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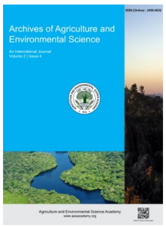

ORIGINAL RESEARCH ARTICLE

Assessment of forest cover change, key drivers of change and perception of locals in Birendranagar Municipality, Surkhet District, Nepal

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ABSTRACT

Land use and land cover change has an immense impact on the global environment and ecosystem and is mostly connected with human activities such as conversion of forest into agricultural land and settlements. Forests are changing globally in quantity and quality, and in both increasing and decreasing trends. For the Birendra Nagar Municipality, this study evaluated LULC dynamics, the conversion of forest cover from 2000 to 2020, as well as community perceptions on forest cover change, its drivers. Landsat images of 2000 and 2020 were used for LULC dynamics and for forest cover change detection Using software GIS 10.8. Questionnaire survey, key informant survey, field observation and secondary data were acquired from journal articles, reports, District Forest office, books, and various other sources to find out drivers of forest cover change and perception of locals. It was found that 1146 ha of forest area, 280.53 ha of water bodies, 752.62 ha of barren land were lost between 2000 and 2020. However, 1147.74 ha of settlement area and 1032.40 ha of agricultural land was gained.Net forest cover decreased overall by 4.67%, however, some areas within the municipality experienced an increase in forest cover namely Ward 11 and ward 16 of Municipality shows Highest positive and Negative Forest cover change in terms of Area. Expansion of agriculture land and settlements with the encroachment of forest area, haphazard infrastructure development, illegal timber harvesting and low regeneration capacity of land responsible for the reduction of forest, along with Community forestry approach, plantations programs, promotion of agroforestry practices, fuel transition were responsible drivers for improvements of forest cover. Water cycle disruption, Increases Natural hazard, Temperature rises, shortage of wood for fuel, extinction of indigenous species were the most perceived negative impacts of the forest cover reduction whereas income generation Activities, support biodiversity, easy to collect fuel wool and fodder and others including purifying air quality, increasing aesthetic beauty were the most perceived positive impacts of the forest cover improvement in the study area. Most of the locals have a holistic understanding of forest cover change. Strengthening forest protection, improving soil and water conservation structures, awareness creation, enrichment planting, Promote Alternate Energy Resources and Equitable benefit-sharing mechanism are possible solutions perceived by locals.

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INTRODUCTION

Generally, Forest is defined as a land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than

10%, or trees able to reach these thresholds in situ. It excludes land that is primarily used for agriculture or for urban lands. Forest resources are valuable to humans due to their economic and environmental value also forests have long been regarded as a national treasure; these forests provide such resources as grazing land for animals, wildlife habitat, water resources, tourism and outdoor recreation areas however, Climatological and anthropogenic factors are causing widespread changes in Earth's forest cover (Chaudhary *et al*., 2017). The term "cover" itself is used to refer to binary (presence vs. absence) and continuous (e.g., percent) scales of representation. Forest cover change processes include deforestation, afforestation, reforestation, forest degradation, and forest improvement (increase in canopy cover within forest). Human-induced land-use change is now a direct cause of changes in forest cover. Regeneration and reforestation efforts have become a primary priority worldwide to preserve a sustainable ecosystem (Tripathi *et al*., 2020). All nations agreed to the Global 2030 Agenda for Sustainable Development Goals (SDG 15). The monitoring of forests and the sustainable management of forest resources have been given priority by the 15th SDG, which seeks to "Protect, restore, and promote the use of terrestrial ecosystems, environmental conservation, and sustainable management of forest resource, combat desertification, and halt and reverse land degradation and biodiversity loss" (Rimal *et al*., 2021). Hence, identifying and detecting the forest cover change at different spatial and temporal scales could provide useful information for planning and sustainable management of forests. Change detection as defined by (Singh, 1989) is a process of identifying changes in the state of an object or phenomenon by observing images at different times. According to change detection studies seek to know, pattern of forest cover change, processes of forest cover change, and human response to forest cover change. Rapid land conversion in Nepal is a significant issue in both the Terai and the Mid-hill regions of the country. The United States Agency for International Development (USAID) reported 45.5% forest in 1978/1979, which reduced to 42.7% in 1978/1979. In the year 2015, forest area remained at 44.74%, as reported by forest resource assessment (DFRS, 2015). In between the period of 27 years between 1964 and 1991, Nepal lost 0.57 million hectares of forest area, out of which, 0.38 million hectares of forests has been converted into agricultural land and rest 0.19 million ha has been used for the various infrastructure development purpose such as roads, urban development, irrigation canals, and to establish educational institution. Forest loss during 1991 to 2011acounts for 32,000 hectares in Terai region at the rate of 0.42 percent (Karkee, 2007).

In context of Birendranagar, the inflow of migrants to Birendranagar city and encroachments upon forest areas accelerated after the eradication program of malaria regionally in 1958. Forests were felled to supply resources for the development of Indian railway line, and subsequent development activities widely provoked deforestation and forest degeneration. More recently, the protection of forest cover to safeguard environmental integrity and ecological functions such as hydrological flow and flood protection has been prioritized in v regions. The national government had launched various community-based forest management plans and President Chure-Terai conservation program to maintain current forest cover (Rijal *et al*., 2018). However, Information on forest status and trends in the study area are limited. Understanding the land cover change, especially forest change, is urgently needed to both understand past development and as a basis for landscape-level planning to guide future conservation and development management interventions. The present study was designed to fill this gap and provide the first detailed information about forest change in the landscape in the study area.

This study aimed to utilize different remote sensing and GIS data to quantify spatial and temporal patterns of forest cover change in the Birendranager Municipality of Surkhet district, Nepal and to map and compare different LULC. Furthermore, this study aimed to understand people's perceptions about these changes. The study area, Birendranagar municipality of Nepal's Surkhet district, is rapidly urbanizing due to high rates of migration. Like in any other city, better facilities such as employment, quality education, health, security, and entertainment are resulting in high immigration into Birendranagar which results in changes in forest cover. The major LULC changes observed were the rapid expansion of urban cover and the gradual decline of cultivated lands. It is a major socioeconomic hub and administrative center and an important gateway to Karnali zone, as well as a migrant-receiving area, mainly from the Dailekh district and the Karnali zone. Land use, land cover change of Birendranager has been haphazard due to deficient plans/ policies and weak implementation. With the increasing population the replacement of forest cover land to other land use like agriculture, settlement is expanding in Birendranagar. Conservation of natural parks, wildlife reverses as well as community forest are receiving a lot of attention these days despite having impotence roles in the urban microclimate protection and maintenance forest cover in urban area are not a priority. The problem of deforestation poses a serious environmental threat in Birendranagar. However, the rate and extent of forest cover change and their drivers remains unclear. The understanding of the local community regarding forest cover change, its drivers and possible solutions are scanty. The overarching objective of this study is to meticulously examine and record the alterations occurring in forest cover within the Birendranagar Municipality of Surkhet district over a span of two decades. In pursuit of this objective, several specific aims have been delineated. Firstly, the research endeavors to gauge the dynamics of Land Use Land Cover (LULC) from the years 2000 to 2020 within the Birendranagar Municipality employing geospatial methodologies. This entails a comprehensive assessment of the various land cover types and their transformations over time. Furthermore, the study aims to specifically pinpoint alterations in forest cover and delineate the different types of land cover changes affecting forests within the municipality. Additionally, a crucial aspect of the research involves the evaluation of the driving forces behind these changes in forest cover. By identifying and analyzing these factors, such as urbanization, agricultural expansion, and policy interventions, the study seeks to unravel the underlying mechanisms steering forest cover change. Finally, the research endeavors to delve into the perceptions of the local populace regarding forest cover changes. Understanding the viewpoints and attitudes of community members towards forest alterations is paramount for informing future conservation and management strategies, thereby ensuring their relevance and effectiveness within the local context. Through the accomplishment of these specific objectives, the study aims to furnish valuable insights into the dynamics of forest cover change in Birendranagar Municipality, facilitating informed decision-making and sustainable land management practices. Change detection, pivotal in resource management, involves identifying, characterizing, measuring, and assessing spatial patterns of changes over time (Singh, 1989; Macleod & Congalton, 1998). Remote sensing facilitates this process by detecting changes in land cover through alterations in radiance values. Accuracy assessment is crucial in remote sensing, ensuring reliable classification by comparing classified pixels with ground truth data (Congalton, 1991). It evaluates overall accuracy, user's accuracy, and producer's accuracy using error matrices and the kappa coefficient (Lillesand *et al.*, 2015). Overall accuracy reflects correctly classified pixels, user's accuracy measures errors of commission, and producer's accuracy assesses errors of omission. These assessments are essential for validating remote sensing data and informing decision-making in natural resource management.

MATERIALS AND METHODS

Study area

The study area, Birendranagar is the capital city of Karnali Province. It has Bheri river in the east and Karnali river in the west. It was known by the name of 'Dobhan Chaur' earlier. After the reclassification of local administrative units as mandated by the New Constitution of Nepal, 2015, the former Village Development Committees (VDCs) were consolidated as Birendranagar city. It is situated at the Longitude of range from 81° 35' to 81° 52' East and Latitude of range from 28° 3' to 28° 50' North in the Surkhet district of west Nepal. Birendranagar is named in honor of the late king Birendra, who planned and established it as the first planned town in Nepal. Birendranagar occupies an area of 245.85 km² with 16 wards having total population 154886 (male 75921, female 78965) (CBS, 2012). Map showing study area is given in Figure 1. Vegetation is of mixed type with tree species such as Sal (*Shorea robusta*), Sissoo (Dalbergia sissoo), Khair (*Acacia catechu*), Chirpine (*Pinus roxburghii*), Oak (*Quercus robur*), Chilaune (*Schima wallichii*), Utis (*Alnus nepalensis*), Saj (*Terminalia tomentosa*). The major non-timber species such as Parijat (*Nyctanthes arbor-tristis*), Amala (*Phyllanthus emblica*), Harro (*Termenalia chebula*), Kurilo (*Asparagus racemosus*), Barro (*Terminalia bellerica*), Bel (*Aegal marmelos*). This area contains both natural and reforested forest and various species of mammals. Local people also stated the presence of mammals, birds, reptiles, amphibians, fishes, insects etc. Animals such as Spotted Deer (*Axis axis*), Sambar (*Rusa unicolor*), Blue Bull (*Boselaphus tragocamelus*), Rhesus Monkeys (*Macaca mulatta*) are present in this area. Birds such as Peacock (*Pavo cristatus*), Grey Headed Fishing Eagle (*Ichthyophaga ichthyaetus*), Jungle Fowl (*Gallus gallus*), Pied Crested Cuckoo (*Clamator jacobinus*), Common Koel (*Eudynamys scolopaceus*) are recorded in this area. Reptiles, amphibians and fishes are also recorded in this area such as Python (*Python reticulatus)* and also various species of Varanus. The Birendranagar city spans Nepal's sub-Himalayan and lesser-Himalayan zones, which are characterized by a warm -moist temperate, hot-dry sub-tropical, warm-dry sub-tropical, and cool-moist temperate climates. Birendranagar city receives intensive monsoonal precipitation, mainly between June and September, causing flooding and soil erosion, including along river banks. The maximum and minimum temperatures ever recorded in Birendranagar were 41.8 °C and - 0.7 °C.

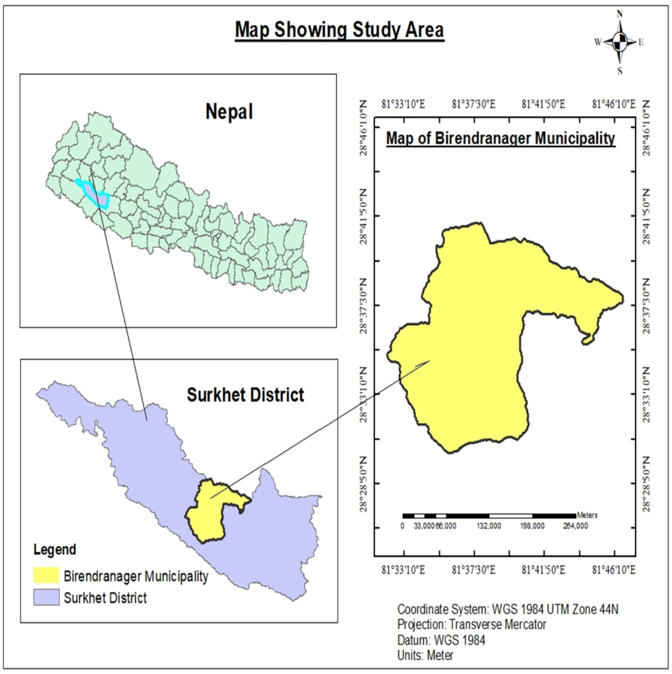

Figure 1. *Map of study area.*

Data collection

Satellite image: Two Landsat images were used for LULC classification of the study. Landsat OLI/TIRS image and Landsat ETM+ image was downloaded from the United States Geological Survey (USGS) official website (https://earthexplorer.usgs.gov/) free of cost. Priority was given to the data with less cloud cover and sensor noise. Details of the Image are given in Table 1.

GPS Coordinates: Enough GPS coordinates (training sample) using spatial reference system of WGS 84/UTM Zone 45 were collected in the field to train the maximum likelihood algorithm for paper supervised classification of 2020 Landsat image. Some of the collected GPS coordinates were also used for the ground truthing during accuracy assessment.

Table 1. Landsat image detail.

WRS (Path/Row)	Scene ID	Sensor	No. of Bands	Spatial Resolution	Acquired Date
Path=144 Row = 40	LE71440402000284SGS00	Enhanced Thematic Mapper	8	30*30m	2000-10-10
Path=144 Row = 40	LC81440402020299LGN00	Operational Land Imager and Infrared sensor	11	30*30m	2020-11-06

Google Earth: Google earth including its "show historical imagery" function was also used in assisting classification and accuracy assessment of Landsat images. It was used to download images of study areas and extract different features on the ground. It is also used to collect coordinates of the year 2000 for accuracy assessment.

Direct field observation: Direct field observation was carried out during the reconnaissance survey to get information about possible LULC classes and in which the study area can be classified. It was also done to speculate the location of areas having topographic shadows and cross-check the spatial information provided by the locals during the key-informant interview and informal conversations.

Social data collection

Household surveys: Household interviews were conducted using structured questionnaires consisting of both open and closed-ended questions. The content of this questionnaire included general information about the respondent's households, their dependency on forests for their livelihoods, level of awareness about forest use and management, perception on forest cover change, drivers of those changes and its impact in their life based on their experience. Ward 11 (Total household No. 2217) and 16 (Total Household No. 438) was selected as a sample plot Area to understand the major drivers of change and Perception of locals on forest cover change. As in ward number 11, greater positive forest cover change in terms of Area is evident among all the positive changes on the classified map, similarly to ward number 16, greater negative forest cover change was evident in terms of Area from year 2000 and 2020. The formula proposed by Cochran, 1977 was used to determine the sample household number. With confidence level (95% level) and precision level of 5% (Cochran, 1977) formula. Purposive Random Sampling was applied to a total of 71 households from Ward 11 and ward 16. Mostly households were taken as sample size as they were covered around the forested area and were directly linked with different forest activities. As often as possible, individuals aged at least above 30 and who have lived in the area for an extended period were considered as respondents.

Key informant interviews: A total of five key informants were selected. The key informants were AFO, DFO from district forest office likewise members from CFUGs and officers from Municipality office who have been living in the area for an extensive period. They were questioned related to land use change, forest cover change over a few decades, drivers of change, forest encroachment and population pressure on forest resources; it was conducted by raising open-ended questions to acquire both qualitative and quantitative data.

Focus-group discussions: A total of four Focus group discussion was carried out with inclusive participation with local people from different groups like Brahmin, Chhetri, Tamang, Dalit, Women groups, and CFUG's committee to gather important information on forest cover use and their condition in past and present scenario, factors responsible for those changes, assess environmental changes in recent years. Focus group discussion was conducted using a checklist to identify the important drivers of forest Cover Change and their perception regarding those changes. FGDs will be facilitated by the researcher. Each FGD will consist of 5–10 people.

Secondary data collection: Secondary data was collected from various sources such as demography, forest land use, land cover change, a market of forest products, government policy over different periods, and so on. This also includes publication in scientific journals, a thesis of various individuals in the field, operational forest management plan, the constitution of forest user groups, annual reports, harvest reports, minutes of meetings, other publications, and related websites of the concerned organizations such as Ministry of Industry, Tourism, and Forest, karnali, Division Forest Office, Surkhet, FECOFUN, Provincial Forest Directorial office and other government or nongovernment agencies working in the field such as ICIMOD, WWF Nepal.

Data processing and analysis

Computer software used for data processing and analysis

The processing and analysis of Landsat images and all the other GIS Data was done using ERDAS Imagine 15.1 and ArcMap 10.8, also all the numerical data was analyzed using MS Excel. MS Excel was also used to interpret the numerical results into bar-graphs, charts and tables.

Landsat image processing

Layer stacking: Layer stacking was done for combining multiple images into a single image. To have the same extent (number of rows and number of columns), which resample other bands which have different spatial resolution to the target resolution.

Image sub-setting: The study area was sub-set from the two Landsat images using the Area of Interest (AOI) file having the delineated study area; by the application of the subset tool in ERDAS IMAGINE 2015.

Table 2. Definitions of Classified LULC Classes (FAO, 2010).

S. No.	Classes	Definitions (FAO)
1.	Forest	Lands dominated by woody vegetation with a percent cover 50% and height exceeding 2 meters
2.	Water	Lake and rivers with clear water. Fishpond and other man-made ponds
3.	Baran land	Lands exposed soil, sand, or rocks and has less than 10% vegetated cover during any time of the year.
4.	Agriculture	broadleaf or grass-type crops that are harvested at the completion of the growing season, then remain idle until replanted. Neither the broadleaf or grass-type crops represent more than 60% of the cropland. At least 60% of the landscape must be covered with cropland.
5.	Settlement	Land covered by buildings and other man-made structures and activities.

Removing scanned line error: The Landsat 7 ETM+ image (2000) has Scanned line error. By using the focal analysis tool in ERDAS Imagine 2015 Scanned line errors have been removed, in which overlapping of the image have been done.

Image enhancement: Image enhancement was done to improve the visual interpretability of different objects or features in the scene. Image enhancement tools in ERDAS IMAGINE such as General Contrast, and Brightness were used.

Band combinations and indices: To assist in the image classification process, Landsat images were converted to false color composites using bands 5, 4, 3 for Landsat OLI/TIRS image and bands 4, 3, 2 for Landsat ETM+ image.

Image classification: First of all, signature files were created from the training samples for all the classes and Supervised Classification was performed using maximum likelihood classifiers in ERDAS IMAGINE 2015. The maximum likelihood classifier is one of the most popular methods of classification in remote sensing, in which a pixel with the maximum likelihood is classified into the corresponding class (Japan Association of Remote Sensing, 1996). The study area was classified into the following 5 LULC classes (Table 2).

Change analysis and quantification: The classified images were imported in ArcMap 10.3 and the area of each class was computed using zonal geometry as Table tool in Spatial Analyst Extension. Also, the LULC conversion table (Table showing quantity of one LULC converted into another 24 over two periods) was computed using the Tabulate Area tool in Spatial Analyst Extension. Similarly, LULC conversion map by was created using "Raster calculator" employing the following expression:

$$(\text{LULC map of 2000} \times 20) + \text{LULC Map of 2020}$$

Finally, Numerical analysis was performed in MS Excel to compute the LULC change and to interpret them in suitable form such as graphs, charts, tables etc.

Rate of change of LULC: The following formula was used to compute the rate of change of land cover and land use in the study area.

$$\text{Rate of change (\%)} = \left[\left(\frac{a}{b}\right)^{\frac{1}{n}} - 1\right] * 100$$

[FAO, 1995]

Where, a = base year data

b = End year data

n = no. of years

RESULTS AND DISCUSSION

Socio-economic background of the respondents

The socio-economic status of the respondents such as gender, age class, ethnic group and education status were collected during household surveys. Out of total respondents, 35 were male and 36 were female. Most respondents were Brahmin (39%) followed by 27% Chhetri, 20% Dalit and 14% other. Similarly, regarding the education level 55% of respondents were literate and 45% were illiterate. Likewise, 26% respondents were farmers, followed by 30 % wage labor, 12% service, 16% foreign employment, 16 % business.

Image classification

For the LULC classification, Landsat ETM+ and Landsat OLI_TIRS images were used for LULC classification. The result shows that the forest is the major land cover and Agriculture is the major land use in the area followed by bare land, settlement, and water bodies. The LULC status of the area in 2000 and 2020 as well as the forest cover changes and conversions in the area from 2000 to 2020 are given below.

Status of land use land cover in 2000

A total of five land use land cover classes were used for classified purposes. The land use land cover patterns included Agricultural land, Forest, Settlement, Waterbody, and baren land areas as shown in Table 3. Forest land had covered the most area 16313.70 ha which was 66.54% of the total study area which almost covered the periphery boundary of Brendranager Municipality. Similarly Barren land is the second most land cover type in the municipality located between forests mostly on the northern and southern parts of the municipality which covered 4061.44 ha, or 16.57% of the total area. Moreover, Agricultural land covered the area of 3143.74 ha which is 12.82% of total study area. Agriculture lands are mostly found in the central valley near urban areas, indicating people of the

Table 3. Details of land use land cover of Birendranager municipality in 2000.

	Year 2000	
Classes	**Area (Ha)**	**Coverage %**
Forest	16313.70	66.54
Agriculture	3143.74	12.82
Settlement	600.362	2.45
Baren Land	4061.44	16.57
Water Bodies	396.74	1.62
Total	24515.88	100

Table 4. Details of land use land cover of Birendranager municipality in 2020.

	Year 2020	
Classes	**Area (Ha)**	**Coverage %**
Forest	15167.70	61.87
Agriculture	4146.14	17.03
Settlement	1748	7.12
Barren Land	3308.82	13.49
Water Bodies	116.21	0.47
Total	24516.84	100

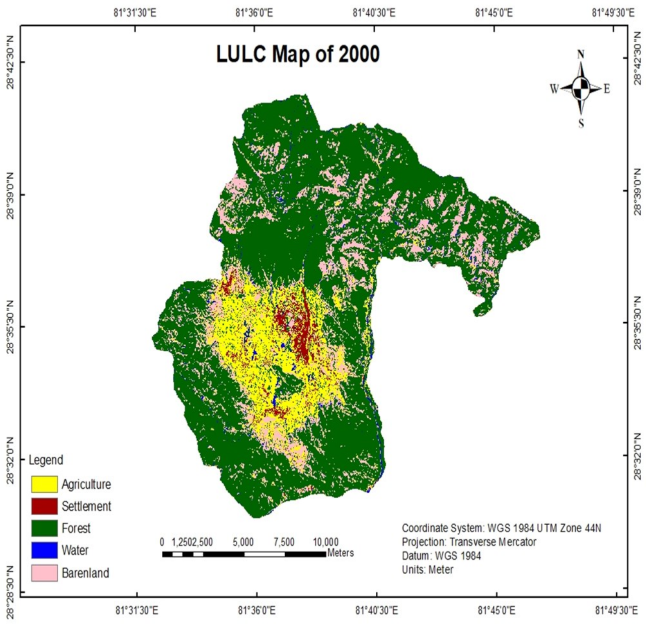

Figure 2. *Land use land cover map of 2000.*

urban area using the land for food output. Likewise, the Settlement area covered 600.26 ha (22.75%) of the total area. Settlement areas are mostly confined in the central part of the municipality. An area of 396.74 ha was occupied by waterbody which was 1.62% of the total area. Land use land cover map of 2000 is shown in Figure 2. Forest land dominated the land cover and very less area was observed for the waterbody over the study area in the year 2000. For the LULC classification, Landsat ETM+ and Landsat OLI_TIRS images were used for LULC classification. The result shows that the forest is the major land cover and Agriculture is the major land use in the area followed by bare land, settlement, and water bodies. The LULC status of the area in 2000 and 2020 as well as the forest cover changes and conversions in the area from 2000 to 2020 are given in Table 3.

Status of land use land cover in 2020

For the same land cover classes, various changes were observed in a twenty -year interval. Though the sequence of land cover remains the same, various changes in coverage can be observed. Here, Agricultural land covered 4176.14 ha which was 17.03% of the total study area. Similarly, the Forest area covered 15167.7 ha which was 61.87% of the total area and the Settlement area covered 1748 ha which was 7.12% of the total area. A very small area of 116.21 ha was occupied which was 0.47 % of the total area. Barren land covered 3308.82 ha area occupying 13.49% of the total study area. Land use land cover map of 2020 is shown in Figure 3. Compared to the result of 2000 there is a significant rise in the settlement and agriculture area. The rest of the land classes i.e., Baran land, Water Bodies and forest land were seen to be decreasing which is shown in Table 4.

Land use land cover change

Various LULC changes were observed during the twenty-year interval. Between 2000 and 2020, the forest cover decreased by 4.67%, the amount of water bodies decreased by 1.15%, and the area of barren land decreased by 3.08%, as well as agriculture and settlements increased by 4.21% and 4.67%, respectively and details are given in Table 5. Forest area present in each ward out of the total forest area of Birendranager and percentage change in forest area of each ward from 2000 to 2020. Despite the reduction in total forest cover area from 2000 to 2020, some parts of the study area show a positive change, such as Ward no. 1(16.78 ha), 2(71.67 ha), 9(69.46 ha), 10(36.07 ha) and 11(108.49 ha) whereas most of it shows a loss of forest cover, which is represented in Ward No 3 (49.83 ha), 4(86.5 ha), 5 (24.21 ha), 6(3.16 ha), 7(16.76 ha), 8 (15.72 ha), 12(54.02 ha), 13 (33orest cover change map was shown in .7.09 ha), 14(146.5 ha), 15(359.09 ha) and 16(345.56 ha) on the current Map of Birendranagar Municipality. Forest cover change map is shown in Figure 4.

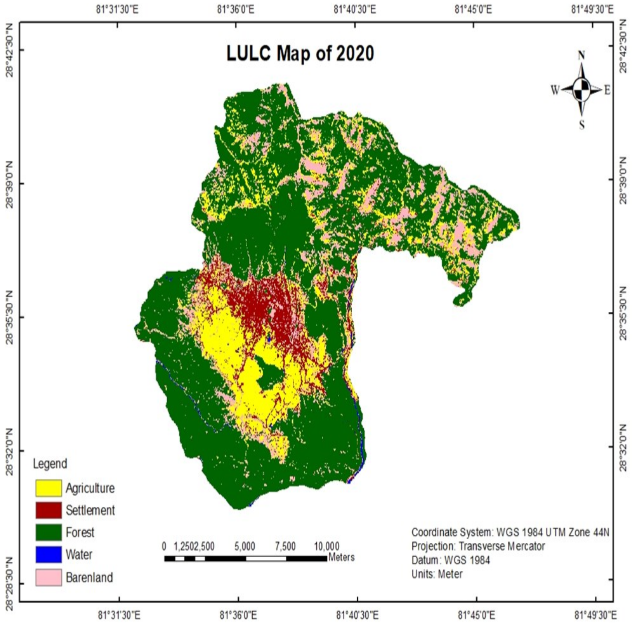

Figure 3. *Land use land cover map of 2020.*

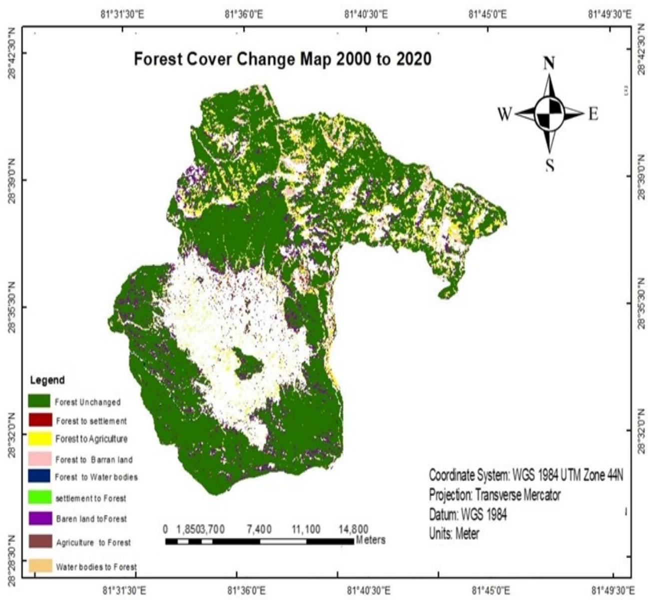

Figure 4. *Forest cover change map 2000 to 2020.*

Drivers of forest cover change

Encroachment for settlement and agriculture, illegal harvesting, infrastructural development, and low land regeneration capacity were identified as key drivers of forest cover reduction. Conversely, community forestry, plantation efforts, fuel transition, and agroforestry practices were recognized as drivers of forest cover improvement. Locals perceived negative impacts of forest cover reduction, including disruptions in the water cycle, increased natural hazards, and loss of indigenous species. In contrast, forest cover improvements were associated with income generation, biodiversity support, and improved access to fuelwood and fodder. Existing remedies and potential solutions included strengthening forest protection, soil and water conservation, awareness campaigns, enrichment planting, promoting alternate energy resources, and equitable benefit-sharing mechanisms. Measures such as community involvement, infrastructure development considerations, and sustainable land management practices are crucial for maintaining and enhancing forest cover in the study area.

The classification and analysis of multi-date Landsat images of 2000 and 2020 shows that Birendranagar has been experiencing rapid LULC change. The result shows that the Overall Forest area has decreased i.e., by 4.67% over the period of 20 years. The result shows that Agriculture land has increased by 4.21% from 2000 to 2020. According to my study, expansion of cropland was one of the major drivers of land cover change. Expansion of agricultural land at the cost of forest loss is a common phenomenon in the developing countries (Uddin *et al.*, 2015) The Result also shows that settlement has increased by 4.67% over the period of 20 years, thus the increment is mainly due to conversion of forest and agriculture land to settlements. According to the statements of the key Informants, forests were converted into agriculture land and settlements due to encroachment activities. Similar trend of conversion can also be seen in the other LULC change studies conducted in Nepal by various researchers such as (Gautam *et al.*, 2002). My study also shows Forest cover increase in some part of the study area due to CF management, plantation on barren lands, and forest conservation by forest users which was also observed by (Gautam *et al.*, 2004).

Increasing population, land encroachment for agriculture expansion and settlement, road infrastructure developments and low regeneration capacity of land have been identified as factors that accelerate drivers for negative forest cover change in the study area. Study conducted in Kenya namely: "Trends and drivers of forest cover change in the Cherangany hills forest ecosystem, western Kenya" also highlight drivers of forest cover reduction which include conversion of forests to croplands and grasslands, grazing, encroachment, illegal logging, firewood harvesting, charcoal production, forest fires, excisions, and climate change, while indirect drivers comprise population growth and institutional failure (Rotich & Ojwang, 2021) which is quite similar with driver of forest reduction in my study area. Erosion, lowland flooding, urbanization, and deforestation are major causes of forest degradation in the lowlands of Nepal (Rimal *et al.*, 2021). Increased demand for timber and building poles has led to illegal chainsaw logging of indigenous tree species. my findings are directly in line with previous findings by (Shrestha *et al.*, 2018), who report that illegal logging of forest in Nepal is among the leading causes of forest degradation. My studies show that increased population results in demand for more land for farming and settlement leading to encroachment into forested areas in Birendranager. That population growth exerts pressure on forests, agriculture land, and protected areas, leading to encroachment and eventually degradation. Changes in forest cover due to forest fires, illegal logging, soil degradation, and biodiversity loss have been considered as major drivers in several studies locally, regionally, and globally (Shrestha *et al.*, 2018, Rotich & Ojwang, 2021).

Community forestry approach, fuel wood transition, plantation

Table 5. LULC change between 2000 and 2020.

Name	Area in Ha		Area Change (ha)	Area in percentage		Change (%)
	2000	2020	2000 to 2020	2000	2020	2000 to 2020
Forest	16313.70	15167.70	-1146	66.54	61.87	-4.67
Agriculture	3143.74	4176.14	+1032.4	12.82	17.03	+4.21
Settlement	600.26	1748	+1147.74	2.45	7.12	+4.67
Barren land	4061.44	3308.82	-752.62	16.57	13.49	-3.08
Water bodies	396.74	116.21	-280.53	1.62	0.47	-1.15

program and agroforestry practices have been identified as factors that accelerate positive forest cover change Changes in the study area. Changes in forest policy have led to immense progress in the conservation and restoration of the nation's forests with the introduction of the CF program. Effective monitoring of the community forests by local user groups was one of the reasons for improved forest conditions (Gautam *et al*., 2004). The authors of key factors in the increase in forest cover (Chhetri *et al*., 2013) identified drivers like awareness through education, use of alternative energy resources, provision of incentives to local communities from different programs and projects, and, most importantly, local ownership. High level of participation of user group member on the forest protection activities which is quite like the drivers of forest improvement of my study also the rate of conversion of non-forest areas especially barren land into forests and the rate of improvement of degraded forest into healthy forest were found to be significantly higher in community-managed forests than other forest areas (Niraula *et al*., 2013) also found that improvements in forest cover in terms of forest area and forest density are more prevalent in community-managed forests than in forests managed by other types of regimes. As from the discussion with DFO, Birendranager now there are in total 75 Community Forest in Municipality and it was found that conservation activities conducted by the CF and other organizations played an effective role in regaining forest cover. Also decreased dependency on forest due to increased use of LP gas, electricity, and other alternative energy seems equally responsible for improvements of forest cover (Tripathi *et al*., 2020). Water cycle disruption, Increases Natural hazard, Temperature rises, shortage of wood for fuel, housing and agricultural implements and extinction of indigenous species were indicated as the direct impact of forest cover reduction in the studied area These findings complement that of Solomon *et al.* (2018) who considered drought , shortage of wood for fuel, housing and agricultural implements and honey bee reduction Soil erosion , aesthetic value reduction, flooding , water cycle disruption as the major direct impact of deforestation in Wujig Mahgo Waren Forest of Northern Ethiopia. Likewise, Income generation Activities, support biodiversity, easy to collect fuel wool and fodder and others including purifying air quality, increasing aesthetic beauty were indicated as the direct impact of forest cover improvement in the studied area. These findings are consistent with research by Tripathi *et al.* (2020) who report positive impact of forest cover change in Mid hills of Nepal.

LULC change dynamics of the study area revealed that overall forest cover has decreased from 2000 to 2020 but also shows improvement in some parts of study area. Although the community forestry program has a positive impact on the forest cover by reducing the forest loss, the other drivers of forest loss have been leading to the overall decline in forest area in Birendranager. Similar results also in Shrestha *et al.* (2018). i.e., Nepal lost almost 46,000 ha forest area while Nepal gained roughly 12,200 ha over 2001–2016. Therefore, to conserve forest areas in Nepal, the current policy can be continued and improved, if necessary, coupled with addressing the underlying cause of deforestation.

Conclusion

The study conducted in Birendranagar Municipality utilized satellite imagery, GIS, and socioeconomic data to analyze land use and forest cover changes over two decades. The findings revealed a gradual decline in forest cover, attributed to factors such as agricultural expansion, settlement growth, illegal logging, and forest fires. Conversely, efforts like community forestry initiatives, plantation programs, and reduced dependency on forest resources contributed to forest cover improvements. Respondents expressed varying perceptions of forest change, with some noting declines and others observing increases. Negative impacts of forest reduction, including disruptions in the water cycle and loss of biodiversity, were highlighted alongside positive outcomes like income generation and biodiversity support from forest cover improvements. Locals' awareness, such as strengthening forest protection, promoting soil and water conservation, raising awareness, and fostering equitable benefit -sharing mechanisms to sustainably manage forest cover and address associated challenges.

DECLARATION

Author contribution statement

Conceptualization: L.S.; Methodology: L.S.; Software and validation: R.D.; Formal analysis and investigation: L.S.; Resources: L.S.; Data curation: R.D.; Writing—original draft preparation: L.S.; Writing— L.S.; Visualization: L.S..; Supervision: L.S..; Funding acquisition: Y.Y. All authors have read and agreed to the published version of the manuscript.

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