Assessing Land Use Dynamics with Climate Change Indicators : A Case Study of Madi Khola Sub-watershed of Kaski District

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Abstract

Land use and land cover change have major impacts on the global environment and climate. Remote sensing and GIS technology are very useful tools and important for monitoring changes. It is accepted worldwide that warming of the globe is responsible for unprecedented climate events posing a number of direct and indirect threats to mountain environment. This study aimed to assess land uses dynamics with climate change indicators and the major causes and effects of climate change on land use in Upper Madi khola Sub-watershed of Kaski district. Landsat satellite images of year 1988 and 2012 were used for quantifying changes using supervised classification method. Household surveys, key informant interview, GPS point and indirect field observation were carried out to agglomerate social, economic and bio-physical data.

Results showed that the forest cover has increased at an annual rate of 0.23% and other (barren land, settlement, water) increased by 0.88% per annual. Similarly, snow cover has decreased at an annual rate of 1.5%. The maximum, minimum and average annual temperature in the study area were found increasing at the rate 0.0147 °C, 0.0396 °C, and 0.0271 °C respectively. Precipitation trend is also increasing by 8.622 mm per annum. Melting of snow, expansion of glacial lake, occurrence of landslide and invasive species moving upper elevation are some distinctly noticed effects of climate within the watershed. Land use/Land cover change in the study area should be monitored and updated regularly and agriculture land of the area should be protected from further transformation which creates food scarcity to the study area.

Keywords: land use dynamics, Climate change, Sub-watershed

Introduction

Land use /land cover (LULC) changes are very dynamic in nature and have to be monitored at regular intervals for sustainable environment development. Remote Sensing data is very useful because of its synoptic view, repetitive coverage and real time data acquisition. The digital data in form of satellite imageries, therefore, enable to accurately compute various LULC categories and help in maintaining the spatial data infrastructure (SDI) which is very essential for monitoring and change detections studies. In other words, the remote sensing satellite data in multi-resolution and multispectral means to provide spatial information for LULC at different levels for various aspects as built-up land, agricultural land, forests, wastelands and water bodies etc. Land use is one of the main factors through which human influence the environment. Land use involves both the "manner in which the bio-physical attributes of the land are manipulated and the intent underlying that manipulation – the purpose for which the land is used" (Turner *et al.*, 1995).

Land cover corresponds to the physical state of the ground surface, such as forest, grassland etc. whereas land use reflects human activities such as the use of the land for different purpose such as industrial zones, resident zones. This definition established a direct link between land cover and the action of the people in their environment i.e., land use may lead to land cover change (Phong 2004). Likewise, land cover refers to features of land surface, which may be natural, semi-natural, managed, or manmade. On the other hand land use refers to the activities on land or classification of land according to how it is used, such as residential, industrial, commercial, agriculture, recreational, urban, rural, etc. To make sound planning for land use purpose, accurate and meaningful contemporary data on land use are essential.

Global warming, early decades of the twenty-first century will see a moderate warming of 1-2 resulting in reduced crop yields in seasonally dry and tropical regions, while crop and pasture yields in temperate region may benefit. Further warming in the second half of the century will negatively affect all regions, although agriculture in many developing countries in semi-tropical and tropical region will bear the brunt of the effects (Easterling et al., 2007). Climate monitoring efforts and communication of information is essential to convince farmers those climate changes projections are real and require response actions. Information services should include surveillance of pests, diseases and other factors of important to production system (Howden et al., 2007).

Primary indicators are the instrumental observation of climate over time such as temperature, rainfall, humidity, cloud cover etc. Secondary indicators are systems/ organization change in response to condition change. According to OECD (1993) an indicators is a parameter which provides information about the state of phenomenon/environment/area with significance extending beyond that directly associate with a parameter value. Thus, indicators provide information about phenomenon that are regarded typical to the environment quality.

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Indicators of climate change should give an overview of the climate and its development (Sweeney, 2002).

The displacement of present vegetation belts towards higher altitudinal or latitudinal areas may serves as a simplistic theoretical construct to demonstrate that climate change induces shift in the vegetation zonation (Walther *et al.*, 2002).

The proposed research in this context is useful to assess the LULC changes linking measureable climate change indicators.

Objectives

The general objective of the study is to assess the LULC change from 1988 to 2012 as well as climate change indicators (precipitation and temperature) from 1980 to 2012 in Upper Madi khola Sub-watershed of Kaski district.

The specific objectives are:

- Mapping of LULC changes in Upper Madi khola sub -watershed using Landsat imageries.
- To assess the indicators of climate change within watershed.
- To explore out the causes and effects of climate change on land.

Material and Methods

Study area

The part of Upper Madi khola watershed (28°32'9.69"N-28°19'33.58"N latitude, 84° 7'11.83"E-84° 5'22.22"E longitude) covering about 39,950 ha lies in 23 km north-east from Pokhara, of Kaski district (Fig.1). The study area is presently covered by agriculture, forest, snow, rocks, settlement, and water bodies. It represents features of mountain watershed and has fragile geology with rugged topography.

Fig. 1 : Map of study area

Data Collection

Both Primary and secondary data were collected and used for analysis.

Primary Data

Satellite Images

The primary data for this study were Landsat Thematic Mapper (TM) and Enhanced thematic mapper (ETM) satellite imageries of two different dates1988 and 2012. Criteria to the selection of the multi-temporal Landsat data set involved assessment of cloud cover percentage, time of acquisition, and sensor type so that LULC mapping and change detection scope could be optimized. Google earth and topographical map (scale 1:25000) of the study area were used for boundary delineation, extracting Area of Interest (AOI) from whole map and ground truth information were gathered for supervised classification of 1988 satellite image and accuracy assessment of classification of 1988 satellite image.

Bio-physical Data

Reconnaissance Survey

A reconnaissance survey was carried in order to get the general understanding of land use status of the study area before starting the field work.

Training Samples

For acceptable classification results training data must be both representative and complete. All the spectral classes constituting each information class must be adequately represented in the training set statistics used to classify an image (Lillesand *et al.,* 2004). Training samples were collected with the help of GPS during field visit. These training samples were used for the supervised classification of the 2012 satellite image. Stratified random sampling where each land use category was considered as stratum used (Lilesand *et al.*, 2004). Ten samples from each stratum were taken for using as the training sample for supervised classification.

Socio-economic Data

Household Survey

In this research, 56 household (5% sampling intensity) were selected for the purpose of household survey. The household survey plan was prepared incorporating different aspects of socio-economic condition especially the people including gender, ethnicity, education and geographic location.

Key Informant Interview

Informal key informant interviews were carried out with local old leader, teacher etc to document the secondary indicators of climate change, agriculture change pattern, emergence of new invasive species, occurrence of extreme climatic events etc. Perception of the people about the role of climate change on climatic hazards, agricultural change pattern, cropping and harvesting time and duration between them, vegetation shift, water sources availability, flowering time, invasive species and their invasiveness were taken as the secondary indicators of climate change.

Focus Group Discussion

Discussion were conducted with different groups of people like committee members, disadvantaged group and women group about the research issue.

Climate Data

Climatic data (1980 to 2012 for a period of more than 30 years) such as monthly maximum and minimum temperature, monthly precipitation of Sikles station was collected from meteorology department which was used for trend analysis of temperature and precipitation pattern and finally, social data were linked to technical data. Finally, obtained social data and climatic data from meteorological station were linked to verify people's perception.

Least Square curve fitting technique was used to find linear trend in the data. The linear trend between the time series data(y) and time (t) is given in the equation

$y=a+bt$ Where, y=temperature or rainfall, t=time (year) "a" and "b" are constant estimated by the principal of least square

Secondary Data

Relevant literatures from different publication, report, library, and journal were referred from different sources such as Institute of Forestry (IOF) library, District Soil Conservation Office (DSCO) and District Forest Office (DFO) of Kaski. Statistical data was accumulated from central Bureau of statistics, Department of survey, Department of forest research and survey and from the World Wide Web.

Data Entry and Data Analysis

Data collected from different sources were entered into SPSS 16. Primary Socio-economic data from household survey, climatic data from the meteorology department and secondary data from Central Bureau of statistics (CBS) and DSCO were entered, analyzed and interpreted on SPSS 16 whereas ground truth

data by GPS and training samples were fed, analyzed and interpreted on ArcGIS 10and ERDAS IMAGINE 8.4. GPS Utility of GIMIS was used to download and convert the GPS points and tracts to the ESRI shape file. For the change detection, Spatial Analyst on the ArcGIS was used. Quantitative data were analyzed in descriptive manner and qualitative data were analyzed by various appropriate tools and presented in charts and graphs. Climatic data obtained from Department of Hydrology and Meteorology (DHM) were analyzed using software's like Excel and SPSS.

Digital Image Processing

Image Pre-processing

Perfect remotely sensed data from satellites have not yet developed. So it is expected that error creeps into the data acquisition process and can degrade the quality of the remote sensor data collected (Lunetta et al., 1991 cited in Jensen 1996). Radiometric error in remotely sensed data might be introduced by the sensor system itself when the individual detectors do not function properly or due to atmospheric attenuation that the energy recorded by the sensor does not resemble that which was reflected by the terrain (Jensen 1996). To improve visible interpretability of an image by increasing apparent distinction between the feature in the scene digital enhancement level slicing, spatial filtering and histogram equalization were carried out by the help of image enhancement tools of ERDAS imagine software (ERDAS). The images were normalized. The spectral distribution of TM bands of Landsat ETM 2012 were normalized to Landsat TM 1988, which was chosen as a standard scene. This radiometric correction was conducted because it is impossible to obtain radiometric measurements for historical Landsat images. In such cases the only way to have images with approximately the same radiometric characteristics is to run image match equation. The purpose of image normalization was to reduce variations in pixel brightness between different images acquired at different dates so that variation in spectral reflectance could be interpreted as real change on the landscape. The strip line of Landsat 7 ETM 2012 scene was corrected by using focal analysis tool of ERDAS IMAGINE.

Pre-classification Processing

Sub-setting the Satellite Image

The study area was separated out from the whole scene of 172*183 Km^2 of the Landsat satellite images of both dates (1988 and 2012) using shape file obtained from digitization. Extract by mask tools of ArcGIS was used for this process. These separated area were used as AOI for the research study.

Training site Selection

Five to ten training sites for each class were collected and merged to give the best representation of the class spectral reflectance. Much care was taken to sub-divide semi-natural areas to two classes to reduce the topographic effect, hence, semi-natural areas in the shade shows different spectral reflectance from semi-natural areas exposed and illuminated by the sun. It was obvious that introducing prior knowledge especially about the topography aided in collecting separable signatures. Much attention was given to pick homogeneous areas in the Landsat image to ensure good classification results. The ancillary data were converted from shape file format to Arc / Info format, which is readable on remote sensing software. These files were then displayed over the Landsat scenes to aid in picking representative training sites.

Digital Classification

Supervised classification approach was applied for the image classification. Algorithm, maximum likelihood classifier (MLC) with parametric test was used for supervised classification (Lilisand et al., 2004). Thresholding was also done which is the process of identifying the pixels in a classified image that are the most likely to be classified incorrectly. The distance image and output thematic raster layer produced by MLC were used for thresholding. The tails of histograms (pixels that are most likely to be misclassified have the higher distance file values at the tail of the histogram of the distance image) were cut off interactively and saved and the removed pixels were viewed. Consequently there were only a few small speckles of the removed pixels. Once the collected signatures were comparatively satisfactory, multiple signatures were merged into one signature for a given LULC category and used for the classification. Data of the different classification items i.e. land use classes obtained from field study was used as training sample for supervised classification of image 2012 and that of topographical map was used for supervised classification of image 1993. The land use classes that were considered in image classification are forest land, agriculture land, and other (rocks, settlement, barren land and water bodies).This classification was used to prepare land use maps.

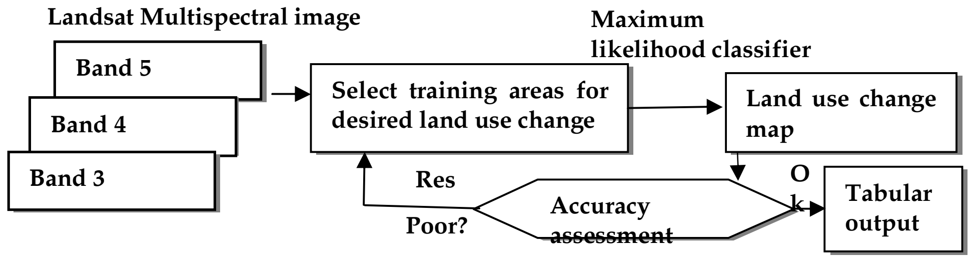


Fig. 2 : General workflow for a supervised LULC classification of a Landsat image

Accuracy Assessment

Once the classification was done, further knowledge of the area was obtained through the use of previous data collected from the field. High resolution topography map and Google earth were used as valuable source of data for the purpose of validating the classification accuracy. ERDAS imagine was used for the accuracy assessment.

Detection of Land Use Change

The raster grids of 1988 and 2012 images were overlaid using Spatial Analyst on the ArcGIS. Land use change was calculated by using raster calculator. Finally, the area converted from each of the classes to any of other classes were computed. The analysis and interpretation of different aspects of the numeric data of land use change were done on Microsoft excel.

Social Change Analysis

The social data collected from household survey was entered on SPSS. The analysis and interpretation of different aspects of the social data was done on SPSS and Microsoft Excel. The result were presented in the easily understandable forms such as tables, graphs and charts.

Results

Land Use/Land Cover Change Detection

1988 Image Classification Result

The classification of the Landsat TM 1988 scene (Fig.3) shows that the forest was the major land cover including 18857.25 Ha (47.20%) followed by other (barren, Settlement, rock and water bodies) 10133.82 Ha (25.3%), Snow 8200.62 Ha (20.53%) and Agriculture 2759.13Ha (6.91%)

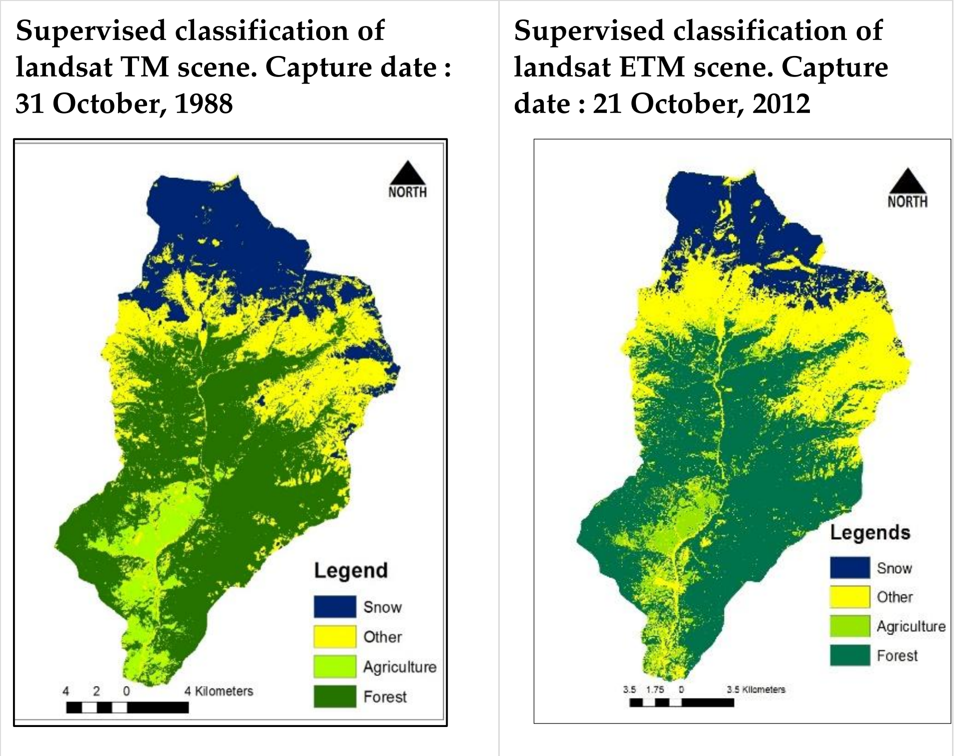


Fig. 3 : Supervised classification of landsat TM left side and supervised classification of landsat ETM on the right side.

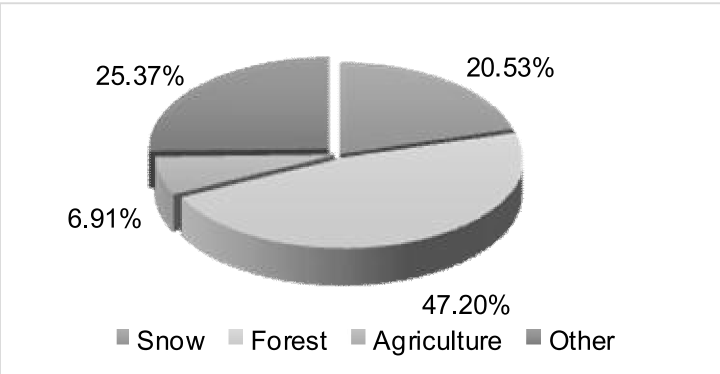


Fig. 4 : Land cover statistics derived using supervised classification of landsat TM 1988 of Upper Madi Khola Sub-watershed

2012 Image Classification Result

The classification of the Landsat ETM images (Fig.5) of the 2012 shows that forest area was the major LULC including 19938.06 Ha (49.91%) followed by others (barren land, settlement rocks and water bodies) 12516.12 Ha (31%), snow 5694.21 Ha (14%) and agriculture 1802.43 Ha (4%) (Fig.5).

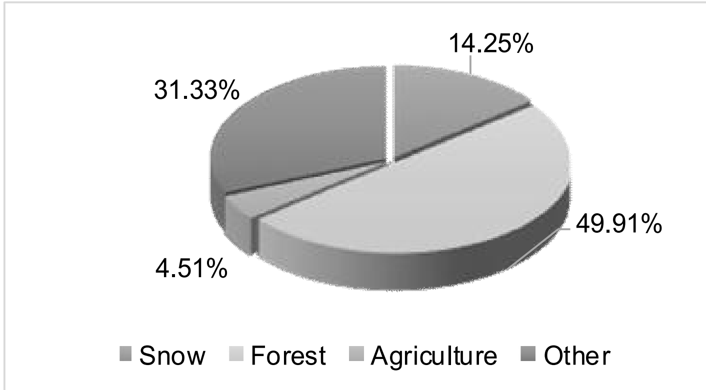


Fig. 5 : Land cover statistics derived using supervised classification of landsat ETM 2012 of the Upper Madi Khola Sub-watershed

Land Use/Land Cover Change

Table 1 below shows that the forest and other has increased during this time period whereas agriculture and snow have decreased. The highest decrease is on snow by 6.27 % followed by agriculture with 2.39%. Similarly the highest increase is on others (barren, settlement, rock and water bodies) by 5.96% followed by 2.71% on forest.

Table 3 : Land use/land cover change

Land use	Landsat TM 1988		Landsat ETM 2012		Increase		Decrease	
	% Cover	Area(Ha)	% Cover	Area(Ha)	% Cover	Area(Ha)	% Cover	Area(Ha)
Snow	20.53%	8200.62	14.25%	5694.21	-	-	6.27%	2506.41
Forest	47.20%	18857.25	49.91%	19938.06	2.71%	1080.81	-	-
Agriculture	6.91%	2759.13	4.51%	1802.43	-	-	2.39%	956.7
Others	25.37%	10133.82	31.33%	12516.12	5.96%	2382.3	-	-
Total	**100%**	**39950.82**	**100%**	**39950.82**	**8.67%**	**3463.11**	**8.67%**	**3463.11**

Table 4 : Land use dynamics table

Land use	Snow	Forest	Agriculture	Others	Total 1988
Snow	5406.84	116.01	0.18	2914.14	8437.17
Forest	0.09	17273.79	80.1	1471.23	18825.21
Agriculture	-	702.9	1127.79	898.92	2729.61
Others	169.74	1669.86	558.99	7560.27	9958.86
Total 2012	5576.67	19762.56	1767.06	12844.56	39950.85

Table 2 Show that the dynamics on land use change within the watershed for a period 30 years. The main reason for decrease in snow cover in the study site is attributed to temperature rise melting of snow and formation of glacial lake. Others (barren land, settlement, and water bodies) increase is due to increase in population, construction of dam/rural roads, landslides and soil erosion. Similarly, agriculture land has decreased in the study area due to shortage of labor as most of people migrated to city area and foreign country.

Climate Data Interpretation

For climate data, two variables such as temperature and precipitations were collected from Sikles station. Missing data were calculated fitting trend line.

Maximum, Minimum and Average Temperature Trend

The maximum, minimum and average annual temperature in the study area were found increasing at the rate 0.0147 c. 0.0396°c and 0.0271°c respectively as shown in the Fig.6.

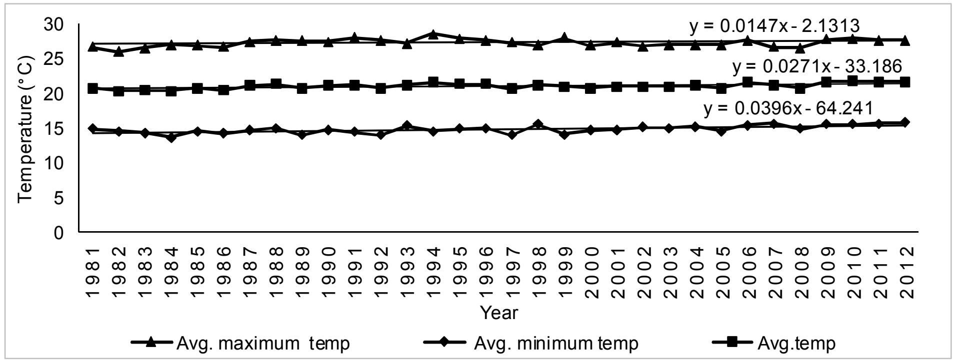


Fig. 6 : Maximum, minimum and average temperature trend

Precipitation Change

Analysis of precipitation data between (1980-2012) confirmed the minimum rainfall in the years 1992, 1980 and 2009 and maximum in the year 1990, 1995 and 2003, respectively. The average rainfall for this period was 300.7 mm.

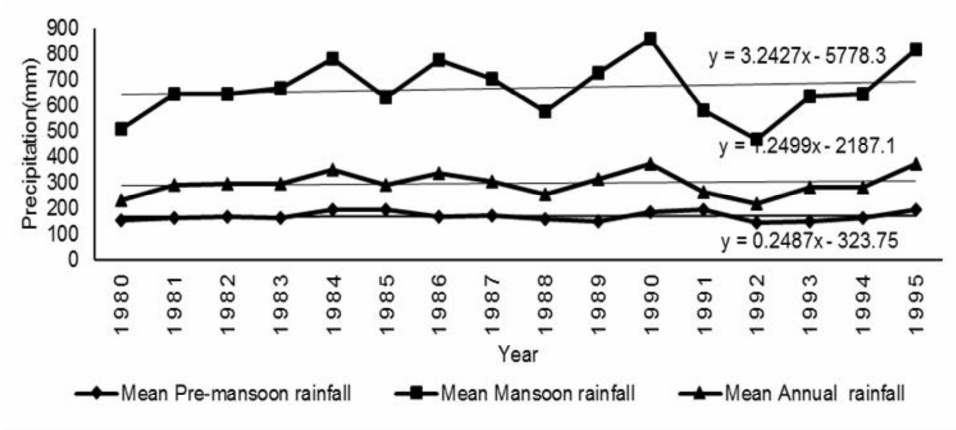


Fig. 7 : Mean yearly seasonal rainfall from 1980 to 1995

In the first period, mean monsoon rainfall increased by 3.24 mm, mean pre-monsoon rainfall increased by 0.24 mm and mean annual rainfall went up by 1.24 mm. In this period, monsoon, pre-monsoon and annual rainfall increased resulting in more wetness (Fig.7).

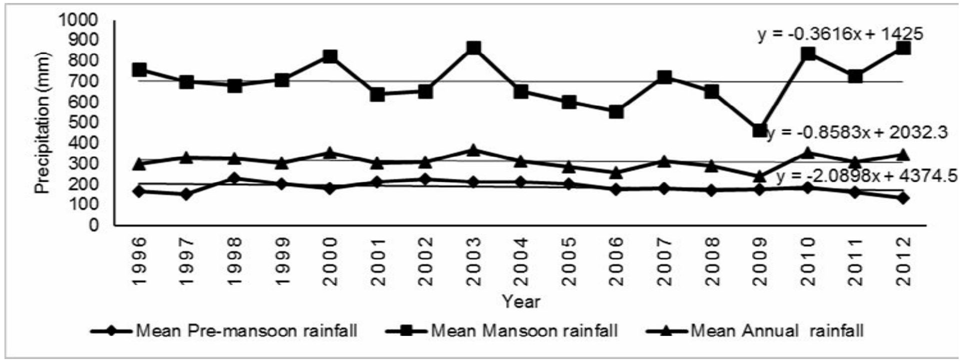


Fig. 8 : Mean yearly seasonal rainfall from 1996 to 2012

Similarly, in the second period, data showed a gradual decline in mean monsoon rainfall, mean pre-monsoon rainfall and mean annual rainfall by 0.36mm, 2.08mm and 0.85mm respectively.

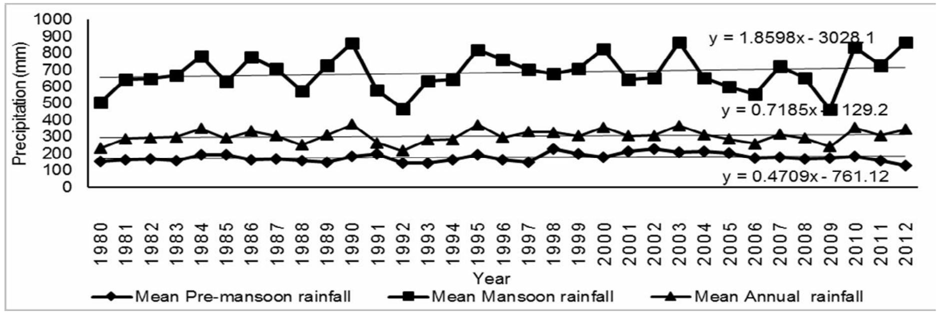


Fig. 9 : Trend of mean annual and seasonal rainfall from 1980 to 2012.

The analysis revealed that there is a variation in monsoon and pre-monsoon rainfall patterns. Fg.9 illustrates that mean annual monsoon rainfall of the period had an increasing trend (1.85 mm year^{-1}). This diagram depicted large inter-annual variation in mean monsoon rainfall.

From the analysis of precipitation trend, it is evident that mean annual, monsoon and pre-monsoon rainfall were in an increasing trend (0.72 mm, 1.86 mm, 0.47 mm year^{-1} respectively) over the period.

People's Perception on Climate Change

The respondent in the study included representation of ethnicity, profession, cast to include inclusive perception. It seem that all the categories of the respondent are facing problem with natural hazards due to climate change as shown in Fig 10.

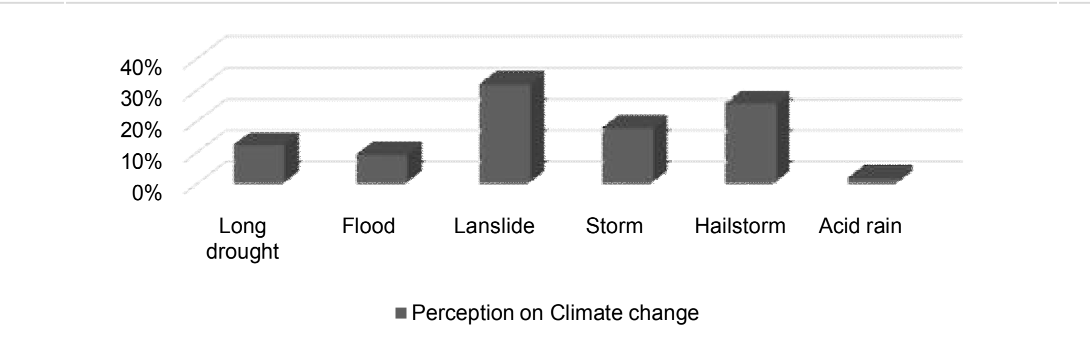


Fig. 10 : Inclusive perception on climate change and their impact

Occurrence of landslide was voted first followed by occurrence of hailstorm and log. Whereas, flood, and acid rain are the minor hazardous factor faced during the time period of 30 years in their daily life.

Climate Change Impact Assessment on Land Use/Land Cover

Major Causes of LULC Change in the Study Area

Response exercise were carried out to find out the respondent opinion causes of LULC change in the study area. Fig. 11 shows that population growth (43.2 %) is the major causes of LULC change in the study area followed by climate change (33.3%), policy (12.3 %), migration (7%) and Infrastructure development (4.2 %). Migration of people from upper part of the study area to the lower more developed area and different policies like introduction of community forest, alternative energy sources, stall feeding system etc. help change the land uses of that area.

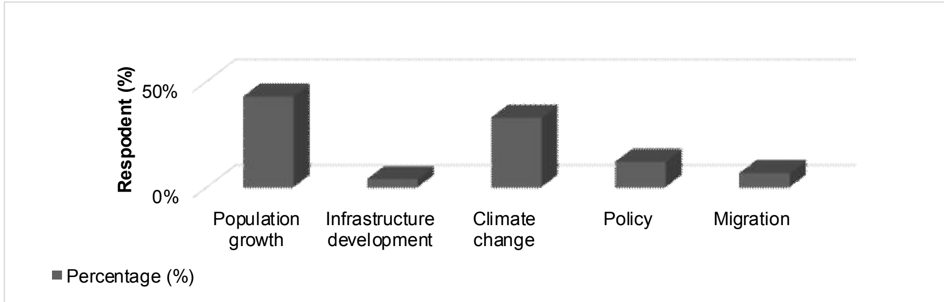


Fig. 11 : Causes of LULC change

Melting of Snow and Glacial Lake Formation

One of the most prominent and best visible evidence of climate change are glaciers (Benn & Evans 2010). Glaciers react sensitively to global climate changes.

Landsat 5, 1988, October

Landsat 5, 1993, October

Landsat 7, 2003 October

Landsat 8, 2013, October

Fig. 12 : Accelerated glacial melt and retreat, giving birth to hazardous glacial lakes in the study area.

The glacial lakes are increasing in number and size that we can see the size of Kopuche glacial lake continuous increasing (Fig. 12).

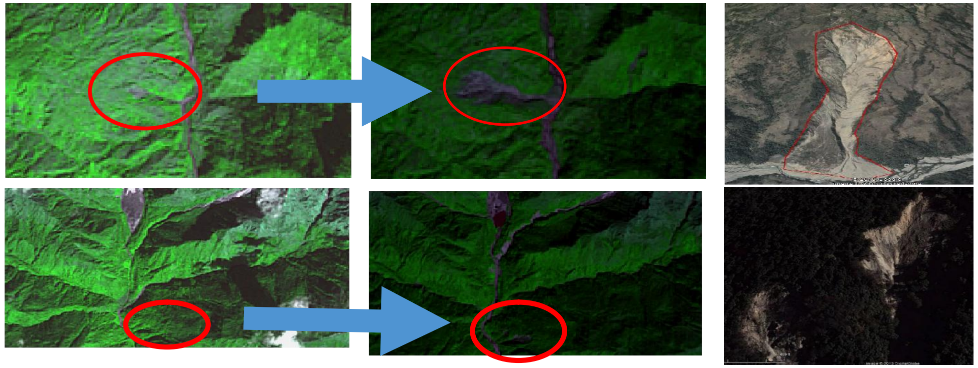
Rapid Proliferation of Unwanted Weeds

Unwanted weeds have outgrown in most agriculture and forest lands. Many new plants which have invasive character were observed at the watershed area in recent years. Some of the examples include: *Ageratum adenophora* (Kalo Banmara), *Chromolaena odorata* (Seto Banmara) and (*Commelina benghalensis)* Kane Jhar. It is found from the key informant's interview that the invasive species are moving gradually to the upper elevation.

Land Slides

Occurrences of landslides were increasing according to respondents. The image of two dates 1988 and 2012 shows that occurrence of landslides at different places (Fig. 13).

Climate acts as a complex agent on the magnitude and frequency of landslides via the nonlinear soil water system (Bogaard & van Asch, 2002).



1988 Image   2012 Image   Google Earth Image

Fig. 13 : Occurrence of landslides at different places

Spread of Insects and Pests

The increase and decrease spread of insects and pests can also be taken as secondary indicators of the changing climate. Based upon the key informant's interview, it was found that there was increasing and widespread evidence of the insects that were common to the area are gradually disappearing but new species types of insects and pests are emerging. According to respondents mosquitoes and *Liohippelates spp.* were not seen before but now these insects are commonly occurring in the area.

Change in Flowering Time

During formal and informal interview, the old and experienced persons, who have been observing the environment of the study area, shared their experience about the change in flowering and fruiting time of the plants giving the examples of the seasonal vegetables and plants. The flowering time of *Bombax ceiba* has been changed i.e. it is about a month earlier than that of past.

Conclusions/Recommendations

The dynamics of LULC change between 1988 and 2012 depicted from analysis of remote sensing images coupled with analysis of long term climate data and local people's observations confirm impacts of climate change in the study area. The forest cover has increased at an annual rate of 0.23% and other (barren land, settlement, water) increased by o.88% per annual. Similarly, snow cover has decreased at an annual rate of 1.5%. The decreased of snow cover is due to rise of temperature as result melting of snow and formation glacial lake. This study has provided important insights into the dynamics of the major four land use classes (forest, snow cover, agriculture others (barren land, settlement and water) between 1993 and 2010 using remote sensing and GIS.

The maximum, minimum and average annual temperature in the study area were noted to be increasing at rates of 0.0147 ºC, 0.0396 ºC and 0.0271ºC, respectively. The precipitation trend also indicates an increase by 8.622 mm per annum. The measurement of the climate parameters temperature and rainfall provided evidences of change in climate. Melting of snow, expansion of glacial lake, occurrence landslides and invasive species moving upper elevation are some distinctly noticed effects of climate change within the watershed. Increase in insects and pests such as mosquitoes, gnats and flies, change in composition of herbs community, earlier flowering of the plants are some secondary indicators (or the distinctly noticed effects) of climate change which were pragmatic at local level within watershed.

The study thus recommends that LULC change in the study area should be monitored and updated regularly, and agriculture land of the area should be protected from further transformation which would lead to food scarcity in the study area. Furthermore, awareness of climate change and adaptation strategies should be enhanced at the local level.

Acknowledgements

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