ISSN NO. 2091-1742

SCITECH

Journal of Scientific and Technical Studies

Nepal Engineering College, Pokhara University

Received: May 27, 2025

DOI: https://doi.org/10.3126/scitech.v18i1.90805

Accepted: January 30, 2026

Climate Change induced hazards impact on water sources and adaptation practices in Mulkharga of Kathmandu, Nepal

Srijan Regmi, Robert Dongol, Anita Bhuju*

Center for Postgraduate Studies, Nepal Engineering College, Pokhara University

**Corresponding Author: srizon.regmi@gmail.com*

Abstract:

Water availability is the major impact which humans will face, especially in developing countries because of climate change. This study analysed the observed and locally perceived climatic variation along with the assessment of impacts of climate induced hazards on spring sources in Mukharka Village of Kathmandu District, Nepal along with the exploration of the local autonomous adaptation practices to withstand these induced hazards and water scarcity. Recoreded monthly rainfall and temperature data were collected from Department of Hydrology and Meteorology of Sundarijal Station and Budhanilkantha station of 24 years (1995 – 2018) and 16 years 1995 – 2010) respectively. Questionnaire survey with 128 households along with a Focus Group Discussion and Key Informant Interviews were conducted. Linear trend analysis of the observed rainfall and temperature was carried out. The obtained trend was corroborated with locally perceived climate variability. Hazard ranking tool was used to prioritize hazards with a likert scale assigning the value of maximum and minimum criteria of possible hazards in the community. The changing pattern of rainfall with decreasing trend with an average of 1.16 mm rainfall per year was observed. The average maximum temperature showed increasing trend with the slope of 0.06°C per year and minimum temperature showed decreasing trend with the slope of 0.02° C per year. Local people have expereined an increase in temperature despite a reduction in monsoon by -3.11 mm per year and winter rainfall by -0.2587 mm per year. They also revealed depletion of water sources resultant of decreased monsoon and winter rainfall patterns along with increase in the frequency of natural disasters. The study area's vulnerability to hazards such as drought and landslides is made clear by the depletion of spring sources, which is a significant concern. Climate variability, characterized by changes in rainfall patterns and temperature, has been found to exert a significant impact on the availability of water resources, including the springs dry up, thereby increasing the risk of Climate-induced hazards such as drought and water scarcity. Local people have adapted various autonomous adaptation practices such as plantation of Alnus nepalensis, construction of storage tanks and implementation of rainwater harvesting to respond to depleting water sources and the hazard that they faced during extreme climatic events.

Key words: Spring sources, Mulkharga Village, Climate variability, Local perception

1. Introduction

Freshwater resources around the world are under immense pressure. Despite the fact that most countries emphasize achieving basic human needs for water, one-fifth of the world population lacks access to safe drinking water (Agarwal, 2000). In addition, the world will have to deal with the impacts of climate variability on water resources (Piao et al., 2010). Climate variability is anticipated to have a net negative impact on freshwater ecosystems and water supplies in almost all parts of the world (Abbaspour et al., 2009). Climate variability impacts on water resources are felt by society, environment and economics. The availability of water is not uniformly distributed, the quality is frequently in question, and the sustainability of the water supply system continues to present challenges.

Approximately one-sixth of the world's population resides in South Asia. Due to their dependence, this population of Bagmati Basin is more vulnerable to the growing effects of climate variability (Dahal, et al., 2016). This is likely due to the unique characteristics of this area, which include steep slopes, rapid river flow and heavy sediment transport, all of which can exacerbate the impacts of climate variability. The overall effects of climate variability on water resources are noted and that the world's hydrological cycle was intensifying, having an influence on both groundwater and surface water supplies (Babel et al., 2014). Proper Water supply services increase water availability, providing a safeguard in times of water shortage, meaning that poor and marginalised are capable to cope with impacts of climate variability. Bain et al., (2014) argues through his article that rural areas around the world are deprived of drinking water, both in terms of quality and quantity. Not only in water scheme scenario, but also in a climate variability scenario, rural areas are more vulnerable to the impacts of climate change. Climate variability and its impacts in rural areas may be complex to project because of several intervening factors. But, it is for sure that, these impacts may originate from extreme events such as floods and landslides. These extreme events directly affect rural infrastructure threatening livelihood. The rural population around the globe lack climate knowledge. They are the ones with less income level depending on everyday labour or agriculture for a living. This limited knowledge and income increase their vulnerability against climate change (IPCC, 2014). Climate variability threatens to increase the frequency, severity and intensity of climate related hazards such as drought, violent storms, heavy rainfall resulting flooding (OECD and FAO, 2017). If rainfall does not occur for a prolonged period, drought occurs. Drought decreases the groundwater recharge reducing water availability in the regions where the community are groundwater dependent. Also, in the locations where community depends on streams, households struggle even to meet least drinking water needs in the dry season since most of the water points dry up and their yield decreases. Pollutants dilution decreases when water is in limited quantity, this reduces the quantity (Calow, et al., 2015). Frequency of drought is projected to increase in many regions where reduced rainfall is projected. However, in some basins, both flood and drought are expected to incur. The land surface in extreme drought is expected to increase ten times from 2008 to 2090s AD (Kundzewicz et al., 2008). According to Bower (2014), landslides damage the infrastructure aimed for water conveyance blocking water supply for communities along with contamination of water sources. Environmental Hazards, for example, landslides in the region of water supply and sanitation system may prompt direct harm to the infrastructure. Degradation because of the landslide in the more extensive catchment increases runoff and diminishes groundwater recharge (UNICEF-GWP, 2017). In Hill and Mountainous area like Nepal, spring sources are one of the primary sources of water for local communities. The depletion of these sources can have severe consequences for the livelihoods and well-being of the local communities. Therefore, it is crucial to address the issues of climate-induced hazards in order to ensure the sustainable management and protection of spring sources. The overall objective of this study was to assess the impacts of climate induced disasters on the local water sources with the documentation of the adaptation strategies of the local people in Mulkharga Village.

2. Methods and materials

2.1 Study area

Mulkharka (Figure 1) is a small village located at an altitude of 1,800 meters above sea level in the Kathmandu District. It is located in the hilly region of Nepal. The Mulkharka has a subtropical climate characterized by hot and humid summers and cool and dry winters. It is located at 27°46’36.29” N- 85°25’56.84” E. The total area of the study site is around 90.53 hectar. The area lies in the conservation zone within the territory of Shivapuri Nagarjun National Park. The village mostly consists of Tamang Community and are mostly dependent on natural resources for their livelihood.

2.2 Research approach and design

This research was primarily concerned with the documentation and analysis of the various impacts and adaptation strategies employed by the local people. Both qualitative and quantitative approaches were used in the research. The qualitative approach was used in survey work to know and understand about villager perceptions of climate variability and the stresses induced. Similarly, a quantitative approach was used to learn about current climatic data obtained from the Department of Hydrology and Meteorology (DHM).

2.3 Data Collection

2.3.1 Primary Data Collection

In this study, the Focus Group Discussion (FGD) was conducted with individuals older than 40 years to gain knowledge on climatic variability, associated hazards and adaptation practices. During the FGD, the participants were assigned to rank the hazard based on criterions of hazard ranking tools. The FGD was conducted in an interactive group setting, where participants were free to talk with each other, using a checklist.

Key informant Interviews were conducted with individuals representing various sectors of society, including member of Buffer Zone User Committee (BZUC), Water and User Sanitation Committee (WSUC) and local women group of Mulkharga. The interviews focused on topics such as the use of water resources, rainfall patterns, induced hazards events and any adaptation practices followed by the community to cope with these hazards. The aim was to gather insights and perspectives from a diverse group of knowledgeable individuals on these issues.

Questionnaire Survey was also conducted in the study area with the required number of sample population determined by using the Cochrane Formula with the fixed household population of 805 with 5 % degree of freedom and 95 % confidence interval. The questionnaire survey was design to understand the perception of local people on climate variability and its consequences on water sources.

2.3.2 Secondary Data Collection

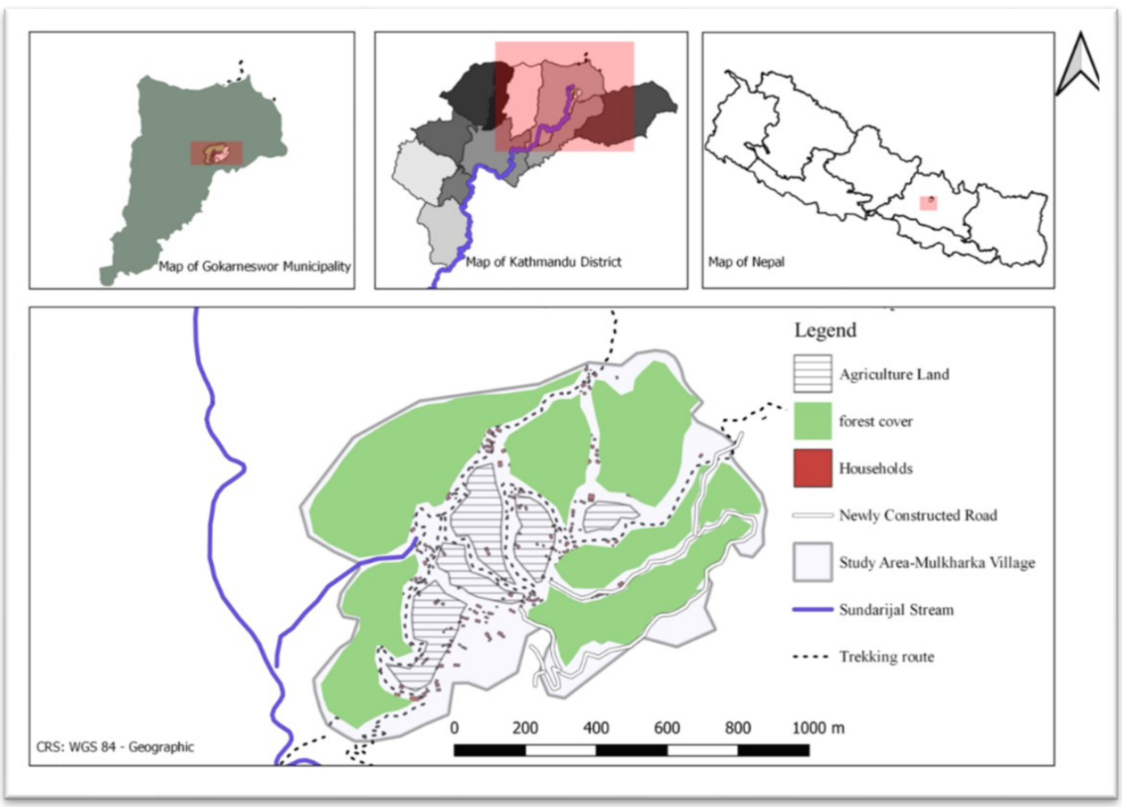


Figure 1 Study Area Map

Twenty four years data from 1995 to 2018 AD on rainfall recorded at Sundarijal Station and sixteen-year data from 1995 AD to 2010 AD on temperature recorded at Buddhanilkantha Station was collected from DHM. The salient features of the meteorological stations used in the analysis are presented in Table 1. The summary of annual rainfall and temperature records were prepared from the monthly records of rainfall and temperature prior to use in analyzing various indices of climatic variability. The missing rainfall data were estimated by simple arithmetic average method. The method involves utilizing rainfall records from three nearby stations simultaneously, where the stations should be uniformly distributed around the station with missing records (Kennedy, 2014). The Simple

Arithmetic Average Method assumes even distribution of rainfall over the area and time period being considered and is the arithmetic mean of the rainfall measurements from a given period of time.

Table 1 Meteorological station details

Index number	Stations	Geographical Coordinates		Elevation (m)	Period of Meterological data
		Latitude (deg min)	Longitude (deg min)		
1074	Sundarijal	27.772695	85.4277003	1658	1995 AD – 2018 AD (Rainfall)
1071	Buddhanikantha	27.764655	85.3522048	1428	1995 AD – 2010 AD (Temperature)

2.4 Data Analysis

Linear Trend Analysis was conducted to examine the trend or direction of change in a time series of data. It involves fitting a straight line to the data and calculating the slope of the line, which can be used to determine the rate of change over time. The departure from average rainfall, also known as departure from normal, is a measure of how much rainfall at a specific location deviates from the average amount that is typically received over a long-term period, such as several decades (Singh et al., 2015). It is calculated by subtracting the average rainfall value for a particular location from the accumulated rainfall amount for that location for a specific period of time. The percentage

$$D\% = (x_i - x_m) / x_m) \times 100\ \%$$

Where, D % = Departure of rainfall

x_m = mean annual rainfall and

x_i = annual rainfall series

A Hazard Ranking tool is a tool used to evaluate the hazard potential to cause harm to human health or the environment (EPA, 2016). It is often used by regulatory agencies to prioritize the assessment and management of hazardous substances. This study used people's experience to rank the climate induced hazards based on the criterion provided in the hazard ranking tool (Table 2). During the FGD, the participants were asked to discuss about the possible occurence of hazards in the study area. They were asked to rank the shortlisted hazards using likert scale assigned value of 0-5. Hazard Ranking tools are commonly used in the field of risk assessment and can be an important tool for identifying and managing potential hazards. Criterions used for the hazards ranking tool in this study included i. The severity of the hazard, ii The likelihood of the hazard occurrence, iii The level of uncertainty associated with the hazard, iv. The susceptibility or vulnerability of the population or community exposed to the hazard, v. The level of exposure to the hazard, vi. The potential for cascading or compound hazards, vii. The potential for adaptation or mitigation and viii. The potential for long-term impacts.

Table 2 Hazard Ranking Tool

	Severity	**likelihood**	**level of uncertainty**	**vulnerability of the population**	**exposure**	**Cascading potential**	**Potential for long term impact**	**Adaptation/ mitigation potential**	**Score**	**Ranking**
Water induced Hazard	0-less severe 5-more Severe	0-less Likehood 5-More Likelihood	0-less 5-more	0-lessVulenrable 5-More Vulnerable	0-less Exposure 5-More Exposure	0-less 5-more	0-less potential for long term impact 5-More potential for long tem impact	0-High adaptive capacity 5-lowest adaptive capacity		

3. Results and Discussion

3.1 Rainfall variability

3.1.1 Average and annual rainfall variability

The mean annual rainfall received over the period was found to be 2132.57 mm at Sundarijal station with a range of annual rainfall amounts from 889.7 to 2867.2 mm (Figure 2). The maximum rainfall occurred in year 1998 and minimum average rainfall occurred in th year 2005. Kripalani et al., (1996) also noted a similar pattern in mean annual rainfall in Kathmandu over the period 1921-1975.

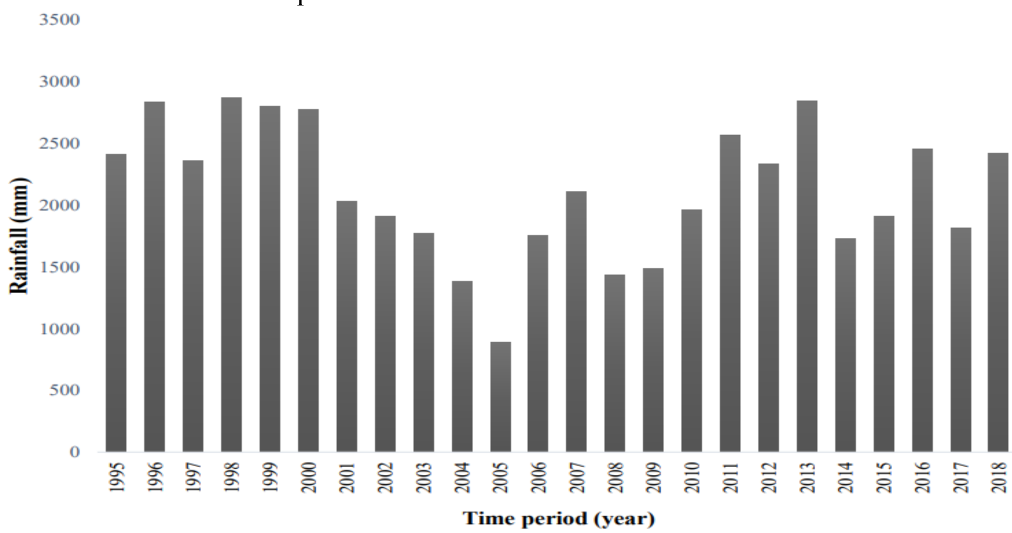


Figure 2 Total annual rainfall in study area

Rainfall departure shows the difference between the actual amount of rainfall and the long term average amount of rainfall for a specific location. A positive departure means that the amount of rainfall received is more than the long-term average, while a negative departure means that the amount of rainfall received is less than the long-term average. Figure 3 illustrate the departure of rainfall from average annual rainfall in the study area within 24 years. The year 1998 recorded the positive departure for the rainfall by 34.45% whilst in 2005, the departure of rainfall was below by 58.28 %, indicating that the amount of rainfall received in that year was below the long-term average.

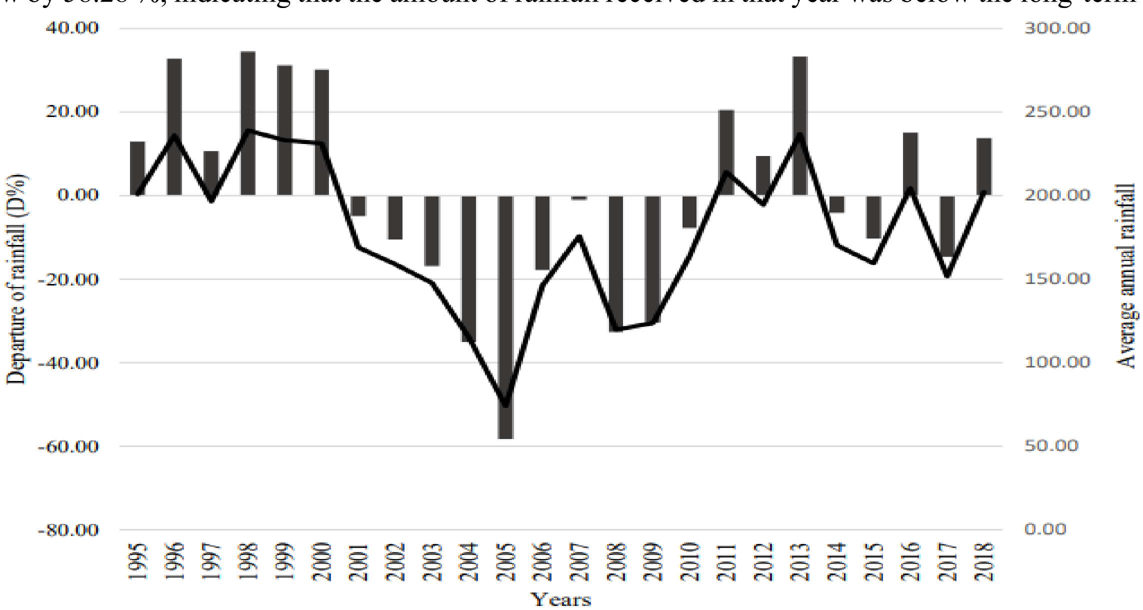


Figure 3 Departure of rainfall from average annual rainfall

The linear trend of average annual rainfall at Sundarijal station shows decreasing trend with an average of 1.16 mm rainfall. The monthly rainfall data showed an overall increasing trend in the month of march and April, with an increase of 0.806 and 0.7296 mm respectively (Table 3). On the other hand, monthly rainfall data showed an overall decreasing trend in the month of July and June with an decrease of 6.95 and 3.763 mm.

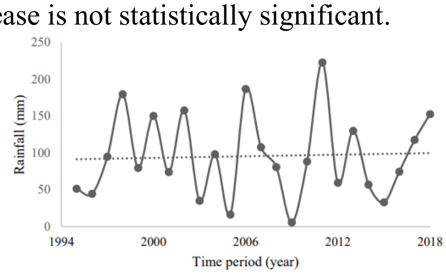
Table 3 Trend of monthly rainfall during 1995-2018 AD

Months	Value of m	Trend
January	-0.491	Decreasing
February	0.251	Slightly increasing
March	0.806	Increasing
April	0.7219	Increasing
May	-0.4399	Decreasing
June	-3.763	Decreasing
July	-6.95	Decreasing
August	-1.4018	Decreasing
September	-1.9689	Decreasing
October	0.106	Slightly increasing
November	-0.5535	Decreasing
December	-0.5356	Decreasing

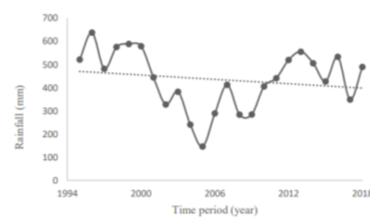
3.1.2 **Seasonal rainfall variability**

Average rainfall of the study area has been classified in four seasons: pre-monsoon (March-May), monsoon (June-Sep), postmonsoon (Oct-Nov), and winter (Dec-Feb). Long term climate data for 24 years have been applied to notice changes in the pattern of pre-monsoon, Monsoon, post monsoon and winter rainfall trend.

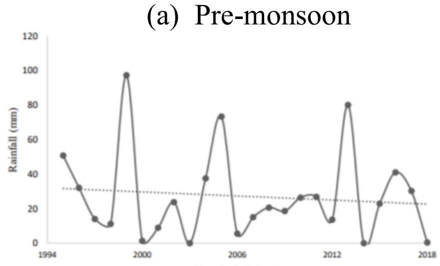
The 1995-2018 temporal trend in pre-monsoonal rainfall (Figure 4a) within the study region exhibits fluctuation in annual rainfall from March to May The maximum observed rainfall event during this time frame occurred in May 2011, reaching a intensity of 457.1 mm. A slight upward trend in mean pre-monsoon rainfall is apparent, although this increase is not statistically significant.



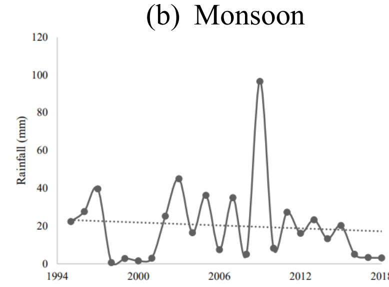
(a) Pre-monsoon



(b) Monsoon



(c) Post-monsoon



(c) Winter

Figure 4 Seasonal monsoon trend

The temporal variability in mean monsoon rainfall (Figure 4b) within the study region exhibits fluctuation in average annual rainfall. The maximum recorded rainfall event during this time frame occurred in August 1996, reaching an intensity of 897 mm, while the minimum recorded in June 2005, with an intensity of 49.7 mm. A decreasing trend in mean monsoonal rainfall is clearly visible, with a slope of -3.11 mm/year. The temporal variability in mean Post-monsoon rainfall (Figure 4c) exhibits a slight downward trend with a slope of -0.39 mm/year. The maximum recorded rainfall event during this time frame occurred in October 1999, with an intensity of 194.6 mm, while the minimum recorded rainfall was in November 2002, totaling 0.4 mm. The temporal trend in mean winter rainfall (Figure 4d) exhibits fluctuation in annual rainfall. The maximum recorded rainfall event during this time frame occurred in January 2009, with an intensity of 290 mm, while the minimum rainfall occurred in December 2001, totaling 0.2 mm. A downward trend in mean winter rainfall is visible, with a slope of -0.2587 mm/year.

3.2 Temperature variability

3.2.1 Annual average minimum and maximum termperature

The average maximum temperatures during winter (Dec-Feb), spring (Mar – May), summer (June-Aug) and autumn (Sep – Nov) seasons in the period 1995-2010 exhibited distinct trends. Specifically, there was an increasing trend in the winter maximum temperature, with an annual increase of 0.1138°C. Similarly, the spring maximum temperature showed an increasing trend, with a yearly increase of 0.0429°C, as did the autumn maximum temperature, with a yearly increase of 0.0434°C. The observed temperature trend for the summer season show increasing trend. The increase in maximum summer temperature was noted to be 0.0625°C per annum. On the other hand, the minimum temperature during the winter season demonstrated a decreasing trend, with a yearly decrease of 0.0244°C. In contrast, there was a slight increasing trend in the minimum temperature during the spring season, with an annual increase of 0.0035°C. The minimum temperature during the summer season also displayed a decreasing trend, with an annuadecrease of 0.0228°C. Nonetheless, there was a slight increasing trend in the minimum temperature during the spring season, with a yearly increase of 0.0444°C.

Table 4 Trend of seasonal maximum and minimum temperature

Seasonal Temperature	Trend	Value of m
Maximum temperature		
Winter	Increasing	0.1138°C
Spring	Increasing	0.0429°C
Summer	Increasing	0.0625°C
Autum	Increasing	0.043°C
Minimum Temperature		
Winter	Decreasing	0.0244°C
Spring	Slightly increasing	0.0035°C
Summer	Decreasing	0.0228°C
Autum	Increasing	0.044°C

3.3 Observed climatic variability and people perception on variability in rainfall and temperature

An analysis of the variability in rainfall and temperature attributes was conducted using linear trend analysis. The results of the analysis revealed a decrease in the annual average rainfall in the study area over a period of 24 years. Specifically, a decreasing pattern was observed for the months of June and July, while an increase was observed for the months of March and April. The local community was also surveyed to gauge their perceptions on the variability of rainfall. The majority of respondents reported a decreasing trend of rainfall in the area and also noted an irregular pattern of rainfall, with a lack of sufficient rainfall even during the monsoon season. The study found that the maximum temperature has been rising and the minimum temperature has been dropping. Additionally, the summer season had an increasing trend in temperature while the winter season had a decreasing trend. The similar trend was also reported by respondents in the study area (Table 5).

Table 5 Comparison of observed and perceived climatic variability

Climate date	**Rainfall and temperature Indices**	
	Observed	**Perceived**
Total rainfall	Decreasing	Decreasing
Monsoon rainfall	Decreasing	Non persistent and decreasing
Winter rainfall	Decreasing	Non persistent
Duration of summer season	Increasing	Increasing
Winter season	Decreasing	Decreasing

3.4 Climate-induced hazard identification and hazard ranking

In order to determine the most significant hazards in the study area, three potential hazards were identified: Flood, Landslides, and Drought (Table 6). The criteria were given higher values if the hazard was considered more severe, with the exception of adaptability potential, which was given more weight if the hazard was considered easier to adapt to. These criteria were used to rank the hazards and to identify which one was most likely to have the greatest impact on the study area. The study revealed that landslides are the most probable hazard in the study area, followed by drought. While floods are the least probable hazard according to the hazard ranking. The hazard ranking assigns 34 points to landslides, indicating landslide a severe hazard with a high likelihood of occurrence, a high level of uncertainty, and other factors related to the hazard. According to Guzzetti et al., (2006) hilly and mountainous alluvial soil are particularly susceptible to landslides due to the soil's tendency for mass movement. According to information obtained from KII and FGDs, the respondent stated that there has been a change in the pattern of monsoon rainfall. Previously, rainfall was of mild intensity for a longer period of time, but in recent years, it has been more erratic. These changes in the pattern have made the slopes more susceptible to landslides. The respondents of KII and FGD stated that the danger of landslides in the area is made worse by human activities, such as the use of heavy machinery during the construction of a roadway in an area that was previously only used for trekking. Chairman of Buffer Zone User Committee (BZUC) added there have been multiple occurrences of landslides since the construction of the road began, indicating that the hazards are not just due to climate factors, but also to human actions.

Drought is the second most probable hazard in the study area, as it regularly leads to a water crisis. In the hazard ranking, drought is given a total of 27 points. The locals remember a time when there was an ample water supply in the area, but now several sources have declined.

Table 6 Hazard prioritization in the study area

Water induced hazards	Severity	likelihood	level of uncertainty	vulnerability of the population	exposure	Cascading potential	Potential for long term impact	Adaptation/ mitigation potential	Score	Rank
Flood	1	1	3	3	3	2	1	2	16	3
Landslides	4	5	5	4	4	4	4	4	34	1
Drought	4	3	4	4	4	4	4	0	27	2

3.5 Impacts on water sources

The study area is prone to frequent hazards, particularly landslides, which have been observed to have a significant impact on the hydrogeological conditions. During the KII, it was revealed that several springs, which serve as drinking water sources, have been disrupted or destroyed as a result of landslides events. The Chairman of the BZUC cites anthropogenic activities such as heavy machinery, excavators and bull dozers usage during road construction as a contributing factor to the increased incidence of rockfalls and subsequent spring source loss. The BZUC Chairman theorises that the exacerbation of spring source depletion can also be attributed to the drought conditions perceived by the local people, as evidenced by the decreasing monsoon and winter rainfall patterns. The local community attests that the availability of these water sources has reduced, with the springs now only rejuvenating during the monsoonal season and quickly depleting thereafter. The study analyzed 13 spring sources in the study area. The key informants revealed that 5 spring source being depleted in the years 2012 (attribute to drought), 2013 (attributed to landslides), 2017 (attributed to drought), 2018 (attribiuted to landslide) and 2019 (attributed to road construction). This depeted spring sources are witnessed during the field visit. The main reasons for depletion were found to be drought, landslide, road construction, landslide, and drought respectively for sources 1, 3, 6, 10, and 13 (Figure 5 and Table 7). Additionally, the study found that the landslides that caused the depletion of spring sources 3 and 10 occurred in the months of October, 2013 and August, 2018 respectively. These two month recorded above average rainfall according to DHM data, 160.2 mm and 843 mm (Figure 3). The recorded rainfall are the highest recorded rainfall in two decades time.

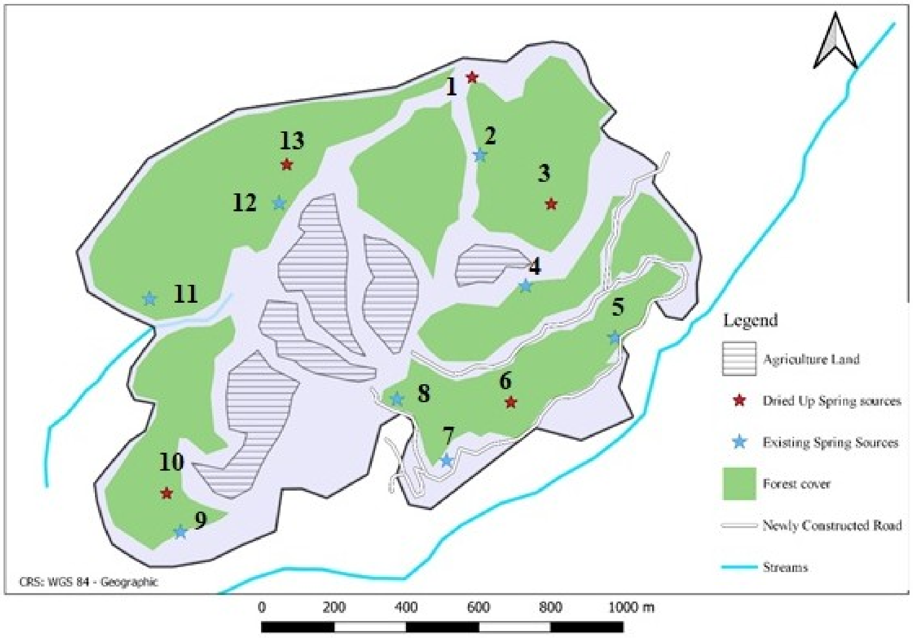


Figure 5 Condition of spring sources

The depletion of spring sources in the study area is a significant concern, as it highlights the vulnerability of the area to climate-induced hazards such as drought and landslides. The findings suggest that extreme rainfall events may be a contributing factor to landslides in the area, which can have a significant impact on water availability and accessibility for the local communities, leading to water scarcity. The study also highlights the importance of considering the impacts of development activities, such as road construction, on water resources. The depletion of spring source 6 due to road construction illustrates the need for integrated water resources management in the planning and implementation of development projects.

Table 7 Details of spring source

Source	Status	Depleted year	Reason for depletion of spring source	Location
1	Depleted	2012	Drought	27°47'4.42"N, 85°26'4.02"E
2	Intact			27°46'58.61"N, 85°26'8.47"E
3	Depleted	2013	Landslide	27°46'52.70"N, 85°26'14.82"E
4	Intact			27°46'44.81"N, 85°26'13.99"E
5	Intact			27°46'41.18"N, 85°26'25.09"E
6	Depleted	2019	Road construction	27°46'31.27"N, 85°26'11.31"E
7	Intact			27°46'30.75"N, 85°26'1.56"E
8	Intact			27°46'26.60"N, 85°25'56.27"E
9	Intact			27°46'18.85"N, 85°25'43.61"E
10	Depleted	2018	Landslide	27°46'32.39"N, 85°25'34.21"E
11	Intact			27°46'49.43"N, 85°25'41.23"E
12	Intact			27°46'53.18"N, 85°25'48.37"E
13	Depleted	2017	Drought	27°46'58.42"N, 85°25'53.13"E

3.6 Adaptation practices by the community to cope with climate induced hazards

The study area has observed decline in annual rainfall and an increase in maximum temperature, which may exacerbate climate hazards such as landslides and drought causing a reduction in spring sources. From field survey and interaction with local people, it was found that the induced hazards are not just due to climate variation, but also from human activities. These hazards have significant effect on water springs (depletion of spring sources, shifting of sources). However, some adaptation processes have been implemented, such as planting *Alnus Nepalensis* (Uttis) which is able to fix nitrogen impriving soil fertility and supporting the growth of other plant species. *Alnus nepalensis* (Uttis) has special characteristics of soil binding, decrease rate of runoff water which reduces the chances of landslides. Compared to landslides, the community has better adaptation practices in place to address drought. They have constructed storage tanks and implemented rainwater harvesting techniques.

The people in the study area have build five rectangular storage tanks nearby spring sources. People have use local materials available within a community to construct tanks. These storage tanks are also used for irrigation as well as other household uses. This can be a cost-effective and sustainable approach, as it reduces the need to import materials and relies on the skills and labor of community members. Storage tanks store water from various sources including rainwater, groundwater, and surface water. Additionally, the use of local resources to build storage tanks can support economic development by creating employment opportunities and building the capacity of community members. Around 35 % of the households have installed traditional rainwater harvesting to store rainwater during wet periods. This measures has increase their water security and reduce their dependence on other sources. Rainwater harvesting is believed to reduce the local dependency on water springs, potentially easing pressure on local water systems. It has also provide a source of irrigation for agriculture, improving crop yields and supporting food security. In addition to these, the local people have been exploring the water sources within the area.

4. Conclusions

The study was undertaken to understand the impact of climate induced hazards on local water sources along with documentation of the adaptation strategies practices by the community to cope with these hazards in Mulkharka Village. The impact of climatic variation has been assessed with decrease in rainfall and increase in temperature. The climatic data shows the fluctuation indicating climatic variability and uncertainity. The study concludes the similarity in the perception of the local people and the observed climatic trend in the study area. Landslides are the most probable hazard followed by drought that greatly affect the hydrogeological conditions of the area. The depletion of spring sources due to these variation in rainfall is a great concern which can have larger consequences for the livelihoods and well-being of the local communities. Some adapation measures for protection of the land and water storage have been implemented along with exploration of new water sources.

REFERENCES

Abbaspour, K.C. *et al.* 2009 'Assessing the impact of climate change on water resources in Iran', *Water resources research*, 45(10).

Agarwal, A. 2000 *Integrated water resources management*. Stockholm: Global Water Partnership. Stockholm, Sweden. ISSN: 1403-5324

Babel, M.S. et al. 2014 'Climate change and water resources in the Bagmati River Basin, Nepal', *Theoretical and Applied Climatology*, 115(3–4), pp. 639–654. Available at: https://doi.org/10.1007/s00704-013-0910-4.

Bain, R., J.A.Wright, E.Christensona & K.Bartram, 2014. Rural:urban inequalities in post 2015 targets and indicators for drinking-water. *Science of the total environment,* Volume 490, pp. 509-513.

Bower, K.M. 2014 'Water supply and sanitation of Costa Rica', *Environmental Earth Sciences*, 71(1), pp. 107–123. Available at: https://doi.org/10.1007/s12665-013-2416-x.

Calow, R., Ludi, E., McKenzie, A. & Kebede, S., 2015. *Climate and environmental risk screening for rural water supply in Ethiopia,* London: Overseas Development Institute.

Dahal, V., Shakya, N.M. and Bhattarai, R. 2016 'Estimating the Impact of Climate Change on Water Availability in Bagmati Basin, Nepal', *Environmental Processes*, 3(1), pp. 1–17. Available at: https://doi.org/10.1007/s40710-016-0127-5.

EPA (2016) *Climate Change Indicators in the United States, 2016. 4th edition*. EPA 430-R-16-004. Washington, DC: U.S. Environmental Protection Agency, p. 96. Available at: https://www.epa.gov/sites/production/files/2016-08/documents/climate_indicators_2016.pdf.

Guzzetti, F. et al. 2006 ‘Landslide hazard assessment in the Collazzone area, Umbria, Central Italy’, *Natural Hazards and Earth System Sciences*, 6(1), pp. 115–131. Available at: https://doi.org/10.5194/nhess-6-115-2006.

IPCC 2014 *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY: Cambridge University Press, p. 1132. Available at: http://www.ipcc.ch/report/ar5/wg2/.

Kennedy, J.J. 2014. A review of uncertainty in in-situ measurements and data sets of sea syrface temperature. *Reviews of Geophysics,* 52(1).pp 1-32

Kripalani, R.H., Inamdar,S and Sontakke, N.A., 1996 Rainfall variability over Bangladesh and Nepal: Comparison and connections with features over India. *International Journal of Climatology.* 16(6). pp 689-703. DoI: 10.1002/(SICI)1097-0088(199606)16:6<689::AID-JOC36>3.0.CO:2-K

Kundzewicz, Z. *et al.* 2008 ‘The Implications of Projected Climate Change for Freshwater Resources and Their Management’, *Hydrological Sciences Journal/Journal des Sciences Hydrologiques*, 53. Available at: https://doi.org/10.1623/hysj.53.1.3.

OECD and Food Agriculture Organization of the United Nations 2017 *OECD-FAO Agricultural Outlook 2017-2026*. Paris: OECD Publishing. Available at: https://doi.org/10.1787/agr_outlook-2017-en.

Piao, S. et al. 2010 ‘The impacts of climate change on water resources and agriculture in China’, *Nature*, 467(7311), pp. 43–51. Available at: https://doi.org/10.1038/nature09364.

Singh, J., Das, S.M and Kumar, A. 2015. Forecasts of rainfall (Departure from normal) over India by dynamic model. *Aquatic Procedia*. 4 pp 764-771. DoI: 10.1016/j.aqpro.2015.02.159

UNICEF-GWP, 2017. *WASH Climate Resilient Development: Local participatory water supply and climate change risk assessment: Modified water safety plans,* s.l.: UNICEF-GWP