North American Academic Research

Journal homepage: http://twasp.info/journal/home

Research

An Assessment of Climate and Land Cover Changes at Local Level: A case study of Rautahat District, Nepal

***Rajesh Sigdel*[1], *Om Prakash Prasad Kalwar*[1]*, *Prabin Poudel*[1], *Pawan Karki*[1], *Jharna Sharma*[2], *Deepa Dahal*[1], *Catherine Mahae B. Jandug*[2, 3]**

[1]*Institute of Forestry, Tribhuvan University, Nepal*

[2]*College of Forestry, Beijing Forestry University, Beijing 100083, China*

[3]*College of Forestry and Environmental Science, Caraga State University, Philippines*

[*]***Corresponding author***

***Accepted**: 02March, 2020; **Online**: 12 April, 2020*

***DOI** : https://doi.org/10.5281/zenodo.3750386*

***Abstract:** This study was carried out in Rautahat District to assess climate and land cover changes at the local level. The main objective was to assess changes in land cover and climatic variables in the Churia and Terai regions of Nepal. The major indicators selected for this study were land cover, temperature, rainfall, river flow, flood, drought and fire. Landsat images of 1989 and 2017, MODIS (Terra and Aqua) and VIIRS fire locations data from 2002 to 2018, CHIRPS rainfall data from 1981 to 2017, MOD11A2 V6 temperature data from 2001 to 2016 and Bagmati river discharges at Pandhere Dovan from1988 to 2015 were used for this study. Similarly, for drought analysis meteorological data from Simara was used. Supervised image classification method was applied to classify Landsat images into forest, agriculture, settlement, bare land and water cover using maximum likelihood algorithm in ERDAS Imagine and changes in land covers were analyzed in ArcGIS. Temperature and rainfall data were extracted from Google Earth Engine and their time series responses were plotted. Standardized Precipitation Index (SPI) was analyzed for drought. Results show that forest area in the district has increased by 8%. Annual rainfall has increased by 3 mm per year and temperature has increased by 0.06^{o}C. Fire incidence has increased by one incidence per year. The year 2012 was extreme drought year having -2.54 SPI value. Similarly, The Bagmati and Bakaiya river beds have expanded by 2.5% per year. The annual water flow in Bagmati River has decreased by 1.84 m^3/s per year.*

***Keywords**: Climate change, Land cover change, Riverbed expansion, Forest fire, Climatic variables.*

Introduction

Land cover generally refers to a physical description of space, the observed (bio) physical cover of the earth surface (Di Gregorio & Jansen, 2000). Land use/cover change has become a central component in current strategies for managing natural resource and monitoring environmental changes (M. K. Tiwari & Saxena, 2011).

Land holds a central position in human existence and development (Briassoulis, 2000). Human activities have been altering the earth's surface significantly for socioeconomic development. These changes have both beneficial and detrimental impacts and effects (Briassoulis, 2009). These changes are the chief causes of concern as they impinge variously on human well-being and welfare (Inca & A, 2009). At the same time these changes directly impact biotic diversity world-wide and contribute to local regional climate change (Sala et al., 2000). Nowadays, it is broadly accepted that both elevated greenhouse gas (GHG) concentration as well as land use/land cover change (LULCC) can influence the regional climate dynamics (Laux et al., 2017).

The changes in land-cover land-use patterns in Churia region are of great socio-economic importance in context of Nepal. Major settlements in the Churia is believed to be started from the middle of the 19th century and gradually increased with the eradication of malaria and the government’s policy of resettling people (Niraula et al., 2013). In many parts of the Churia range, indigenous people, disaster victims and poverty enforced migrants are settled without land ownership and their livelihood primarily depend on nearby forest and shifting cultivation (FAO, 2016).

Recently, Government of Nepal declared Churia as environmental conservation area based on Environmental Protection Act 2053 recognizing Churia range as vulnerable landscape (Ministry of Forests and Soil Conservation, 2016). This step of government is observed positively as well as negatively by various stakeholders. While the objectives of Churia conservation are mainly oriented towards river management, controlling erosion and deforestation, many are sceptic over the government’s move to govern Churia range and its forest resources centrally.

There are various methods that can be used in the collection, analysis and presentation of resources data but the use of remote sensing and geographic information system (RS/GIS) technologies can greatly facilitate the process (Gautam, 2007). Remote sensing along with GIS and Global Positioning System (GPS) helps in maintaining up-to-date land use dynamics information for a sound planning and a cost-effective decision (Ricketts, 1992). One of the widely used methods to determine the temporal dynamics of land use is the analysis of satellite images covering the same area acquired on different dates (Mulders, 2001). Remote sensing and GIS tools can be used for study of land-use and land-cover change over and change in settlement size over time (Rimal, 2011). Similarly, these techniques will also be used to quantify human induced environmental degradation such as change in forest area, increase in river bed span etc. The main objective of this study is to assess the impact of climate and land use change in Churia and Terai region of Rautahat District. The specific objectives are: a) to assess the temporal and spatial change in land-cover during the period 1989-2017; b) to assess changes in climatic variable like rainfall, temperature, drought, flood, and forest fire; and c) to assess changes in river bed of Bagmati and Lal Bakeya.

Materials and methods

Study area

The study was conducted in Rautahat District is shown in figure 1. In the district the lower 2/3rd area lies in the sub-tropical climatic zone whereas the upper 1/3rd area lies in the warm temperate climatic zones. Intensity of rainfall is high in the Churia region. Because of intense rainfall during monsoon, steep slopes and high erosion, vulnerability of soils, gullies and degraded lands are quite common in areas that are devoid of vegetative cover (Ghimire et al., 2013). Forests covered the highest proportion of the total area of the Churia region where as agriculture is the highest cover type (Table 1). The dominant forest species is Sal (*Shorea robusta)* and associates are mixed hardwood forests at low altitudes and Pine at high (FRA, 2014)The Churia region, which is also known as Siwalik, extends along the south of the Mahabharat from the east to west continuously. It covers an area of 20-30 km wide along 1000 km east west of the whole Nepal’s foothills with the altitude range from 914 to 2000 meter from the sea level and constitutes about 12% of the country's land cover. The belt has sub-tropical deciduous forest with comparatively less agriculture land except in the inner Terai valley. The Region is extended through 36 districts and is lined by plains to the south and Mahabharat range to the north. The region consists of loose sedimentary rock dominated by unconsolidated and porous rocks like sand, sandstone, mudstone, boulders and pebbles. The major geomorphic process in the Churia is rapid fluvial erosion. The weak geology, heavy rainfall and tropical weathering are the common features of the Churia range. This area consists of humid tropical climatic zone.

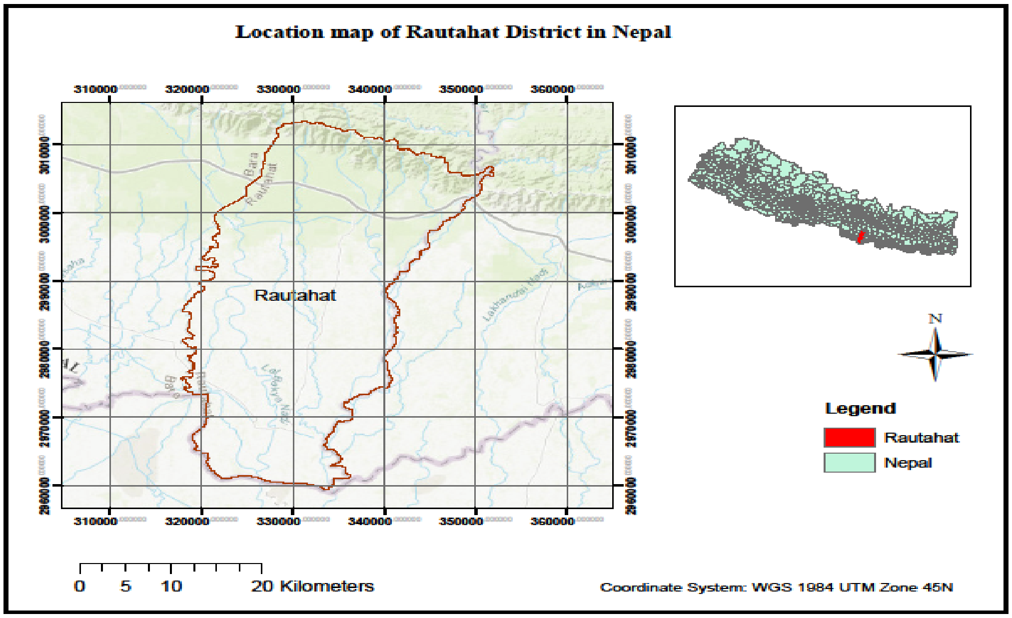

Figure 1: Map showing location of the study area (inset, Location in Nepal)

Table 1: Land covers type of Rautahat District Source: FRA Report, 2015

S.N.	Cover types	Area (ha)
1	Forest	25597 (24.6%)
2	Tree cover 5-10%	322 (0.30%)
3	Shrubs	92 (0.08%)
4	OWL	414 (0.39%)
5	Other land	77528 (74.57%)
Total		103953

Rainfall within the area of Churai throughout nepal receives normally 2000 to 2500 mm per year and during monsoon period Churia becomes quite hazardous for landslides and flash flood (Dahal, 2012; Tiwari & Rayamajhi, 2018). It receives an average annual rainfall between 1500-3200mm. About 80% of the rainfall occurs only in four months, during June- September.

Data collection and analysis

The major types of data need for this study are satellite images, climatic data (temperature and rain fall), forest fire data, and river discharge. The metadata of the data are given in Table 2.

Table 2: Types of used for the study

S.N.	Data type	Data Source	Period	Remarks
1	Satellite images	Landsat image	1989 and 2017	https://glovis.usgs.gov/
2	Historical fire locations	MODIS (Terra and Aqua) and VIIRS	2000 to 2018	NASA Earth data
3	Temperature	MODI11A2 V6	2006 to 2017	Google Earth Engine
4	Precipitation	CHIRPS	1981 to 2017	Google Earth Engine
5	Bagmati river discharge	DHM	1988 to 2015	At Padhere dovan station

The three major activities were carried out for conducting this research. They were data collection, data analysis, and their interpretation. The details of the research methodology are given in the figure 2. The data used for this study were landsat images, MODIS fire data and hydro-metrological data. The landsat images were processed in ERDAS imagine for supervised image classification and change detection (Lemenkova, 2015; Pokhrel et al., 2019). Historical fire data and climatic data were analyzed in Microsoft Office Excel Worksheet for time series plot analysis. And whereas, CHIRPS and MODIS images were used for rainfall and temperature calculation respectively. The details of the data analysis methods are given in the subsequent sections.

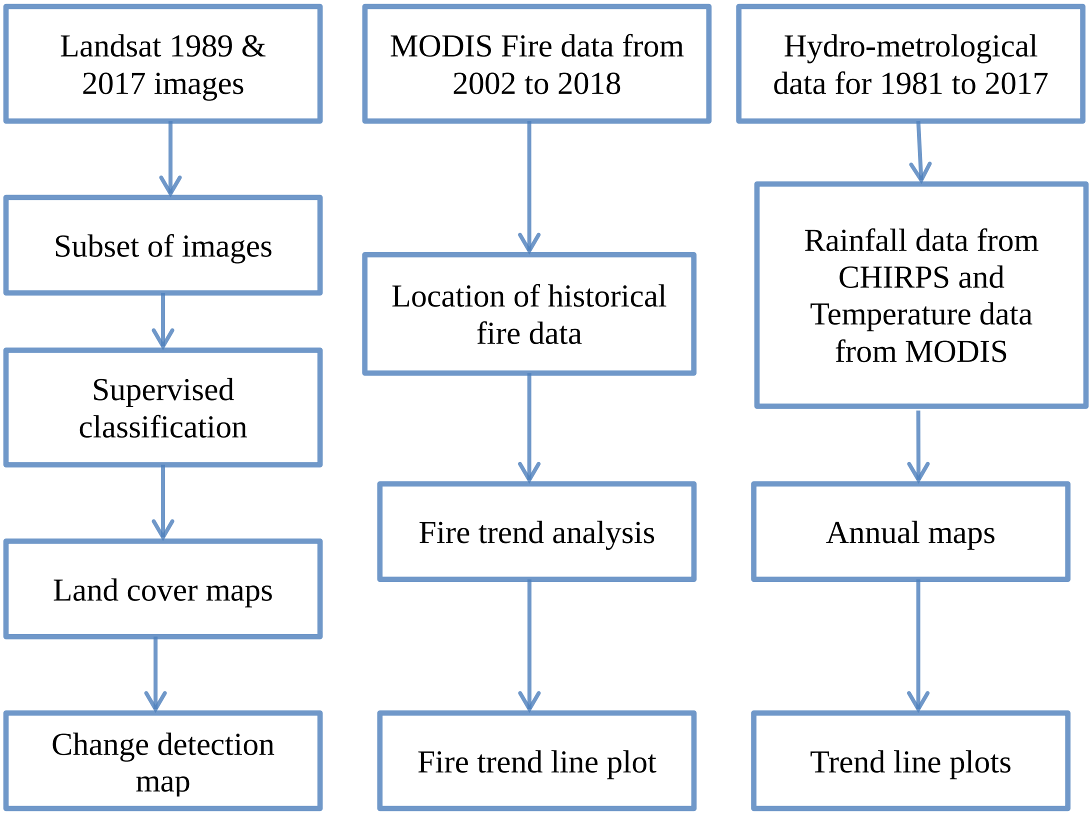

Figure 2: Flow diagram of research methodology

Result and discussion

Land cover mapping

Landsat 5 (TM image of 1989) and Landsat 8 (OLI image of 2017) were download from classified into forest, agriculture, settlement, water and bare soil in ERDAS Imagine 2015. Supervised image classification techniques and maximum likelihood algorithm were used (Richards, 1993). Figure 4 shows land use maps of the 1989 and 2017. The coverage of major cover types are shown in the table 4. The settlement and forest area have increased by 99% and 8% respectively considering 1989 covers as baseline. Similarly, bare, water and settlement area have decreased by 76%, 36% and 19% respectively.

River-bed span

In the Chure and Terai, unmonitored land use/cover changes has been causing significant effects on the narrowing and widening of river channels which affects the integrity of water resources in the Terai (Adhakari, 2013). We studied Bagmati and Bakaiya Rivers shape using Landsat images. River shapes were extracted for the year 1988, 1999 and 2017 (Figure 4). The results revealed the rivers covered 9316 ha, 11746 ha and 7810 ha land in 1988, 1999 and 2017 respectively. From 1988 to 1999, there was about 25% of expansion in the shape of both rivers. Similarly, from 1999 to 2017, there was reclamation of about 30% area due to embankment construction in both the rivers.

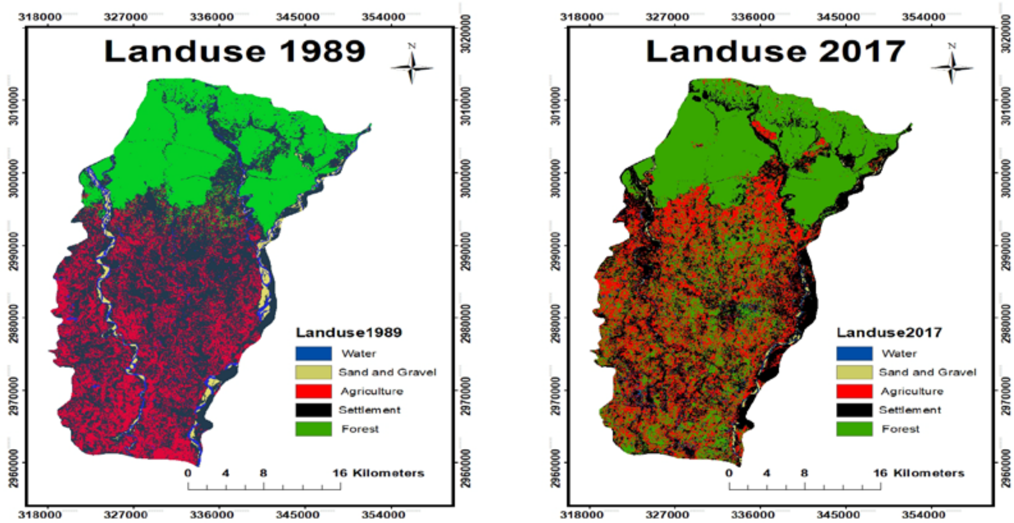

Figure 3: Land use of Rautahat District in 1989 and 2017

Table 3: Land covers change between 1989 and 2017 in Rautahat District

S.N.	Land cover	1989 (ha)	2017 (ha)	Change %
1	Forest	29481	31900	8
2	Agriculture	56613	45666	-19
3	Settlement	11606	23069	99
4	Sand/gravel	2495	588	-76
5	Water	2849	1821	-36
Total		103044	103044	

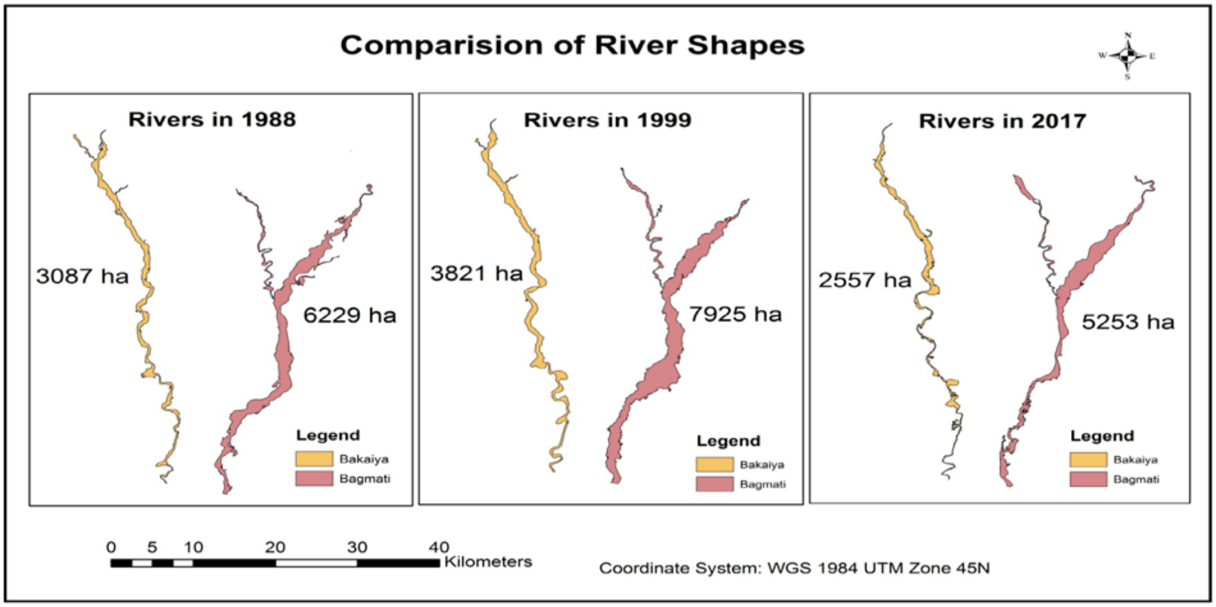

Figure 4: Comparison of Bakaiya and Bagmati River shapes in 1988, 1999 and 2017

Fire distribution and frequency

The fire assessment was based on the analysis of historical fire incidence data to explore the spatial and temporal patterns of forest fires (Matin et al., 2017). Locations of historical forest fires during the period 2002–2018 were obtained from Fire Information from Resource Management System (FIRMS) of NASA's Earth Observation Data. The fires data were verified during the fieldwork using GPS and digital topographic maps. The coordinates of the fires incidences were then registered to the GIS database.

A fire distribution map was prepared which is shown in Figure 5. From the map it is evident that the most of the fire incidences is located in the forest area of the district. There was all together four hundred sixty-eight fire incidences have been recorded. The time series plot of fire incidences shows that the number of fire incidence increased by approximately one event (Figure 6).

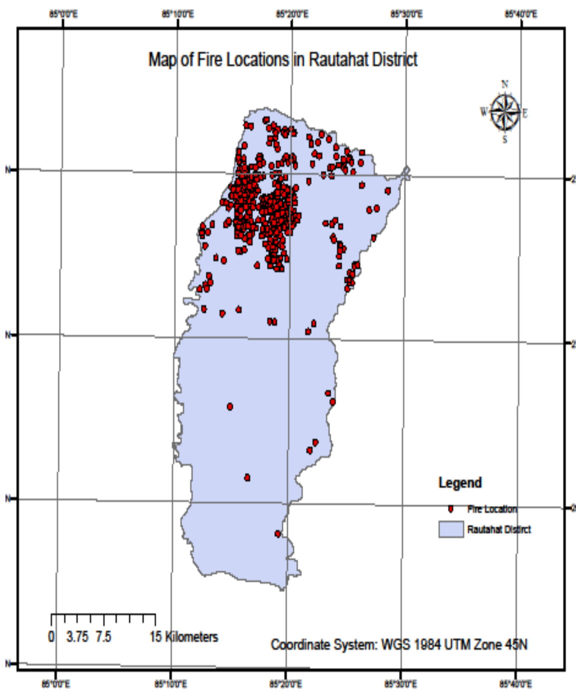

Figure 5: Distribution of fires incidences

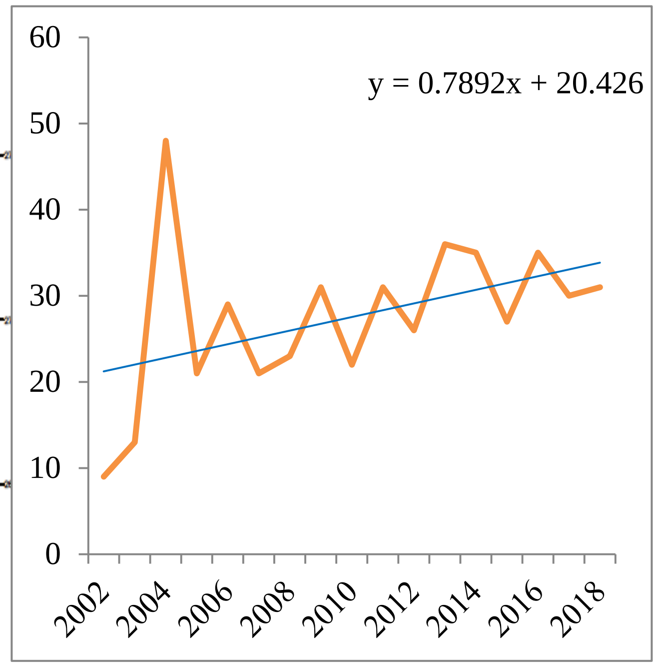

Figure 6: Time series plot of fire incidences

Rainfall analysis

The annual distribution of rainfall for year 1981 to 2017 by CHIRPS is shown in figure 7 and figure 8. CHIRPS incorporate 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring (Funk et al., 2015). Climatic data of other place of Nepal i.e. Syangja showed that the average annual rainfall was found to be in diminishing trend at the rate of 0.6507 mm/yr (Bhattarai et al., 2020) and somewhere erratic (Sharma et al., 2019). While the total annual rainfall of this district is 1,555.70 mm. Figure 8 illustrate that in 1985 received maximum annual rainfall observed as 2096mm.The slope of trend line shows that annual rainfall is slightly increasing. Map shows that northern part mostly of Churia region of district received more rainfall compare to southern part.

Temperature analysis

MODIS global Land Surface Temperature (LST) and Emissivity 8-day data are composed from the daily 1-kilometer LST product (MOD11A1) and stored on a 1-km Sinusoidal grid as the average values of clear-sky LSTs during an 8-day period (Lu et al., 2018). For temperature averages of MOD11A1 of 1 km sinusoidal grid of 8 days illustrated in figure 9. Areas above the churya also experiencing warmer temperature for example (Gautam et al., 2019; Karki et al., 2019; Kharal et al., 2019). LST from 2001 to 2017 are plotted, where average temperature is increasing by 0.6 degree Celsius per year, shown in figure 10.

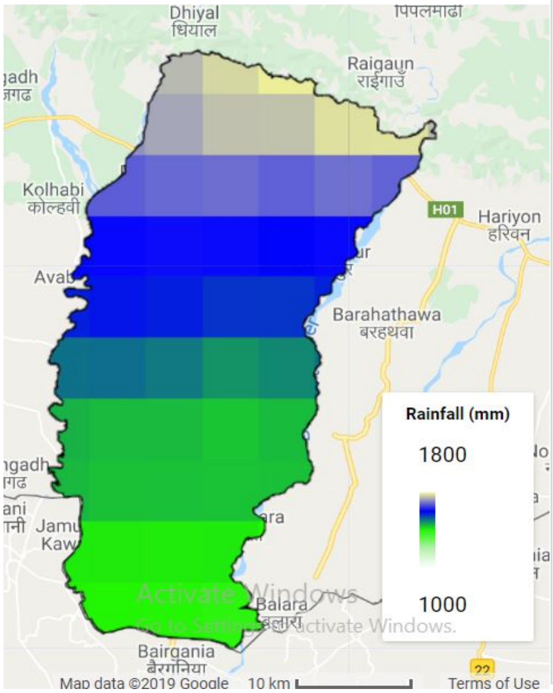

Figure 7: Map of annual rainfall

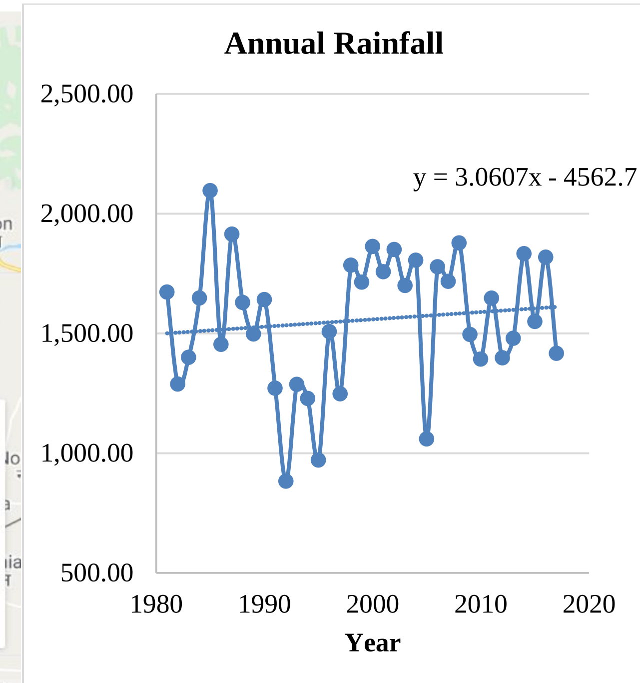

Figure 8: Graph of annual rainfall

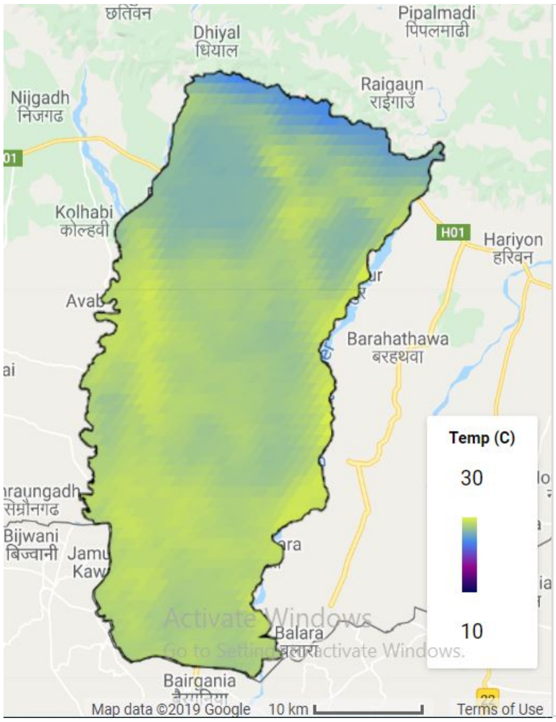

Figure 9: Map of annual temperature

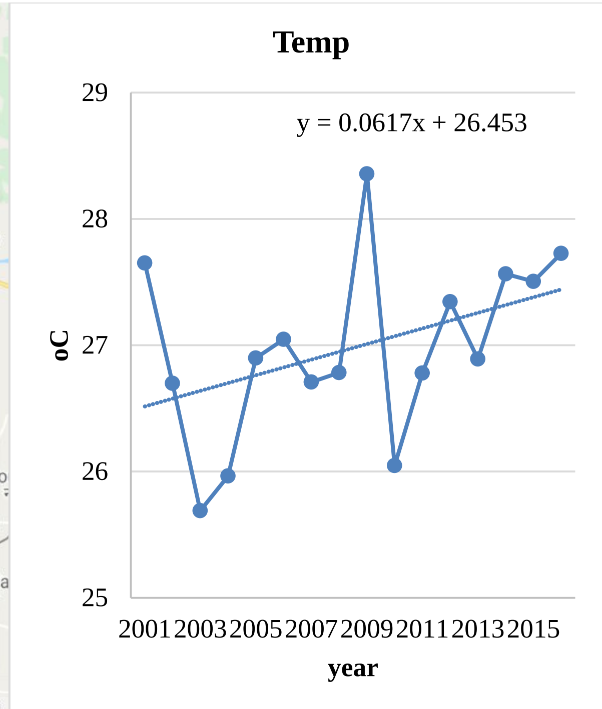

Figure 10: Graph of annual mean

Drought analysis

According to Komuscu, (1999) define drought is a natural phenomenon that has significant economic, social and environmental impacts. It is develop slowly, and its impacts may remain for years after termination of the event. No single definition of drought exists that applies to all circumstances, but most definitions of drought are based on an expression of deficiency of precipitation resulting in water shortage for some activity related to use of water (Wilhite & Glantz, 1985). Similarly, a study by Sharma (2019) had concluded that the major threats prevailing in the Makwanpur district were drought, storm, thunder and lightning, forest fires etc.

In this study we applied the drought classification category based on (Mckee et al., 1993). Time series of the SPI values computed from meteorological station Simara for 12-month time scale. A 12-month SPI is a comparison of the precipitation for 12 consecutive months with that recorded in the same 12 consecutive months in all previous years of available data. From 1985 to 2015 there are four major drought events; 1989 – 1990, 1992 – 1997, 2009 – 2011 and 2012 – 2015. In figure 11 extreme type of drought having -2.54 SPI is shown in 2012.

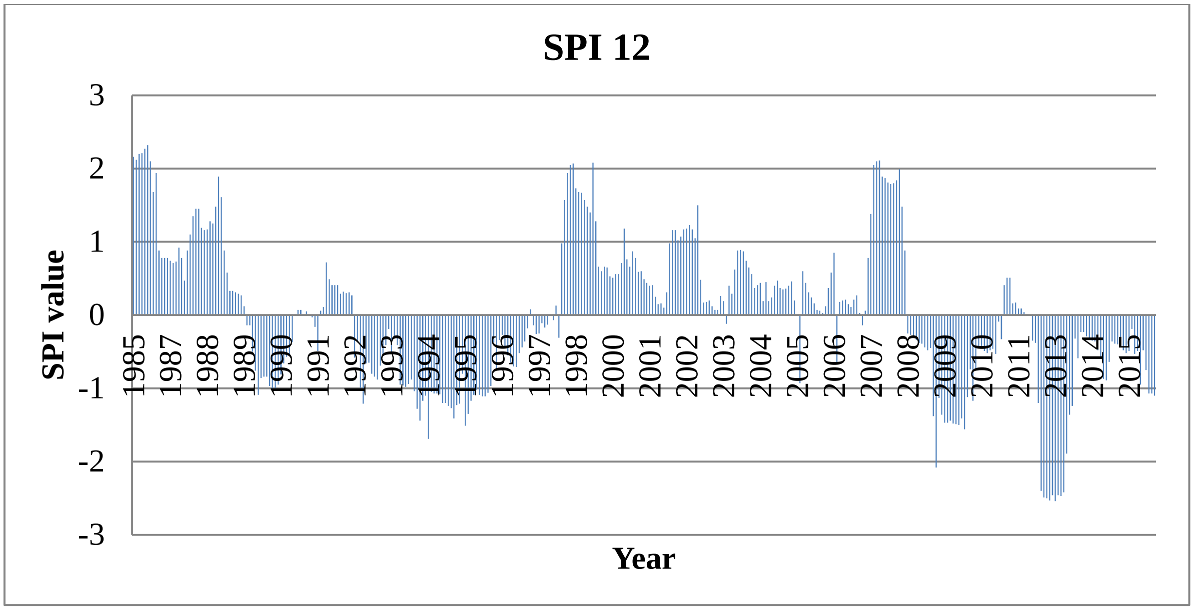

Figure 11: 12 month SPI value

River flow analysis

Bagmati River originates from Shivapuri hill the northern part of Kathmandu valley which is fed by monsoon and springs and flows through the middle mountains and churiya range (ADB, 2013). This is an important river for irrigation facilities and coverage irrigable area of 122000 ha. of Bara, Rautahat, Sarlahi and Mahottari district. The average daily and monthly flow are used for calculate long term mean annual flow which is about 125 m3/s as shown in figure 12. Results revealed that maximum average mean flows in the month of July whereas March and April are the month of least flow.

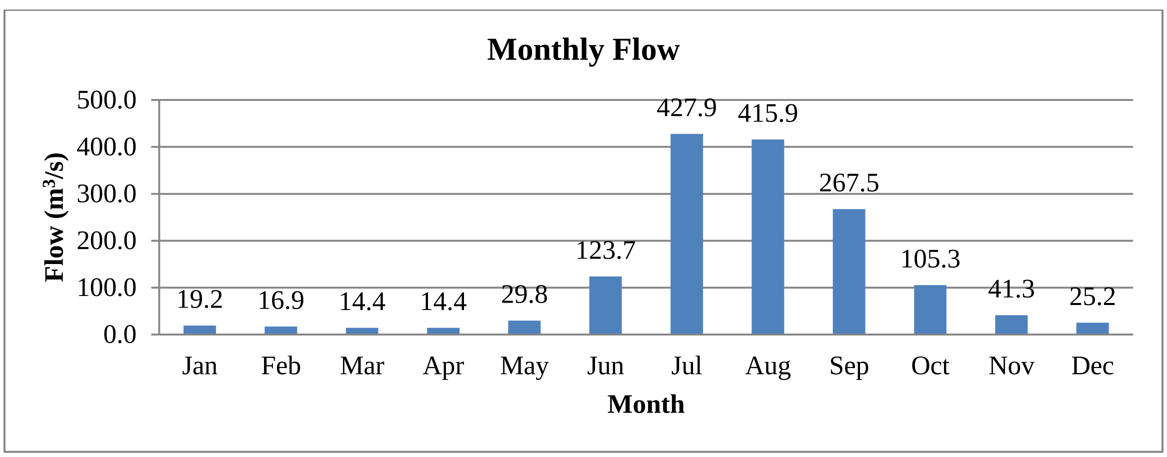

Figure 12: Monthly flow of Bagmati at Pandhera Dovan station

Kulekhani River in the Mahabharat range flowed into the Bagmati Project was completed in 1981. The cloudburst also affected this project. A station in Tistung in the Kulekhani catchment recorded 540 mm of rainfall in 24-hours on July 19, the maximum 24-hour rainfall ever recorded in the history of Nepal (Dixit et al., 2007). The resultant massive swelling of the Bagmati and its tributaries caused major flood devastation in the mid hills and the lower Bagmati basin. As a result of the floods, about 1,300 people died nation-wide with about 111 only from Rautahat district (DPTC, 1993). Furthermore, another two major flood event were showed in 2002 and 2004 recorded 5380 and 5600 cumecs respectively. Whereas figure 14 shows that average annual flow of Bagmati River is decreases.

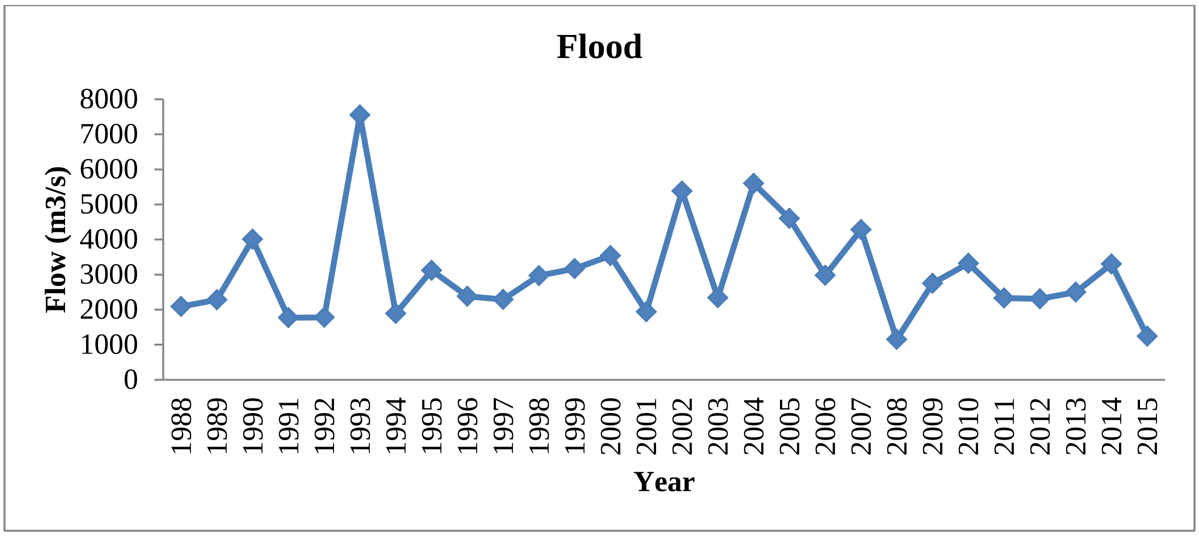

Figure 2: Maximum flood records

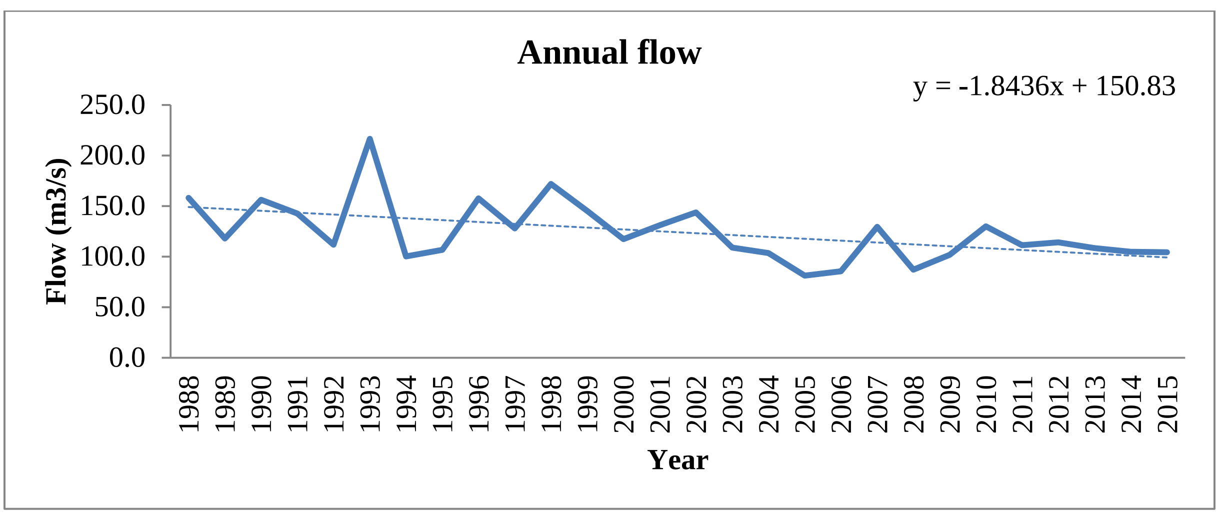

Figure 3: Average annual flow

The annual one day maximum runoff was sorted from the database to estimate the probable maximum flood (PMF) for one day duration (Casas et al., 2011). The Hershfield theory of extreme values was used for estimation of PMF for one day duration based on an appropriate frequency factor (Singh et al., 2018). The value of the frequency factor for one day duration is taken as 15. This frequency factor was used to estimate one day PMF values in Hershfield technique describe in equation (i). It was observed that PMF of one day duration over the region was found as 24368 cumecs, which is nearly equal to twice of the 10000 years return period given by Gumbel’s distribution. This means people of lower region should to prepare for another extreme event in near future.

$$PMF = P + K * \sigma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

Where P = mean of maximum flood

σ = standard deviation of maximum flood

where "k" is frequency factor, with varying between 6 and 30

Conclusion

In this study area, forest area has increased by 8%. Most of the fires incidences were distributed within the forest area of the district. Fire incidences are increasing by one per year. Bagmati and Bakaiya river beds are expanding each by 2.5% of their original shape. Annual rainfall is increasing by 3 mm per year. Annual temperature is increasing by 0.06 °C per year. Annual flow of Bagmati River is decreasing at 1.84 m3/s per year.

References

ADB. (2013). *Environmental Impact Assessment, Bagmati River Basin Improvement Project; DHI Group for Asian Development Bank*.

Adhakari, B. R. (2013). Flooding and inundation in Nepal Terai: issues and concerns. *Hydro Nepal: Journal of Water, Energy and Environment*, *12*, 59–65.

Bhattarai, B., Sigdel, R., Gautam, D., Jandung, C. ., & Sharma, B. (2020). People’s Perception on Climate Change, its Impact and Adaptive Strategies in Kaligandaki Rural Municipality, Syangja. *South Asian Research Journal of Biology and Applied Biosciences*, *2*(1), 1–6. https://doi.org/10.36346/sarjbab.2020.v02i01.001

Briassoulis, H. (2000). Analysis of Land Use Change: Theoretical and Modeling Approaches. In *The Web Book of Regional Science*. Wholbk, Regional Research Institute, West Virginia University. http://www.rri.wvu.edu/WebBook/Briassoulis/contents.htm

Briassoulis, H. (2009). Factors influencing land-use and land-cover change. Land cover, land use and the global change. *Encyclopaedia of Life Support Systems (EOLSS)*, *1*, 126–146.

Casas, M. C., Rodríguez, R., Prohom, M., Gázquez, A., & Redaño, A. (2011). Estimation of the probable maximum precipitation in Barcelona (Spain). *International Journal of Climatology*, *31*(9), 1322–1327. https://doi.org/10.1002/joc.2149

Dahal, R. K. (2012). Rainfall-induced landslides in Nepal. *International Journal of Erosion Control Engineering*, *5*(1), 1–8.

Di Gregorio, A., & Jansen, L. J. M. (2000). Land Cover Classification System (LCCS): Classification Concepts and User Manual. In *Fao* (Vol. 53). Food & Agriculture. https://doi.org/10.1017/CBO9781107415324.004

Dixit, A., Upadhya, M., Rai, D. R., & Devkota, M. (2007). Flood Disaster Impacts and Responses in Nepal Tarai's Marginalised Basins. *Working with the Winds of Change - Toward Strategies for Responding to the Risks Associated*, 120–157.

DPTC. (1993). *Annual Disaster Review, Water Induced Disaster Prevention Technical Centre*.

FAO. (2016). *Shifting cultivation, livelihood and food security: New and old challenges for indigenous peoples in Asia*.

FRA. (2014). *Churia Forests of Nepal. Forest Resource Assessment Nepal Project*.

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations - A new environmental record for monitoring extremes. *Scientific Data*, *2*. https://doi.org/10.1038/sdata.2015.66

Gautam, A. P. (2007). Land use dynamics and landscapes change pattern in a Mountain watershed of Nepal. *Mountain Research and Development*, *22*(1), 63–69.

Gautam, D., Bhattarai, S., Sigdel, R., Jandng, C. M. ., Mujahid, A., & Gharti Chhetri, D. . (2019). Climatic Variability and Wetland Resources in Rupa Lake Catchment, Nepal. http://twasp.info/journal/home. https://doi.org/10.5281/zenodo.3568477

Ghimire, S. K., Higaki, D., & Bhattarai, T. P. (2013). Estimation of soil erosion rates and eroded sediment in a degraded catchment of the Siwalik Hills, Nepal. *Land*, *2*(3), 370–391. https://doi.org/10.3390/land2030370

Inca, G., & A, C. (2009). *Assessing the Land Cover and Land Use Change and Its Impact on Watershed Services in a Tropical Andean Watershed of Peru Environmental Science and Technology with a Specialization in Development and International Cooperation*. University of Jyvaskyla.

Karki, J., Gautam, D., Thapa, S., Thapa, A., Aryal, K., & Sigdel, R. (2019). A Century Long Tree- Climate Relations in Manaslu Conservation Area, Central Nepalese Himalaya.. http://twasp.info/journal/home. https://doi.org/10.5281/zenodo.3523581

Kharal, D. ., Gautam, D., Jandug, C. M. ., & Mujahid, A. (2019). One and half Century Long Tree-Climate Relations in Western Nepalese Himalaya. http://twasp.info/journal/home. https://doi.org/10.5281/zenodo.3562426

Komuscu, A. U. (1999). Using the SPI to analyze spatial and temporal patterns of drought in Turkey. *Drought Network News*, *11*, 7–13.

Laux, P., Nguyen, P. N. B., Cullmann, J., & Kunstmann, H. (2017). Impacts of Land-Use/Land-Cover Change and Climate Change on the Regional Climate in the Central Vietnam. *Water Resources Development and Management*, 143–151. https://doi.org/10.1007/978-981-10-2624-9_9

Lemenkova, P. (2015). Processing Remote Sensing Data Using Erdas Imagine for Mapping Aegean Sea Region, Turkey. *Informatics*, *3*, 11–15. https://elibrary.ru/item.asp?id=26663916

Lu, L., Zhang, T., Wang, T., & Zhou, X. (2018). Evaluation of collection-6 MODIS land surface temperature product using multi-year ground measurements in an arid area of northwest China. *Remote Sensing*, *10*(11), 1852. https://doi.org/10.3390/rs10111852

Matin, M. A., Chitale, V. S., Murthy, M. S. R., Uddin, K., Bajracharya, B., & Pradhan, S. (2017). Understanding forest fire patterns and risk in Nepal using remote sensing, geographic information system and historical fire data. *International Journal of Wildland Fire*, *26*(4), 276–286. https://doi.org/10.1071/WF16056

Mckee, T. B., Doesken, N. J., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. In: Proceedings of the Ninth Conference on Applied Climatology. *American Metereological Society, Boston*, 179–184.

Ministry of Forests and Soil Conservation. (2016). *Conservation Landscapes of Nepal*.

Mulders, M. A. (2001). Advances in the application of remote sensing and GIS for surveying mountainous land. *International Journal of Applied Earth Observation and Geoinformation*, *3*(1), 3–10.

Niraula, R. R., Gilani, H., Pokharel, B. K., & Qamer, F. M. (2013). Measuring impacts of community forestry program through repeat photography and satellite remote sensing in the Dolakha district of Nepal. *Journal of Environmental Management*, *126*, 20–29. https://doi.org/10.1016/j.jenvman.2013.04.006

Pokhrel, K., Poudel, P., Neupane, B., & Paudel, R. (2019). Comparative Study in Habitat Suitability Analysis of Wild Water buffalo (Bubalus arnee) in Two Flood Plains of Chitwan National Park (CNP), Nepal. *International Journal of Research Studies in Zoology*, *5*(3), 1–10. https://doi.org/10.20431/2454-941x.0503001

Ricketts, P. J. (1992). Current approaches in geographic information systems for coastal management. *Marine Pollution Bulletin*, *25*(1–4), 82–87.

Rimal, B. (2011). APPLICATION OF REMOTE SENSING AND GIS, LAND USE/LAND COVER CHANGE IN KATHMANDU METROPOLITAN CITY, NEPAL. *Journal of Theoretical & Applied Information Technology*, *23*(2).

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L. R., Sykes, M. T., Walker, B. H., Walker, M., & Wall, D. H. (2000). Global biodiversity scenarios for the year 2100. *Science*, *287*(5459), 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Sharma, G., Gautam, D., Jandug, C. ., Bhattarai, S., G.C, D. ., Baral, K., Manandhar, B., & Sidgel, R. (2019). Climate Change Impact and Local Adaptation Strategies at Chitlang, Makwanpur, Nepal. *South Asian Research Journal of Humanities and Social Sciences*, *1*(4), 405–410. https://doi.org/10.36346/sarjhss.2019.v01i04.013

Singh, A., Singh, V. P., & AR, B. (2018). Computation of probable maximum precipitation and its uncertainty. *International Journal of Hydrology*, *2*(4), 504–514. https://doi.org/10.15406/ijh.2018.02.00118

Tiwari, K. R., & Rayamajhi, S. (2018). Devastating Monsoon: Water Induced Disaster Management Practices in Nepal. *Forestry: Journal of Institute of Forestry, Nepal*, *15*, 57–76. https://doi.org/10.3126/forestry.v15i0.24921

Tiwari, M. K., & Saxena, A. (2011). Change Detection of Land Use/ Landcover Pattern in an Around Mandideep and Obedullaganj Area, Using Remote Sensing and GIS. *International Journal of Technology And Engineering System(IJTES)*, *2*(3), 342–350.

Wilhite, D. A., & Glantz, M. H. (1985). Understanding: The drought phenomenon: The role of definitions. *Water International*, *10*(3), 111–120. https://doi.org/10.1080/02508068508686328

Acknowledgments

First of all we would like to acknowledge SUNREM-Himalaya, NORHED South driven project, Institute of Forestry (IOF), Tribhuvan University, Office of the Dean for providing a small research grant to conduction a research on title- "An Assessment of Climate and Land Use Changes Impacts on Local Level, a case study from Rautahat District". We are grateful to Institute of Forestry, Hetauda Campus for providing necessary logistics support during the research. We are very much indebted and grateful to Prof. Dr. Krishna Raj Tiwari, Prof. Dr. Santosh Raaymajhi, Mr. Krishna Prasad Dahal, Mr. Bijay Thakur, Mr. Debendra Gelal and Mr. Bikram Singh, students of Institute of Forestry, Hetauda Campus for their support in field works and data analysis.

Conflicts of Interest

There are no conflicts to declare.