LAND USE LAND COVER DYNAMICS AND ITS IMPACTS ON WATERSHED: A CASE STUDY OF MARDI WATERSHED.

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ABSTRACTS

Located in western Nepal near Pokhara city, Mardi Khola watershed is a notable example of degradation in the middle-mountain region. No previous studies in the watershed have delved into identifying, analyzing and storing the bio-physical, environmental, social, economic and demographic information of the watershed to aid the development and timely update of its management and land use plan. Therefore, all watershed management activities in the watershed have resulted in underwhelming outcomes. This study highlighted the Land Use Land Cover (LULC) Change of Mardi watershed area, which has emerged as a significant environmental issue and its impacts on water resources availability at local level resources. LULC change analysis revealed land covers such as forest, built-up area and water bodies was increased while the area under agricultural land and barren land declined between 2001 and 2021. Furthermore, 61% of the households have perceived a decreased availability of water resources such as springs, rivers, and ponds in Mardi Khola watershed over the past few decades for various natural and anthropogenic reasons, which has not only affected the water availability, but overall environmental balance in the watershed. This study generalized the importance to synchronize scientific based watershed information for developing Watershed Management Information System (MIS) at national level to enable sustainable conservation and management of watershed resources of our country.

Keywords: Landsat, land cover, land use, watershed, Remote Sensing, Geographic Information System.

Introduction

LULC change is global phenomenon that is considered as accurate and updated information for detailed eco-system studies having hydrological modeling (Usman et al., 2015, p. 1503). Land cover is defined as physical condition and biotic components of the earth surface; whereas the land use is defined as the modification of the land cover based on human needs and actions (Prakasam, 2010, pp. 150–151). Similarly, the land use land cover change detection is known as identifying these modifications over time series (Anderson, 1977, pp. 143–152). LULC data is highly recognized to be used for watershed management through its wide application in hydrological modeling studies (Schilling et al., 2008, p. 10).

Watersheds in the middle-mountains of Nepal have undergone notable land-use and land-cover (LULC) changes over the past few decades (Awasthi et al., 2002; Fleming & Fleming, 2009; Gautam et al., 2003; Paudel & Thapa, 2004; Sthapit & Balla, 1998; Thapa & Weber, 1995)). Existence of estimated 6000 rivers and many of them originated from the protected mountain areas and Himalayas label the nation as abundant in water resources (Gautam, 2010). However, despite having a lot of water resources in the country, most villages and urban areas lack potable water in their immediate reach. They have witnessed significant population and economic growth, which has led to exacerbations of point and non-point source pollution, deforestation, hydrological alterations, sedimentation and direct habitat destruction. Over the past few years, the forest area, water resources, and barren land have been changing and are likely to continue to change in the future (Dinka and Chaka, 2019).

Over the past few decades, remote sensing (RS) and geographic information system (GIS) become the prominent approaches for the understanding of spatiotemporal characteristics, and extraction of valuable information by classifying the spectral characteristics of land cover features for natural resource management (NRM) (Jensen, 2005; Lilles et al., 2015; Panigrahi et al., 2017). These techniques are useful for the management and improvement of the watershed by integrating and analyzing spatiotemporal data to study LULC changes at different levels (Attri et al., 2015). The image pixel was used as the basic unit of analysis in the 1980s and 1990s classification procedures, with each pixel being assigned to a certain land cover class. With progress, different classification techniques considering pixel as a basic analysis unit were developed, such as supervised (artificial neural network, decision tree, random forests, support vector machine, maximum likelihood classification), unsupervised (K-means and ISODATA), and hybrid classification (semi-supervised and mixing of supervised and unsupervised) techniques (Zhang et al., 2005; Alajlan et al., 2012).

Nepal's terrain, dissected by many rivers and streams, forms a complex of watersheds having a weak geological structure and shallow soils, and are tectonically unstable and fragile. Most are characterized by steep slopes; large variations in altitude over short distances incise river and stream beds. Watersheds in Nepal have relatively high population densities with nearly all the people relying on watershed-based resources for their livelihoods (Poudel, 2003). Natural and human-induced processes operate on these watersheds. The main processes that lead to the degradation of watersheds are landslides, soil erosion, floods, biodiversity loss, and unsustainable water extraction and farming practices. These lead to the loss of soil fertility, the depletion of water tables, the drying up of springs, desertification and sedimentation (Poudel, 2003).

Mardi Khola Watershed, a sensitive watershed in the central mid-hills of Nepal, has been chosen due to the fact that the watershed provides majority drinking water to nearby Pokhara city as well as increasing pressure on the watershed resources from population growth, urbanization, population, agricultural intensification and global drivers such as climate change. Considering the growing challenges facing watershed management in the mid-hills of Nepal, access to information regarding the evaluation of LULC dynamics of this watershed with the combined tools of RS, GIS, and the social study has not been practiced until the date. Therefore, these scientific based findings and sharing could contribute to an integrated watershed management in the project area as well as similar watersheds in the mid-hills of the country. Hence, promote developing an integrated watershed management information system at national level.

The general objective was to understand the dynamics of LULC between 2001 and 2021 and their impact on water availability. In addition, the specific objectives can be summarized as follow:

a. To assess the effectiveness of historical Landsat images for detecting LULC changes over the twenty years (2001-2021),

b. Integrating the remote sensing techniques with local people's perception regarding the changes, and

c. Creating a detailed LULC change map of the Mardi watershed area at a spatial resolution of 30 m.

The long-term study of the change in the land cover and its linkages with the water availability bolsters the efficient use and preservation strategies of these water sources in most of the hilly landscapes. Temporal information of land coverage and its conservation is an asset for the sustainable development of a community. Entire HKHs region is facing water resources depletion over few decades due to different environmental and climatic changes. In this context, this study emphasizes the importance of temporal change in land phenomena and its impact on water resources.

Study Area

The study area, Mardi watershed (83°50'E to 83° 56' E and 28°19'N to 28°29'N) is representative of mid-hill watersheds of western Nepal. Mardi Khola is the major tributary of Setiriver. It is a glacier fed stream, situated at the northern part of Pokhara in the foothills of Annapurna mountain range. The total area of Mardi watershed is 136 km2. Mardi Khola originates from Mardi Himal, 5587m and terminates at Setidovan joining with Setikhola. The total length of river from Sidding (first site) to Setidovan (last site) is about 25 km. The elevation ranges from about 1049 m to 4954 m above mean sea level from valley floor to mountain peaks. The climate of the area varies from warm and humid subtropical to cool and dry alpine along with the elevation variation. The temperature in the study area is the range between 20-30 degrees in the summer and 7-18 degrees in winter Rainfall is monsoonal with average annual rainfall amounting to 4300 mm, of which 80-85% occurs between June and October (Awasthi et al., 2002).The geological features constitute of major thrust plane passing through the northern part of the watershed. The dominant bedrocks are phyllite, quartzite, and dolomite and dip angle of bedrock varies from 150 to 600. Valley bottoms consist of unconsolidated sediment. The main physiographic features are alluvial valley, hills, mountains and narrow valleys. Broad-leaved mixed hardwood forest at lower elevations and coniferous forest at higher elevations are the dominant vegetation composition of this watershed. DystricLuvisol and DystricCambisol in gentle slopes, Rigosols in steep slopes, and Fluvisols in flat and river valleys are its common soil features.

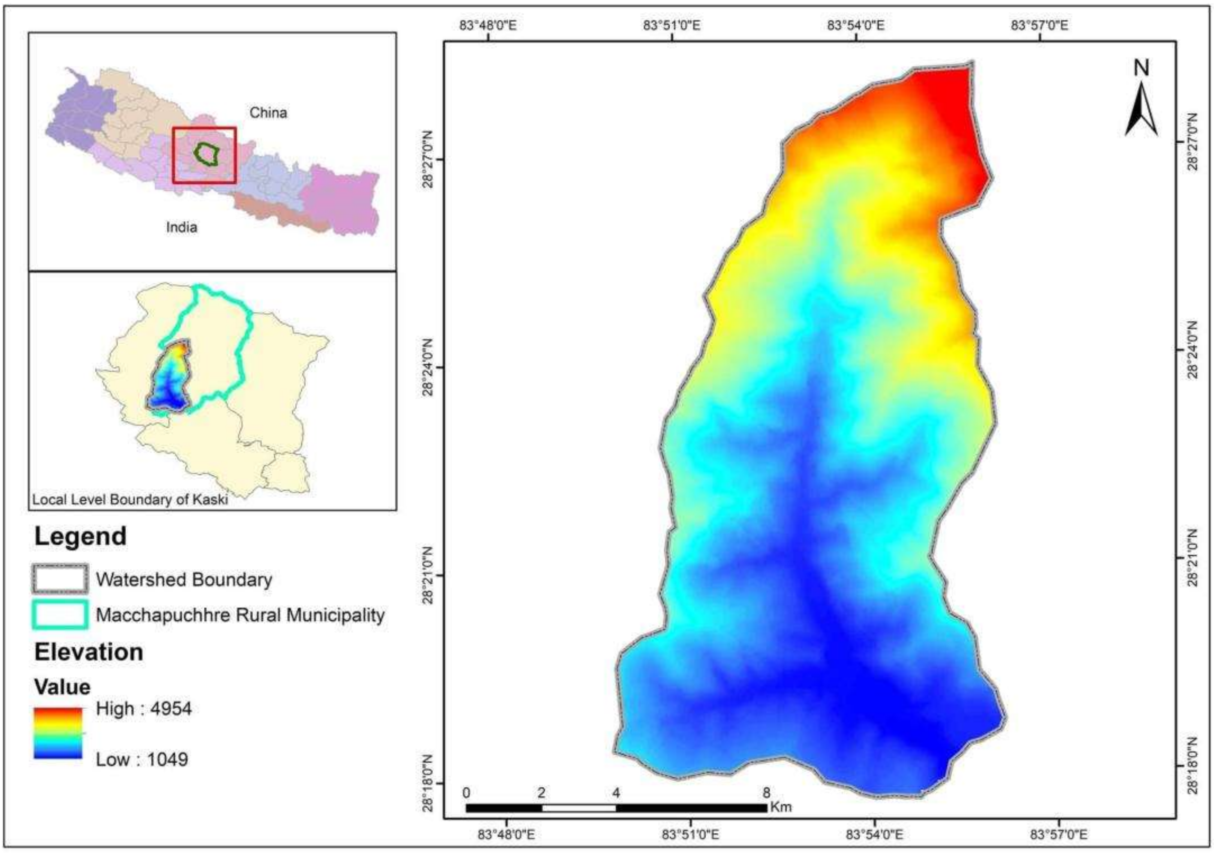

Figure 1: Study area-Mardi Khola Watershed

Data Collection

Primary data. Households surveyed were carried out in total 176 households of this watershed area whose population (total family members of the 176 households) was 760 in order to identify water availability, to elucidate other relevant watershed related information from the community like conservation activities, use, status and perception. Fieldwork was started with a reconnaissance survey to obtain a general understanding of the LULC status of the study area

Key Informants Interview with key informants (DFO Kaski, Nepal Water Authority Pokhara Office, ADB Officials assigned in Project for Improvement of Water Supply in Pokhara, NTNC-ACAP, Machhapuchhre RM Officials, Ministry of Forests and Soil Conservation Pokhara Soil Conservation Section Head, Soil Conservation Office Kaski, Local Water Supply and Sanitation Users Group, Local Elder people, and other people/organization identified to contain relevant information for the study) was carried out to elicit information to collect information on various matters of the watershed based on the expertise and experience, as well as to substantiate information obtained from household questionnaire survey

Secondary data. Secondary data like Landsat images were used for image classification and to determine LULC change, and other literature to acquire knowledge about methods and analysis techniques. The remote sensing data used in this research were divided into satellite images and ancillary data. Cloud-free, multi-temporal Landsat satellite images were chosen from years 2001 and 2021. Two satellite images from past 20 years were used for land cover analysis. The images were acquired from United States Geological Survey Global Visualization Viewer (Glovis) and EarthExplorer (available from https://earthexplorer.usgs.gov/). All the images were of the month of November. Images acquired was from Landsat ETM+ (2001) and Landsat OLI/TIRS (2021) sensors having a spatial resolution of 30m and 7 and 9 spectral bands.

Ancillary data included land use and land cover maps and ground truth data for the land cover/forest cover classes. Topographic maps of scale 1:50,000, Land System maps of the same scale and digital topographic data with contour interval of 20 m published by the Survey Department, Government of Nepal were acquired from Department of Survey, Kathmandu. These maps were digitized and used to extract the area of interest (AOI). These maps were also used as ground truth information for classifying the satellite image. The ground truth data were in the form of reference data points collected using Geographical Positioning System (GPS) in June 2022 for to be used as training data and accuracy assessment of the classification results.

Table 1: Details of Satellite Imagery Used in the Study

Year	**Satellite**	**Sensor**	**Number of Spectral Bands**	**Pixel size (m)**	**Source**
2001	Landsat-VII	ETM+	7 + 1 PAN	30x30, 15x15 PAN	USGS Glovis
2021	Landsat-VIII	OLI & TIRS	9 + 1 PAN + 1 aerosol	30x30, 15x15 PAN	USGS Glovis

Data pre-processing. All Landsat data were downloaded as level-1 Precision and Terrain corrected product, i.e. having been pre-processed by the Level 1 Product Generation System of the USGS. However, ecological applications such as monitoring LULC changes require further preprocessing than that provided by Level-1 products before performing an analysis. Preprocessing of satellite images prior to actual change detection is essential and has as its unique goals of establishing a more direct linkage between the data and biophysical phenomena and the removal of data acquisition errors and image noise (Coppin and Bauer, 1996) to produce a corrected image that is as close as possible to the radiometric and geometric characteristics of the original scene. Of the various requirements of preprocessing for change detection, radiometric, atmospheric and geometric corrections were undergone.

Results

Land Use Land Cover (LULC) classification. Normalized Difference Vegetation Index (NDVI) has been used to monitor vegetation conditions on continental and global scale (Lunetta and Elvidge, 1999). It is used to distinguish healthy vegetation from others or from non-vegetated areas using red and near-infrared reflectance values and this was integrated in object-based image analysis to discriminate between vegetated (forest) and non-vegetated areas. Mathematical formulae for calculating NDVI is

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \#$$

where: ρ_{NIR} is surface reflectance value for near-infrared band, and ρ_{RED} is surface reflectance value for red (visible) band. Theoretically, NDVI value ranges between -1 to +1. Areas of water, barren rock, sand, or snow usually show very low NDVI values, while sparse vegetation such as shrubs and grasslands show moderate NDVI values (approximately 0.2 to 0.5). High NDVI values (approximately 0.7 to 0.9) correspond to dense vegetation.

For improved classification, few other spectral indices such as Ratio Vegetation Index (RVI) and Normalized Difference Water Index (NDWI) (McFeeters) were calculated as:

$$RVI = \frac{\rho_{NIR}}{\rho_{RED}}$$

$$NDWI = \frac{\rho_{GREEN} - \rho_{NIR}}{\rho_{GREEN} + \rho_{NIR}} \#$$

Where ρ_{GREEN} is surface reflectance value for green band.

While comparing the land use land cover between the year 2001 and 2021 it was found that there was increase in built up areas which suggest that the urbanization is increasing. The urbanization was found to be increasing mainly in the downstream region. Agriculture land was seen to be expanding in downstream region where as contracting in upstream region of watershed. Thus, there is increasing human influence in the downstream region of the watershed.

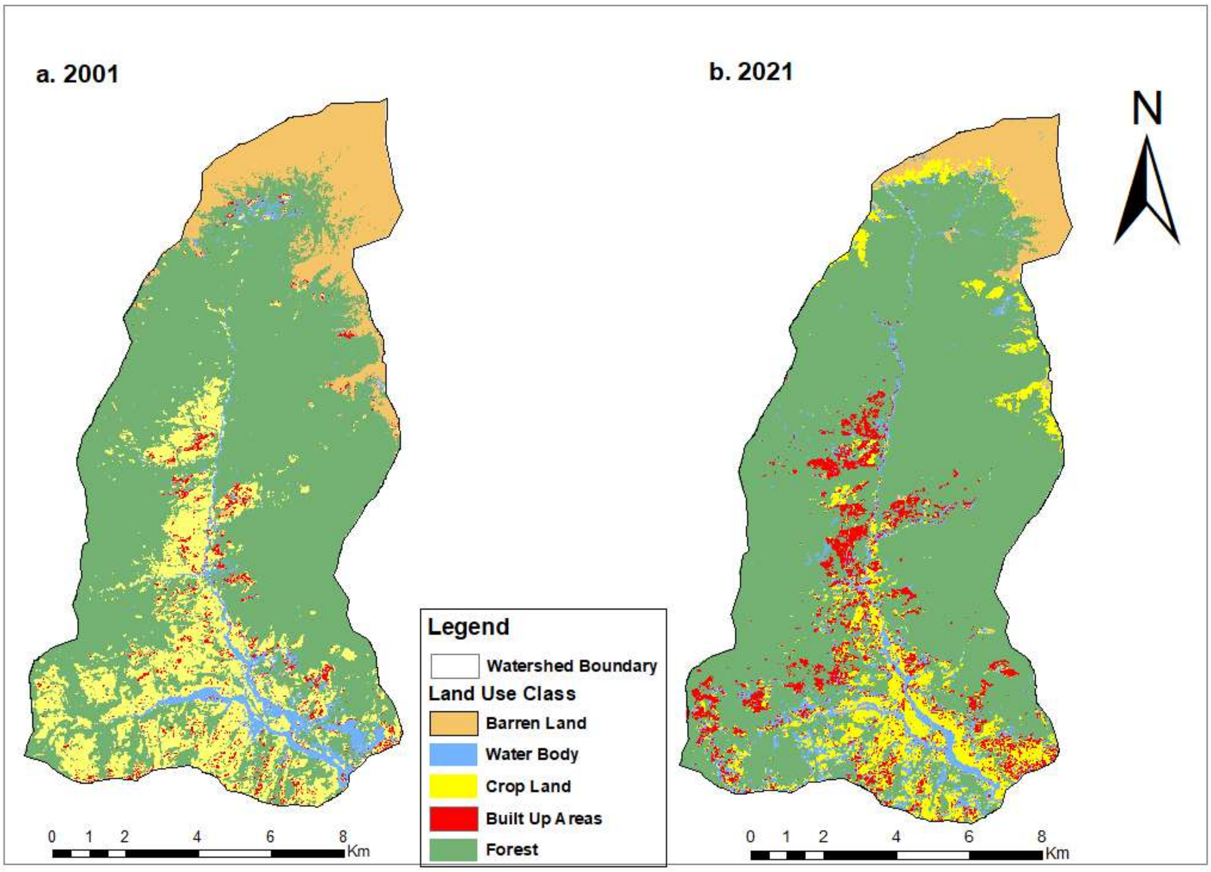

Figure 2: LULC classification of Mardi Khola watershed for 2001 and 2021

For Object-based Image Classification Anderson Level I classification scheme (Anderson, 1976) was used in this study. It utilizes a hierarchical LULC classification scheme with classes at Level I able to be mapped from medium resolution satellite imagery such as Landsat TM, whereas the extraction of information for level II, III and IV requires the use of high-, medium- and low-altitude aerial photographs, respectively (Corner, Dewan, and Chakma, 2014). Accordingly, five information classes were derived namely Water Body, Forest Land, Barren Land, Built Up and Crop Land. Choice of the classification scheme was guided by the objective of the research and the expected degree of accuracy. During image classification ECognition Developer 9.0 (Trimble Inc., Sunnyvale, CA, USA) was used to perform object-based image classification. At least 10 training samples representing each land-use/land-cover type were selected. Training samples were collected using high resolution Google Earth images. At the end, classifications at different levels were reclassified to form a unified classification output with already defined five LULC classes which was exported to ArcMap for better visualization.

Summary of Landsat Classification Area Statistics for 2001 and 2021 in Square Kilometers (km2) and Proportion of the Total Landscape (%)

Table 2: LULC extent of Mardi Khola watershed for 2001 and 2021

LULC Type	2001		2021	
	(km2)	(%)	(km2)	(%)
Barren Land	16.872	12	8.131	6
Built Up	2.537	2	8.068	6
Cropland	23.217	17	13.551	10
Forest	87.949	65	98.008	72
Water Body	5.545	4	8.360	6
Total	136.12	100	136.12	100

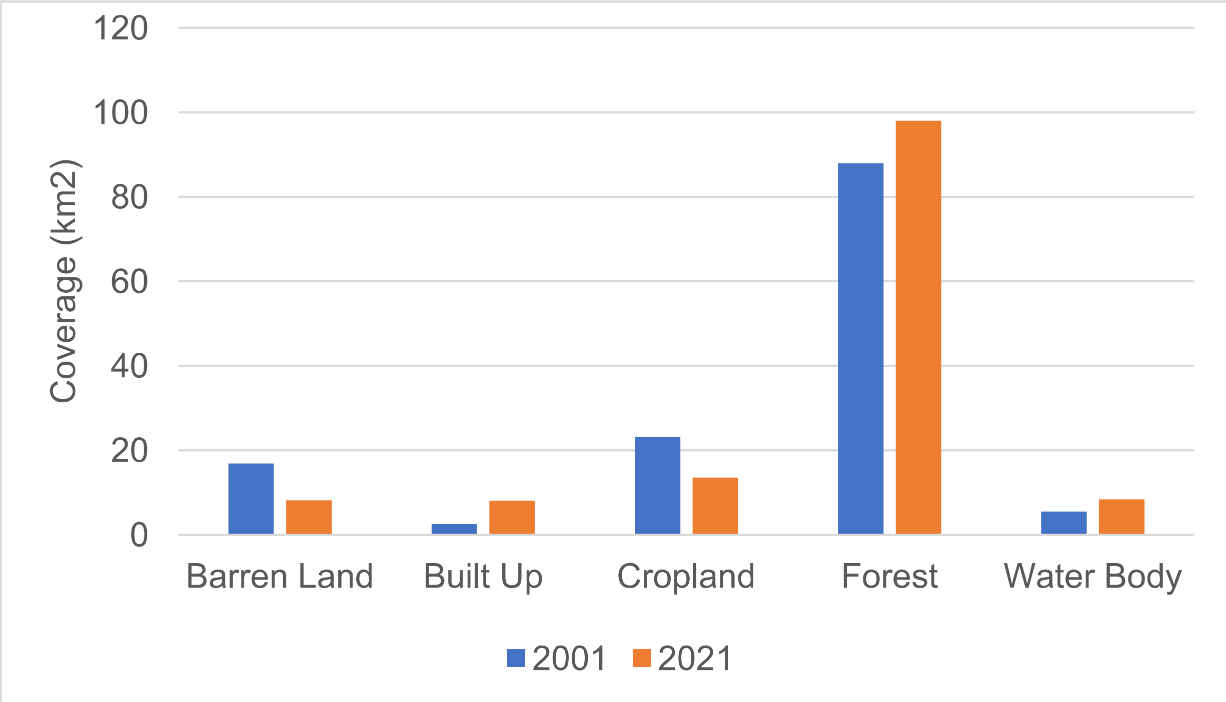

Figure 3: LULC statistics for 2001 and 2021

Accuracy assessment. The accuracy assessment in this study was conducted through a standard procedure described by (Congalton and Green, 2008). Due to lack of high resolution satellite data, we used Google Earth images from December 2001 and October 2021 as reference data for 2001 and 2021 respectively. In this study, a stratified random sampling scheme for selecting sample points of reference data for classification accuracy assessment was chosen with 141 sample points with at least 25 points per class were generated for each of the classified images. The sample points were then used to produce the error matrix, also called a confusion matrix. The accuracy parameters used to evaluate each product were (1) producer's accuracy, (2) user's accuracy, (3) overall accuracy, and (4) Kappa coefficients (Cohen, 1960).

The accuracy of overall classification was done using validation points generated from random sampling. Confusion matrix presents the overall classification accuracy of two classified maps of 2001 and 2021. Arc GIS 10.4 was used to calculate the accuracy of image classification. The overall accuracy for 2001 and 2021 was 91.48% and 93.61% respectively. Similarly, the kappa coefficients for year 2001 and 2021 were 0.89 and 0.92 respectively. The error matrix showing accuracy of LULC maps of different years are presented in below.

Table 3: Accuracy assessment matrix of LULC classification 2001

Accuracy Assessment Table (2001)						
Class	Water Body	Forest Land	Crop Land	Built Up Areas	Barren Land	Total User
Water Body	28	0	2	0	1	31
Forest Land	0	30	0	0	0	30
Crop Land	0	0	27	3	0	30
Built Up Areas	2	0	0	23	0	25
Barren Land	0	0	4	0	21	25
Total Producer	30	30	33	26	22	141
Overall Accuracy			91.48936	Kappa Coefficient		0.89

Class	User Accuracy	Producer Accuracy
Water Body	90.32258065	93.33333333
Forest Land	100	100
Crop Land	90	81.81818182
Built Up Areas	92	88.46153846
Barren Land	84	95.45454545

Table 4: Accuracy assessment matrix of LULC classification 2021

Accuracy Assessment Table (2021)						
Class	Water Body	Forest Land	Crop Land	Built Up Areas	Barren Land	Total User
Water Body	29	0	2	0	0	31
Forest Land	0	30	0	0	0	30
Crop Land	0	0	28	2	0	30
Built Up Areas	0	0	4	20	1	25
Barren Land	0	0	0	0	25	25
Total Producer	29	30	34	22	26	141
Overall Accuracy			93.61702	Kappa Coefficient		0.92

Class	User Accuracy	Producer Accuracy
Water Body	93.5483871	100
Forest Land	100	100
Crop Land	93.33333333	82.35294118
Built Up Areas	80	90.90909091
Barren Land	100	96.15384615

LULC change analysis. The classified LULC data was smoothed by using a 3-by-3 majority filter in ENVI 5.3 which removes the isolated pixels and reduces the *salt-and-pepper* effect (Lillesand and Kiefer, 1994). A pixel based change detection called post-classification comparison (PCC) method, where images from different dates are classified independently and then compared pixel-by-pixel or segment-by-segment using map overlays (P. Coppin, Jonckheere, Nackaerts, Muys, and Lambin, 2004) was selected to determine changes in land cover between period 2001 to 2021.

The percentage LULC changes were calculated using the following equation:

$$\text{Percentage LULC change} = \frac{\text{Area}_{\text{final year}} - \text{Area}_{\text{initial year}}}{\text{Area}_{\text{initial year}}} \times 100 \ \#$$

Where, Area is extent (in hectare/km^2) of each LULC type. Positive values suggest an increase whereas negative values imply a decrease in extent.

The area statistics of various land-use/land-cover types for Mardi Khola watershed are summarized for each year (Table 5). The forest, which is the dominant vegetation type, occupied 65% of the watershed area in 2001 increased to 72% in 2021. On the other hand, the area under agriculture use decreased to 10% of the watershed in 2021 from 17% in 2001. Another land cover that declined in 2021 compared to 2001 was barren land, which declined from 12% coverage in 2001 to 6% coverage in 2021. Coverage of built-up and water body land cover types, however, increased. Built-up land increased from 2% coverage in 2001 to 6% coverage in 2021, which is a 3 fold increase. Coverage of water bodies also increased from 4% in 2001 to 6% in 2021, a 50% increase in a period of 2 decades.

Table 5: Change statistics (in km2 and %) of LULC in Mardi Khola watershed between 2001 to 2021

LULC Type	**2001–2021**	
	(km2)	**(%)**
Barren Land	-8.741	-52
Built Up	5.530	218
Cropland	-9.666	-42
Forest	10.060	11
Water Body	2.815	51
Total	36.812	-27

Table 6 shows the conversion of the land-use/land-cover in the form of a change matrix for 2001-2021. In the table, unchanged pixels are located along the major diagonal of the matrix. 36.8 km2 of the total study area landscape changed between 2001 and 2021, which is approximately 27% of the Mardi Khola watershed. A total of 21 possible land-use and land-cover change trajectories were observed for 2001 and 2021 (off-diagonal values). Many of these changes are a direct result of marginal agricultural land abandonment in the hills and areas of higher slopes, agricultural land expansion in the valley and areas of gentle slopes, forest expansion due to community-based forest management activities, and infrastructure expansion in the hills including road network expansion.

Table 6: Land cover conversion matrix of Mardi Khola watershed for 2001-2021

2021								Grand Total 2001	**Area Lost**
	Land Class	Barren Land	Built-up Area	Crop Land	Forest	Water Body			
2001	Barren Land	7.915	0.249	2.548	5.488	0.646	16.846	**8.931**
	Built-up Area	0.001	0.904	0.700	0.529	0.400	2.535	**1.63**
	Crop Land	0.005	5.544	6.013	8.003	3.635	23.201	**17.187**
	Forest	0.120	0.834	2.307	82.98	1.677	87.926	**4.938**
	Water Body	0.081	0.533	1.971	0.967	1.992	5.543	**3.552**
	Grand Total 2021	8.122	8.064	13.539	97.97	8.351	136.051	
	Area Gained	**0.207**	**7.16**	**7.526**	**14.987**	**6.358**		**36.8**

During the study period (2001-2021), crop land cover class lost the highest area (17.19 km2) while forest cover class gained the most area (14.99 km2), which represents the typical situation in any mid-hill watershed of Nepal where migration has led to agriculture land abandonment and forest establishment in previously cropped lands.

Clean drinking water accessibility in Mardi watershed. Although Nepal generally enjoys abundant water resources, the people, particularly in the hills and mountains suffer from limited availability and accessibility to the resource for various reasons. Drinkable water comes from water springs and must be transported through pipes to settlements by gravity flow/lifting systems. Geographically, access to water supply is a considerable challenge as the unit cost of reaching remote and mountainous is high due to the difficulty in installing and managing infrastructure in such terrain. It is exacerbated by highly scattered nature of settlements. Houses that are part of smaller settlements far away from larger settlements are generally left out due to high costs of reaching them. For such households, a time-consuming trek is required to reach the nearest water source. Furthermore, as a result of climate and land-use changes, the water discharge from a number of springs in the region is on decline, creating not only a situation of water scarcity for communities, but also discouraging further investment in water supply and sanitation in the region. In Mardi Khola watershed, however, the situation was found remarkable, contrast to many hilly regions of the country. A vast majority of the respondents (93%) had access to clean drinking water, of which 96% came from piped water supply systems and the rest came from safer sources such as protected springs (4%). Those without access to clean drinking water (7%) relied mostly on un-protected springs and rivers to satisfy their drinking water need.

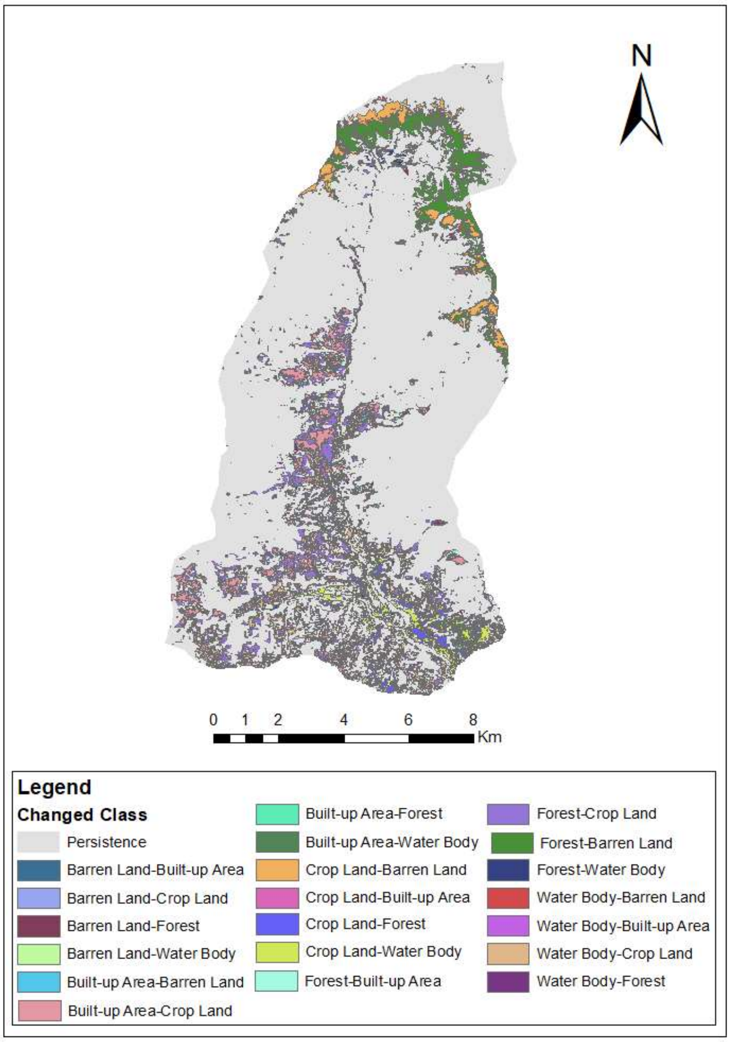

Figure 4: Spatial pattern of LULC change in Mardi Khola watershed between 2001 and 2021

A few households also used rain water harvesting techniques to harvest drinking water in the rainy season and later use it for drinking purposes. A majority of the households without access to clean drinking (75%) water responded to have treated the water before drinking. Water treatment method was mostly boiling, however, a few households used techniques such as filtering and chlorination to purify the water. Occasionally, people caught water-borne diseases, even despite drinking treated water. However, no severe illness leading to hospitalization was reported by the respondents.

Impacts of LULC dynamics in water resource availability. It is widely reported that water resources in the hills of Nepal have undergone changes in the past few decades, primarily due to human stressors such as unplanned development and destruction of natural resources. Climate change has provided additional pressure to the water resources in the country. Mardi Khola watershed was no exception, as the local people have witnessed changes in the resource base and landscape. As a result, water resource availability and quality in the area have undergone substantial changes. When asked about changes in the availability of water resources in the past few decades (or the length of time of their stay in the locality), 61% responded a decreased availability of water resources such as springs, rivers, ponds, etc. 27% responded no change in the availability while the rest (12%) responded an increased availability.

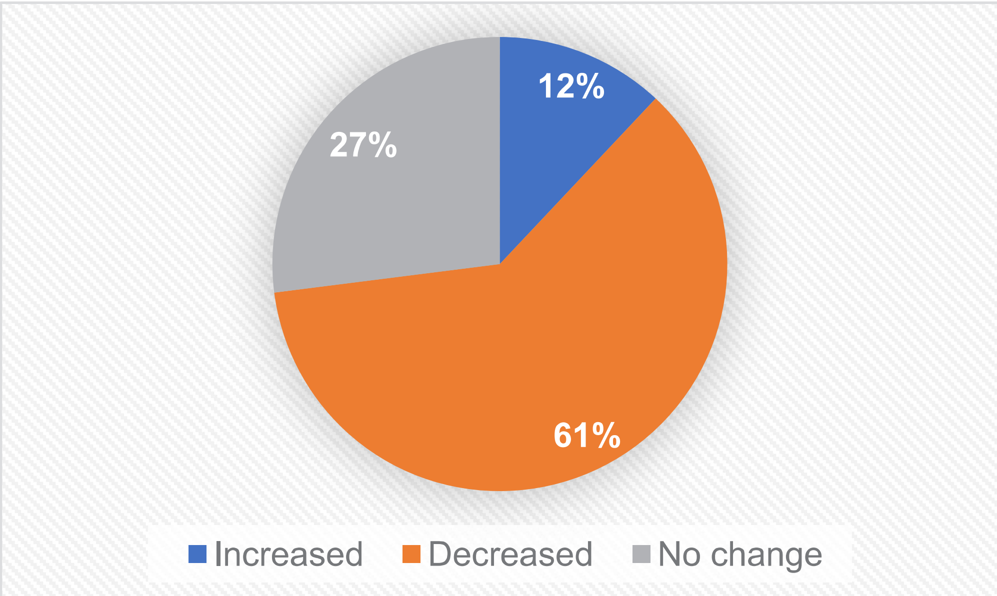

Figure 5: Change in water resource availability as perceived by respondents

When asked about the perceived reason for the decrease in the availability of water resources, 34% pointed out to the unplanned development of road and infrastructure as the primary culprit, while 29% responded pressure from increased population growth as the main driver for the decreased availability. Likewise, 18% pointed out to frequent landslide and soil erosion for the decrease and 11% responded forest clearance for various reason as the main reason. While the rest pointed out to a various reasons including unplanned tourism activities (4%), climate variability (2%), agriculture intensification (1%) and pollution (1%).

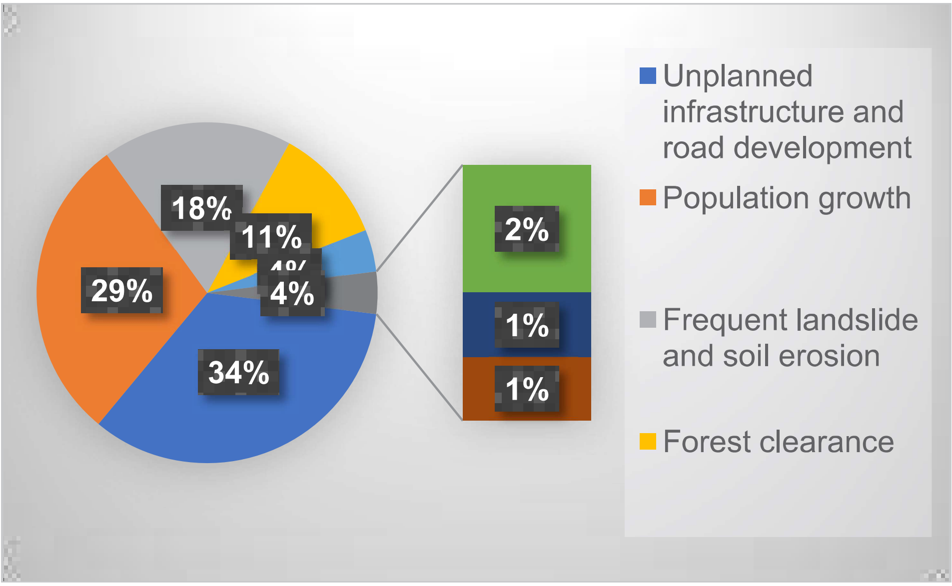

Figure 6: Perceived reason for decreased water availability

All these agents have changed Mardi Khola watershed, including the Mardi Khola river itself. The changes in mardi river, as perceived by the respondents were increased pollution (94%), depleted fish and other aquatic resources (79%), increased flood hazards (64%), decreased water flow during the winter/dry season (55%), increased conflicts related to water apportion (27%), increased quarrying of Mardi river's sand and stone (19%) and permanent changes in river watercourse (2%).

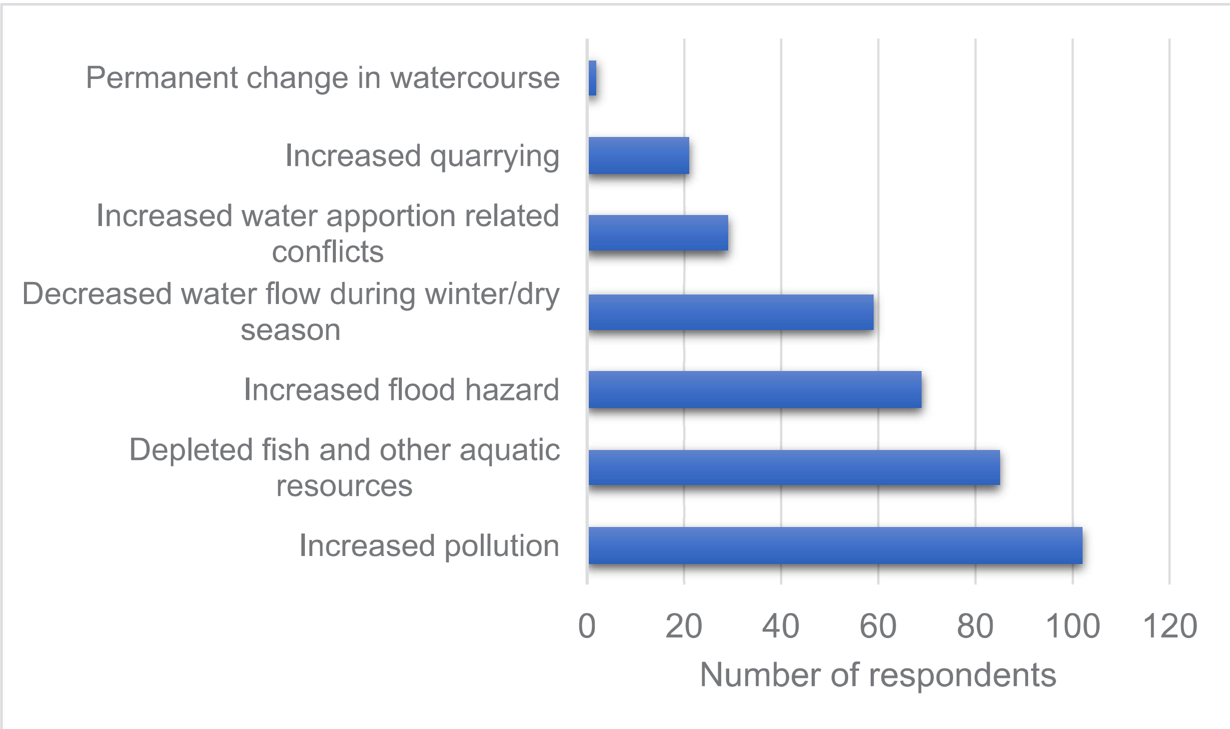

Figure 7: Perceived impact on Mardi watershed

Scientific land-use plan for Mardi Khola watershed. The findings reveal that there are various spatio-temporal changes, change agents and issues and challenges in the watershed leading to unsustainability. However, explicit, evidence-based watershed management plan accompanied by a science-based land-use plan can address the issues and contribute to sustainable management of the watershed when appropriately implemented.

The proposed land use plan and accompanying map (Figure 8) mostly follows the Nepal Land Use Policy (2015) regarding limits and protection of Land and Land Resources (LLRs) and optimum use and effective management thereto. The major objective to prepare a land use plan and map is to define the best use of land without creating environmental and socioeconomic issues to the residents of the watershed

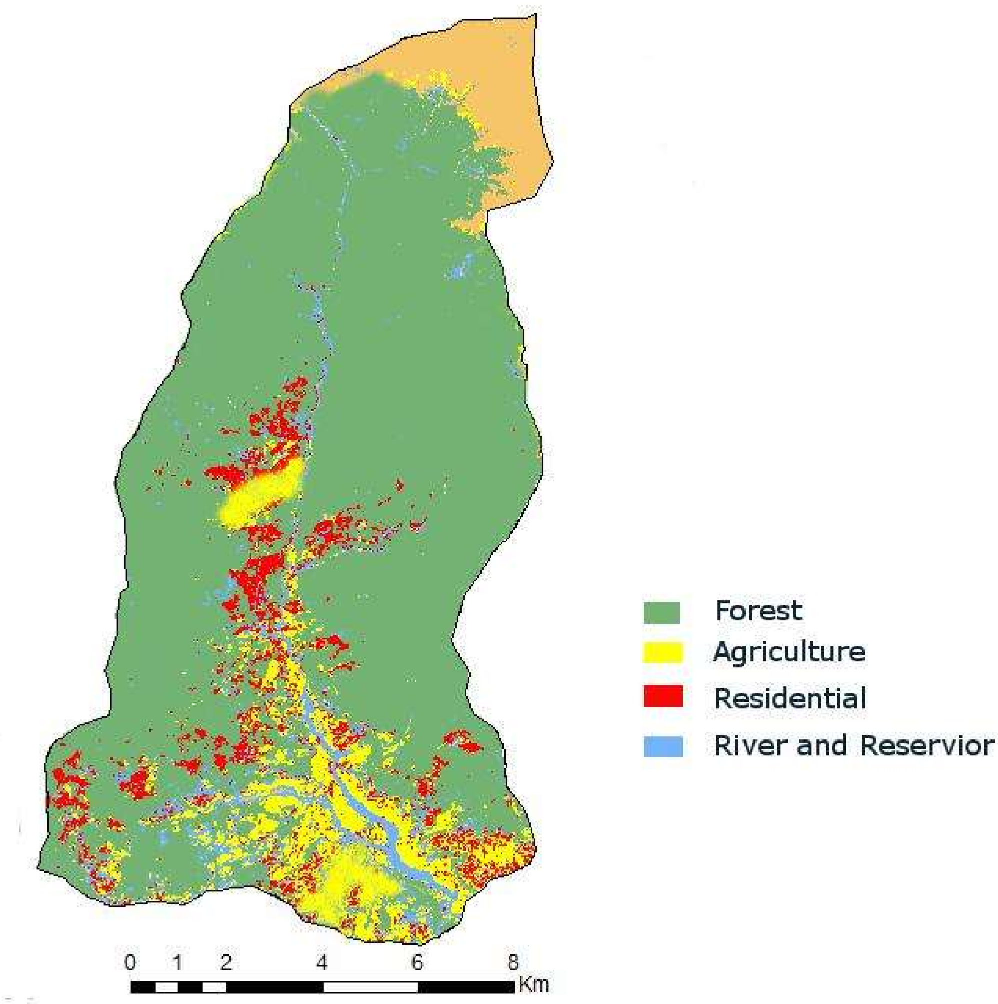

Figure 8: Land-use Plan for Mardi Khola Watershed

Discussion

Scientific planning and successful implementation of water management strategies based on the watershed's specific characteristics are required to sensibly allocate, use, and safeguard the water resource in a watershed (Guo, 2014). Geographic information science theories and geospatial technologies including GIS, remote sensing, and global positioning systems (GPS) have matured to enable the digital spatial representation of features and processes considered essential in a wide array of social and natural science applications. Moreover, the emergence of geocomputation, or "the art and science of solving complex spatial problems using computers" (Griffith et al., 2015) provides a computational structure for advanced spatial analysis and modeling.

The extreme weather phenomena and global warming noted in recent years has demonstrated the necessity for effective flood risk management models. According to this paradigm, a considerable shift has been observed from structural defense against floods to a more comprehensive approach, including appropriate land use, agricultural and forest practices (Alexakis et al., 2013; Michaelides et al., 2009). Land cover changes may be used to describe the dynamics of urban settlements and vegetation patterns as important indicators of urban ecological environments (Yingxin & Linlin, 2010). Satellite remote sensing provides an excellent source of data from which updated land use / land cover (LULC) changes can be extracted and analyzed in an efficient way. In addition, effective monitoring and simulating of the urban sprawl phenomenon and its effects on land-use patterns and hydrological processes within the spatial limits of a watershed are essential for effective land-use and water resource planning and management (Li et al., 2010). Several techniques have been reported in order to improve classification results in terms of land use discrimination and accuracy of resulting classes in the processing of remotely sensed data (Agapiou et al., 2011). As a result of Very High Resolution (VHR) imagery, real world objects that were previously represented by very few pixels are now represented by many pixels. Thus, techniques that take into account the spatial properties of an image region need to be developed and applied.

Land use and land cover (LULC) classification for years 2001 and 2021 revealed that forests and cropland were the dominant land use types in the watershed. Forests covered 65% of the watershed area in 2001 while 72% in 2021. Likewise, agriculture covered 17% of the watershed area in 2001 while 10% in 2021. Other land use types in the area were barren land which also includes area covered under permanent snow, built-up area which includes both residential and industrial areas and water body including rivers, lakes, ponds, etc. The overall classification accuracy for 2001 and 2021 were 91.48% and 93.61% respectively and the kappa coefficients were 0.89 and 0.92 respectively. Accuracy results indicate a high accuracy and success in LULC classification using object-based classification schemes. LULC change analysis revealed the dynamic nature of the watershed where some land cover classes gained in coverage between 2001 and 2021 while other land over classes lost area in the same period. For instance, forest, built-up area and water bodies increased in area between 2001 and 2021 while the area under agricultural land and barren land declined during the same period. LULC conversion matrix (change matrix) uncovered that 36.8 km2 of the total study area landscape changed between 2001 and 2021, which is approximately 27% area of the Mardi Khola watershed. A total of 21 possible land-use and land-cover change trajectories were observed for 2001 and 2021 many of which were a direct result of marginal agricultural land abandonment in the hills and areas of higher slopes, agricultural land expansion in the valley and areas of gentle slopes, forest expansion due to community-based forest management activities, and infrastructure expansion in the hills including road network expansion.

Researcher claim that land cover change in watershed is always caused by multiple interacting factors originating from different levels of organization of the coupled human- environment systems, and these factors vary in time and space according to specific human-environment conditions (Lambin et al., 2003). The definition of drivers of land use and land cover change is often not clear. In scientific literature, there is a common separation of proximate/direct or underlying/indirect drivers. Proximate or direct drivers are human activities that directly alter the land cover in an area/watershed and thus constitute proximate sources of change. Proximate/direct drivers are associated with activities which directly interact with and modify the physical environment, such as urbanization and agricultural expansion. They generally operate at the local level (individual farms, house- holds, or communities). The proximate drivers of land cover change include unsustainable water extraction, deforestation, and agriculture and pasture expansion, infrastructure development and urbanization. All these have had far-reaching consequences in terms of spatial extent, ecosystem impacts, carbon dynamics, climate change, food production and local livelihoods in a watershed. Underpinning such proximate drivers are the fundamental sociopolitical, economic, cultural and biophysical forces that drive land cover change, including population growth, agriculture, water, and forest development policies, and the priorities of local land management institutions

(Geist & Lambin, 2002). The proximate/indirect drivers therefore influence how individuals or groups interact with, and change the land use and land cover 81 (Wisner et al., 2004). They operate more diffusely (i.e., from a distance), often by altering one or more proximate causes (Lambin et al., 2003). Underlying drivers are generally more complex as they are built into the human-environment system. They may originate from the regional (districts, provinces, or country) or even global levels, with complex interplays between levels of organization (Lambin et al., 2003). Eventually, underlying drivers are connected to proximate causes and actors at local level executing the actual change process (Geist & Lambin, 2001).

Located in western Nepal near Pokhara city, Mardi Khola watershed was a notable example of degradation in the middle-mountain region, where forest lands were overgrazed and degraded and stripped of trees for fodder and firewood. Household questionnaire survey was used to determine land use, water availability and to elucidate other relevant watershed related information from the community for an effective management of Mardi Khola watershed. A standardized questionnaire (open and close ended) was used to elicit the required information about water access, availability and impact of such changes on Mardi Khola watershed. The questionnaire survey from the field was sorted, cleaned and entered into SPSS for further analysis. Results were shown using appropriate graphics and tables. Interviews with key informants was carried out to elicit information on various matters of the watershed based on the expertise and experience, as well as to substantiate information obtained from household questionnaire survey.

In Mardi Khola watershed, a vast majority of the households (93%) had access to clean drinking water, of which 96% came from piped water supply systems and the rest came from safer sources such as protected springs (4%). Those without access to clean drinking water (7%) relied mostly on un-protected springs and rivers to satisfy their drinking water need, and those who rely on unprotected sources, three quarters (75%) treated the water before drinking. Water treatment method was mostly boiling; however, a few households used techniques such as filtering and chlorination to purify the water. It was only occasionally that people caught water-borne diseases, even with drinking treated water. Further, 61% of the households have perceived a decreased availability of water resources such as springs, rivers, ponds, etc in Mardi Khola watershed. When inquired about the perceived reason for the decrease in the availability of water resources, a quarter of the households pointed out to unplanned development of road and infrastructure as the primary culprit, while another quarter perceived pressure from increased population growth as the main driver for the decreased availability. Frequent landslide and soil erosion, forest clearance for various reason, unplanned tourism activities, climate variability, agriculture intensification, and pollution were the other perceived reason for the decreased availability. All these agents have changed Mardi Khola watershed, including the Mardi River itself. The changes in Mardi river, as perceived by the locals, were increased pollution, depleted fish and other aquatic resources, increased flood hazards, decreased water flow during the winter/dry season, increased conflicts related to water apportion, increased quarrying of Mardi river's sand and stone, permanent changes in river watercourse, among others.

Conclusion

Scientific planning and successful implementation of water management strategies based on the watershed's specific characteristics are required to sensibly allocate, use, and safeguard the water resource in a watershed (Guo, 2014). Watershed management thus comprises the sensible use of land and water resources for maximum productivity while posing the least amount of risk to natural and human resources. This study applies remote sensing and GIS techniques as well the traditional participatory rural appraisal (PRA) techniques to analyze temporal LULC changes, to identify water accessibility and possible negative impacts watershed is facing.

Forest, built-up area and water bodies is found to be increased in area between 2001 and 2021.For which possible reason can be forest expansion is due to community-based forest management activities; infrastructure like road construction in the hills, climate change like issue is causing the Himalayan glaciers to melt and rise in water level. Whereas, agricultural land and barren land (area covered under permanent snow)declined during the same period can be due to people tending to go abroad for work and study opportunities, urbanization causing people to less motivate in agriculture profession, marginal agricultural land abandonment in the hills and areas of higher slopes snow melting due to global warming. LULC conversion matrix (change matrix) uncovered that 36.8 km2 of the total study area landscape changed between 2001 and 2021, which is approximately 27% area of the Mardi Khola watershed. In Mardi Khola watershed, a vast majority of the households (93%) had access to clean drinking water, of which 96% came from piped water supply systems and the rest came from safer sources such as protected springs (4%). Those without access to clean drinking water (7%) relied mostly on un-protected springs and rivers to satisfy their drinking water need, and those who rely on unprotected sources, three quarters (75%) treated the water before drinking

Further, 61% of the households have perceived a decreased availability of water resources such as springs, rivers, ponds, wetlands like sources in Mardi Khola watershed. When inquired about the perceived reason for the decrease in the availability of water resources, a quarter of the households pointed out to unplanned development of road and infrastructure as the primary culprit, while another quarter perceived pressure from increased population growth as the main driver for the decreased availability. Frequent landslide and soil erosion, forest clearance for various reason, unplanned tourism activities, climate variability, agriculture intensification, and pollution were the other perceived reason for the decreased availability. All these agents have changed Mardi Khola watershed, including the Mardi River itself. The changes in Mardi river, as perceived by the locals, were increased pollution, depleted fish and other aquatic resources, increased flood hazards, decreased water flow during the winter/dry season, increased conflicts related to water apportion, increased quarrying of Mardi river's sand and stone, permanent changes in river watercourse, among others. The trends of changes in Mardi Khola watershed can be representative of many middle-mountain watersheds of Nepal that harbor significant population and economic growth, and an increasing pace of urban expansion. Findings of this study will provide valuable information for designing a sustainable management strategy, not only for Mardi Khola watershed, but also for similar watersheds in the middle-mountains of Nepal. Also it signifies the importance to manage our watershed like resources with proper scientific landuse planning system. All these scattered watershed information needs to be systematically arranged and allocated in a proper watershed information system at national level.

References

Anderson, J. R. (1976). A land use and land cover classification system for use with remote sensor data (Vol. 964). US Government Printing Office.

Awasthi, K. D., Sitaula, B. K., Singh, B. R., &Bajacharaya, R. M. (2002). Land-use change in two Nepalese watersheds: GIS and geomorphometric analysis. Land Degradation & Development, 13(6), 495–513. https://doi.org/10.1002/ldr.538

Baatz, M., & Schape, A. (1999). Multiresolution segmentation—An optimization approach for high quality multi-scale image segmentation. In J. Strobl & StroblBlaschke (Eds.), Angewandte geographische Informationsverarbeitung XI: Beiträge zum AGIT-Symposium (pp. 12–23). Wichmann.

Bahadur, K. (2009). Improving Landsat and IRS image classification: Evaluation of unsupervised and supervised classification through band ratios and DEM in a mountainous landscape in Nepal. Remote Sensing, 1(4), 1257–1272.

Basnet, K., Paudel, R., &Sherchan, B. (2019). Analysis of Watersheds in Gandaki Province, Nepal Using QGIS. 1, 16–28. https://doi.org/10.3126/tj.v1i1.27583

Bharatkar, P. S., & Patel, R. (2013). Approach to Accuracy Assessment tor RS Image Classification Techniques.

Blaschke, T. (2010). Object based image analysis for remote sensing. ISPRS Journal of Photogrammetry and Remote Sensing, 65(1), 2–16.

Bruce, C. M., & Hilbert, D. W. (2006). Pre-processing methodology for application to Landsat TM/ETM+ imagery of the wet tropics. Rainforest CRC.

Chander, G., Markham, B. L., &Helder, D. L. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. Remote Sensing of Environment, 113(5), 893–903.

Coppin, P., Jonckheere, I., Nackaerts, K., Muys, B., &Lambin, E. (2004). Review ArticleDigital change detection methods in ecosystem monitoring: A review. International Journal of Remote Sensing, 25(9), 1565–1596.

Coppin, P. R., & Bauer, M. E. (1996). Digital change detection in forest ecosystems with remote sensing imagery. Remote Sensing Reviews, 13(3–4), 207–234.

Corner, R. J., Dewan, A. M., &Chakma, S. (2014). Monitoring and prediction of land-use and land-cover (LULC) change. In Dhaka megacity (pp. 75–97). Springer.

Gautam, P. (2010). Applying Ecosystem Approach to Integrated Watershed Management: A Case Study from Melamchi Watershed Central Nepal. LAP LAMBERT Academic Publishing.

Paudel, G. S., &Thapa, G. B. (2004). Impact of social, institutional and ecological factors on land management practices in mountain watersheds of Nepal. Applied Geography, 24(1), 35–55. https://doi.org/10.1016/j.apgeog.2003.08.011

Shrestha, B., Ginneken, P., &Sthapit, K. (1983). Watershed condition of the districts of Nepal. Mininstry of Forest and Soil Conservation, Department of Soil Conservation and Watershed Management (DSCWM).