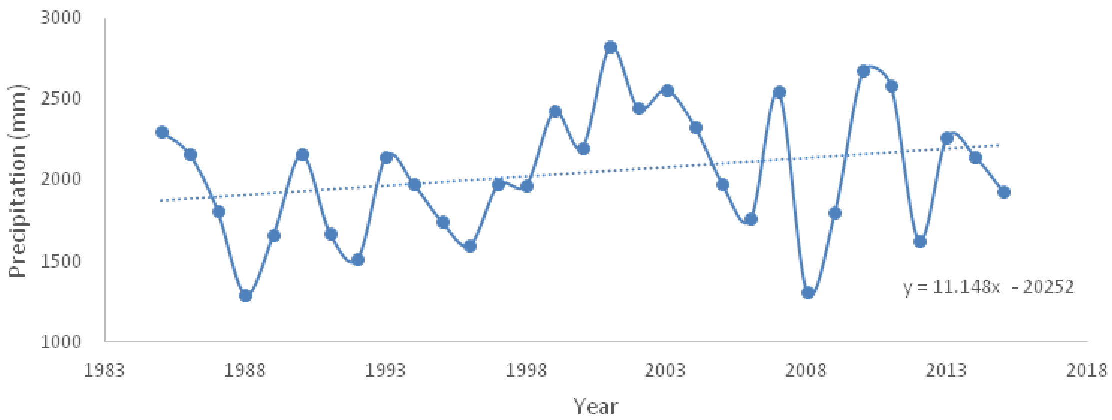

Figure 5 Total annual rainfall trend of Manahari Station.

Table 1 Monthly mean precipitation and mean temperature of 30 years and drought analysis

Months	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Precipitation	13.1	21	21.3	54	152	295.2	570.3	519.7	299.4	85	3.9	9.9
Temperaturee	14.9	17.2	21.7	24.8	26.9	28.1	28.1	28.1	27.1	23.2	19.5	16.1
TA	29.8	34.4	43.4	49.6	53.8	56.2	56.2	56.2	54.2	46.4	39	32.2
Conclusion	P<2T	P<2T	P<2T	P>2T	P>2T	P>2T	P>2T	P>2T	P>2T	P>2T	P<2T	P<2T
	D	D	D	ND	ND	ND	ND	ND	ND	ND	D	D

Note: ND, not drought; D, drought; TA, theory applied

Flood frequency analysis

The flood values were calculated using Gumbel, Log Normal and Log Pearson III distributions fitted to the observed annual maximum flow data. Of these 30 years flood peak, the flood of 1993 is the devastating one (Table 2). Flood frequency using Log Pearson shows the highest flood in 1000 years return period as compared with Gumbel distribution and Log Normal distribution shown in Figure 6 below.

Disaster identification, risk, ranking and status of Manahari

This is a secondary data obtained from District Coordination Committee Office, Makwanpur. This provides detail information of disasters, their rankings and activities to be carried out during pre and post disaster. In Manahari major disaster and their ranking is listed below. Ranking is done numerically, the most severe disaster ranked as 1 and so on (Table 3).

The hazard severity varied according to its source. It was 60 and 40% due to flood value of high and medium hazard severity respectively (Table 4). The mean rank was the highest of drought having value 5 while it was the lowest only 1.4 of flood. The Manahari Rural Municipality has been affected with floods and landslides. So this rural municipality has been also kept in highest hazard probable vulnerability zone. The evaluation from DCC as well from district administration office clearly indicates Manahari to be as one of the most high disaster probable area. The UNDP has also identified Manahari Rural Municipality to be as most vulnerable area. The different disaster plans has also been made to minimize the effects of disaster (Figure 7).

Table 2 Annual maximum flood series at Manahari gauging station

Year	Maximum discharge (m^3/s)	Year	Maximum discharge (m^3/s)	Year	Maximum discharge (m^3/s)
1987	298	1997	75.7	2007	444
1988	182	1998	328	2008	202
1989	510	1999	624	2009	441
1990	366	2000	285	2010	195
1991	263	2001	435	2011	193
1992	113	2002	713	2012	134
1993	1221	2003	873	2013	182
1994	540	2004	631	2014	913
1995	93.5	2005	247	2015	228
1996	90.9	2006	293	2016	256

Table 3 Disaster identification and disaster ranking in Makwanpur

SN.	Disaster	Disaster numbers	Human loss	Affected families	Home loss	Economic loss	Ranking
1.	Earthquake	4	35	86043	56000	5100000000	1
2.	Flood	105	278	60074	4488	23479451	2
3.	Landslide	92	350	32783	1437	7325916	3
4.	Epidemics	93	688	5285	0	30000000	4
5.	Thunderbolt	105	301	292	31	1595000	5
6.	Fire	82	46	1603	511	239727820	6
7.	Hailstone	26	3	0	0	19700000	7
8.	Accidents	11	17	0	0	0	8
9.	Windstorm	10	2	0	49	1000000	9
10.	Road Accident	11	10	0	4	0	10
11.	Forest Fire	6	2	65	19	1850000	11

Table 4 Existing hazard and severity of impact

Hazards	Mean rank of hazard	Hazard severity		
		High	Medium	Low
Flood	1.4	60.00%	40.00%	-
Landslide	1.8	20.00%	60.00%	20.00%
Drought	5	-	-	100%
Soil erosion	2.6	-	90.00%	10.00%
Forest fire	3.2	15.00%	5.00%	80.00%

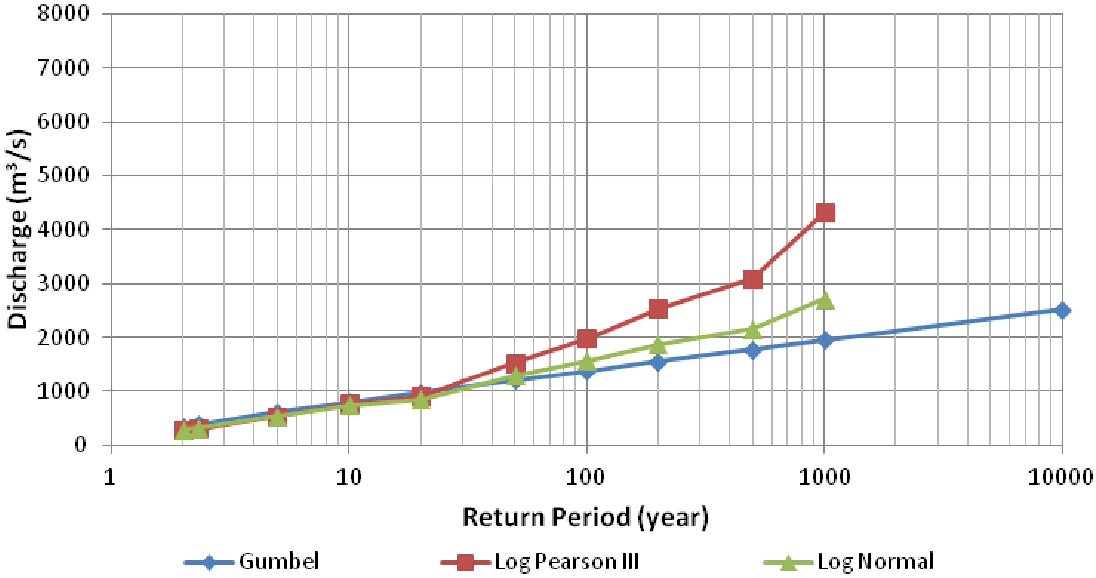

Figure 6 Flood frequency analyses for Manahari River.

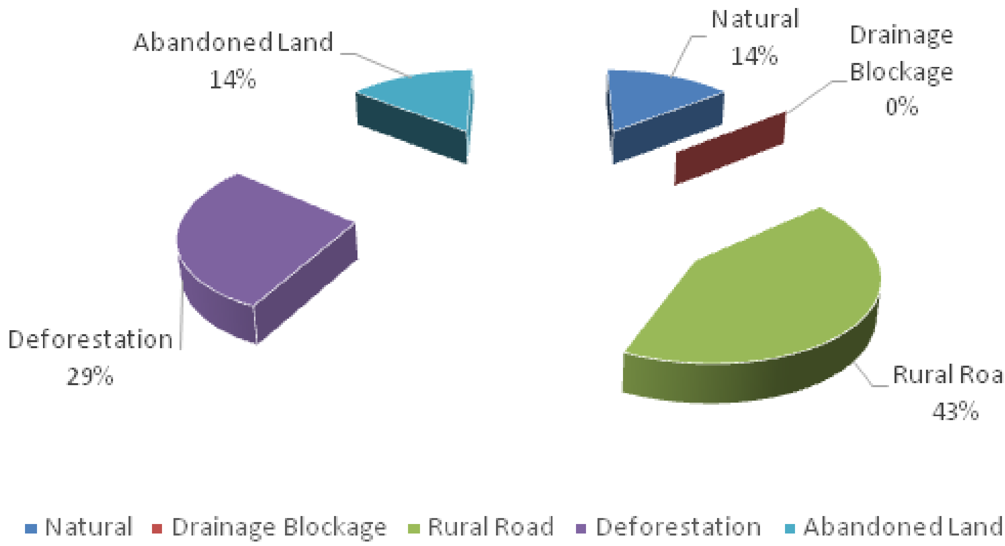

Figure 7 Causes of hazards.

A study by Shrestha[19] has concluded the erosion and landslide issue in case of south facing slopes, is more related to nature than to human influence as these are drier because of more radiation and higher evapo-transpiration. Since the study area is a south facing slope, 14% of the responded supported that the cause of hazard to be natural, however rural road, mostly in monsoon and deforestation has added up to the naturally occurring hazard. Drainage blockage has the minimal causes for erosion. Transportation is convenient and it has access to most of the villages but are constructed haphazardly (Table 5). The roads are constructed without performing environmental assessment and without engineering design with people's desire to connect roads to their house premises. The slope failure at the edges of the rural roads also causes landslides which also fills the agriculture land. This type road are constructed by village committees leading a prominent cause of hazards in the area generally occurring every year and most prominent in monsoon season. The locals responded that the drainage systems were poor and there were no protection structure and/or biological component to reduce landslide risk during construction periods. Most of the landslides were triggered by monsoon rains. Most of the people were also not satisfied with the maintenance arrangements made in the study area. Figure below represents the percentage of response on the impact of flood hazard. Respondents were asked to rate the level of impact by the flood hazard at rating scale of 3 i.e. high, medium and low. Then, the obtained results are plotted in the Figure 8 below. Major five form of disaster observed in Manahari and the particular period of time in year when they affect most is shown in table below. It describes that flood is severe from March to June whereas, wildlife attack throughout the year and so on (Table 6).

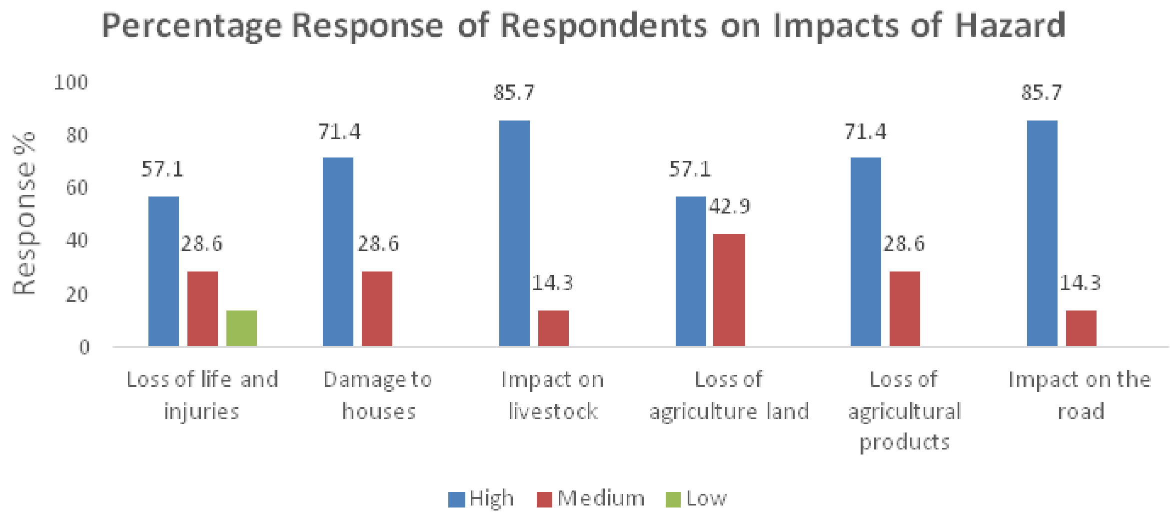

Figure 8 People's perception on impact of hazards.

Table 5 Condition of different components

Components	Condition of Road		
	Good	Satisfactory	Poor
Drainage arrangement	-	19%	81%
Protection structure in landslide susceptible area	-	40%	60%
Biological protection	25%	40%	35%
Maintenance arrangements	5%	25%	70%

Table 6 Disaster calendar

SN	Disaster	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.	Flood						■	■	■	■			
2.	Landslide						■	■	■	■			
3.	Epidemic						■	■	■	■	■		
4.	Windstorm			■	■	■			■	■			
5.	Hailstorm			■	■	■	■						

Discussion

Temperature and rainfall

The mean annual temperature for the 31 years is found to be 23.0°C. Decadal analysis of the temperature and precipitation was done which showed the temperature of Makwanpur increasing till 1996 from 1985 and then sharp declining trend reaching 21.6°C in 2002, again increasing till 2015. Because of which overall mean temperature trend appeared to be increasing. Similarly, the rainfall shows the decreasing trend of total annual precipitation in Hetauda at the rate of 5.6607 mm per year. Annual rainfall fluctuates regularly in last 31 years. The highest rainfall recorded is about 3323.1 mm in year 2002 and least amount rainfall i.e. 1626.2 mm was recorded in year 2012. Even though it fluctuated regularly throughout 31 years, the rainfall has decreased a bit. The Variance in annual rainfall can be elaborated deeply as we study it in partially. The total annual precipitation of Manahari Station shows the increasing trend at the rate of 11.148 mm per year. Annual rainfall fluctuates regularly in last 31 years. The highest rainfall recorded is about 2824.3 mm in year 2001 and least amount rainfall i.e. 1295.8 mm in year 1988. The maximum temperature days as well as extreme temperature of the Makwanpur show the increasing trend. The average maximum temperature of 31 years is found to be 32.9°C. It is found that the days with maximum temperature is increasing year by year with the maximum being in 2009 AD.

In the study conducted by Practical Action Nepal in 2009, a general increasing trend in temperature has been found over Nepal. The maximum temperature was found to be increasing at a rate of 0.05°C per year 2009 and 0.057°C/yr.[20] whereas a decreasing trend was found in maximum temperature in terai region during winter season. Mean annual maximum temperature in terai reached above 30°C which gradually decreased towards North. At Siwalik range, the mean maximum temperature varied between 26°C to 30°C. About 79.6 % of rainfall occurs during monsoon season since annual precipitation dominated by monsoon. For the calculation of temperature and rainfall data, Hetauda NFI and Manahari station data was used. However, in my study, the mean annual temperature trend is increasing at a rate of 0.0226°C. This trend supports my study. The mean annual maximum temperature trend shows increasing trend by 0.0328°C per year being average maximum temperature of 32.9°C for the period of 31 years. The point station data used for this study resembles with the same trend as of Practical Action, 2009 as well as DHM 2015.[20]

In addition, the region gets around 80 % of the precipitation during monsoon season dominated by monsoonal rainfall and rests in post monsoon, winter and pre-monsoon seasons. In the same way my results get matched and support with the study made by DHM 2015. The quite similar study conducted by Dhital,[21] for precipitation and discharge pattern analysis for Bagmati River Basin, frequency analysis was used to analyze the future rainfall and river discharge data to calculate future peak flood value of different return periods of 2,5,10,25,50,100,200 and 1000 years. The present study also calculated the future flood peak values of different return periods as studied by Dhital.[21] The return periods were calculated using Gumbel Distribution, Log-Pearson Type III distribution and Log Normal Distribution. The methods and methodology used for the study gets nearly matched whereas the values obtained doesn't resemble because of the different basins used for study.

Climate pattern and impacts of climate change in different sectors of study area

The varying climate patterns have significant impact in different sectors. In Makwanpur experiences sub-tropical climate. The areas 1.200 meters above msl, which is about 40% of the district, fall on temperate climate zone. The mean annual temperature is found to be 28°C to 30.5°C.[12] The region experiences the hot climate during summer as the maximum temperature is increasing year by year. The number of hotter days has also been increased year by year. So, the region has been experiencing hot climate. The rainfall pattern has changed either high intensity rainfall for short duration or late rainfall. The flooding has also created threat to the community. River bank cutting has become common in some parts of Manahari. River cutting has damaged forest edge, agriculture lands and roads. Intensive flow in river will change its course and gets enter into the villages. The findings of this research are also supported by the research conducted entitled perceptions and realities of climate change among the Chepang communities in rural Mid-Hills of Nepal by Piya et al.[22] on climatic changes perceived by the community in the rural Mid-Hills in temperature and rainfall pattern as well as trend. The present study was supported by Dhakal[23] and it showed the effect of floods and their disaster in Terai were increasing.

Conclusion and recommendation

The temperature and rainfall records have been varying. Flood, Landslide, hail, droughts and intensive rainfall are likely to become more frequent and intense. The changes in rainfall pattern have brought changes in farming environment and crop varieties. The flood and landslide are major contributors to human loss, home loss, affecting families and economic loss being ranked as first after earthquake. Therefore, it is a need of impact identification and adoption to cope with vulnerabilities to minimize the impact of climate change.[24–29]

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Conflicts of interest

Author declares that there is no conflict of interest.

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