Land use/ land cover changes in the Chitwan Annapurna Landscape, Nepal

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This study evaluates land use/cover changes in the Chitwan Annapurna Landscape, Nepal between 2000-2020 using satellite images. Spatial and temporal changes of land use/cover changes are quantified by using Landsat images. The images were classified into eight different classes and the accuracy assessment was performed by calculating actual accuracy, producer's accuracy, user's accuracy and kappa coefficient based on ground-truthing points for 2020 and google map and topographic maps for images of 2010 and 2000 respectively. The land cover analysis showed that the study area was composed of water bodies (1.97%), barren area (1.76%), grassland (1.73%), riverine forest (1.93%), sal forest (15.4%), cropland (28.13%), developed area (4.13%) and mixed forest (44.95%) and there were the synergic temporal changes in land cover from 2000 to 2020. The classification of the images of 2000, 2010 and 2020 had 81%, 81.6% and 84.77% overall accuracy respectively. Our study showed a clear scenario of spatio-temporal changes of land use/cover from 2000 to 2020. As reliable and recent data are lacking for the Chitwan Annapurna Landscape in Nepal, the present findings can be used as a baseline information for the development of proper management plans to protect wildlife habitats and forecasting possible future changes, if needed.

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Abstract

This study evaluates land use/cover changes in the Chitwan Annapurna Landscape, Nepal between 2000-2020 using satellite images. Spatial and temporal changes of land use/cover changes are quantified ~~by~~ using Landsat images. The images were classified into eight different classes and the accuracy assessment was performed by calculating actual accuracy, producer's accuracy, user's accuracy and kappa coefficient based on ground-truthing points for 2020 and google map and topographic maps for images of 2010 and 2000 respectively. The land cover analysis showed that the study area was composed of water bodies (1.97%), barren area (1.76%), grassland (1.73%), riverine forest (1.93%), sal forest (15.4%), cropland (28.13%), developed area (4.13%) and mixed forest (44.95%) and there were the synergic temporal changes in land cover from 2000 to 2020. The classification of the images of 2000, 2010 and 2020 had 81%, 81.6% and 84.77% overall accuracy respectively. Our study showed a clear scenario of spatio-temporal changes of land use/cover from 2000 to 2020. As reliable and recent data are lacking for the Chitwan Annapurna Landscape in Nepal, the present findings can be used as a baseline information for the development of proper management plans to protect wildlife habitats and forecasting possible future changes, if needed.

Keywords Accuracy assessment, Habitat change detection, Image classification, Landsat image, Remote sensing

Introduction

Land use/land cover changes (LULCC) are widely observed in the world as the result of increasing socio-economic necessities needed for ever increasing human population (Hassan et al. 2016; Reis 2008; Zhu et al. 2021). The LULCC leads to the loss of biodiversity (Petrou et al. 2015) and loss of vegetation cover (Halmy et al. 2020) as the result of habitat destruction (Reif & Theel 2017). It is, thus, important to know the extent of LULCC to find out the drivers and their exact impacts on ecological, physical and anthropogenic processes.

~~Satellite Remote Sensing (RS) and Geographic Information System (GIS) are the most common methods used for quantification, mapping and detection of patterns of LULCC as the information about landscape or environment are obtained from a distance without making physical contact (Rimal et al. 2019; Wang et al. 2020). Information obtained from remote sensing and GIS are accurate and reliable (Räsänen & Virtanen 2019; Rather et al. 2020; Thapa et al. 2021) as maps are processed by computer that uses repetitive data acquisition (Lu et al. 2004; Chen et al. 2005; Nuñez et al. 2008; Rahman et al. 2011). Other than finding out about LULCC, remote sensing is used in many fields, including wildlife monitoring (Stephenson 2019), habitat classifications (Agrillo et al. 2021; Nagendra et al. 2013), urban classification (Rimal et al. 2020; Wellmann et al. 2020; Zhang et al. 2020), land cover change detection such as forest extent, deforestation and urbanization (Lei et al. 2017; Wang et al. 2020; Zhang et al. 2019), wetland mappings (Lefebvre et al. 2019; Mahdavi et al. 2017), natural disaster assessments (Bhattarai & Kondoh 2017; Liu et al. 2018), etc~~.

Studies ~~focusing~~ on the LULCC in Nepal have focused ~~their studies~~ mainly on ~~the~~ urbanization patterns (Thapa & Murayama 2009; Wang et al. 2020), glacier fluctuations, outburst and landslides (Huggel et al. 2002; Rimal et al. 2019; Sharma et al. 2019), land cover change in and around the watershed and river systems (Lamsal et al. 2019; Paudyal et al. 2019; Rai et al. 2018) and land cover change in relation to conserve biodiversity in the protected areas (Chettri et al. 2013; Kafley et al. 2009; Thapa 2011). However, studies at landscape level land cover change ~~analysis~~ are not in high numbers and are mainly from the places where urbanization rate is very high (Chhetri et al. 2017; WWF 2013a; Zomer et al. 2001). Hence, this study ~~is aimed in classifying~~ the temporal and spatial pattern of land cover change in the Chitwan Annapurna Landscape (CHAL), central Nepal. ~~To achieve our goal, we used the images between 2000 to 2020 developed by google earth, topographic map developed by Department of Survey, Government of Nepal. Our analyses considered eight classes including three categories of forest (sal forest, riverine forest and mixed forest), grassland, cropland, barren land, developed area and water bodies).~~

Materials & Methods

Study area

The study area (the Chitwan Annapurna Landscape) connects two biologically important protected areas, the Chitwan National Park (CNP) in the south and the Annapurna Conservation Area (ACA) in the north. This landscape is rich in biodiversity, including three ~~Word Wildlife Fund (WWF)~~ Global 200 Ecoregions (Terai–duar Savanna and Grasslands, Himalayan Subtropical Forests, Alpine Shrubs and Meadows) (Wikramanayake et al. 2002) and two Ramsar sites (Beeshazari and associated lakes, Chitwan and Lake Clusters of Pokhara valley, Kaski)

(Bhuju et al. 2007; NLCDC 2020) (Fig. 1). This area is prime habitat for many ~~important~~ mammal species ~~such as tiger, rhinoceros, common leopard, sloth/Himalayan black bear, sambar, chital, hog deer, Himalayan goral~~, birds, herpetofauna, fish and many other micros and macroinvertebrates (Bhuju et al. 2007; WWF 2013b). The study area covers Chitwan (around Barandabhar Corridor and surrounding areas), Tanahun (Seti River basin), Kaski and some parts of Syanja and Parbat districts (Panchase and Annapurna Conservation Area) with an area of 2749.48 km^2. ~~This area is inhabited by different ethnic groups (23 ethnic groups in Chitwan, 26 ethnic groups in Tanahun, 12 ethnic groups in Kaski) (CBS 2012~~). The altitude of this study area ~~is varied~~ from 150m to 3300m. ~~The climatic variation changes with changing the altitude.~~ The lowland of this region has tropical and subtropical type of climate, whereas mid-hills have temperate type of climate and the upper mountain region have subalpine type of climate.

~~Methods~~

Data sources

Landsat images from 2000, 2010 and 2020 were used to detect ~~the~~ land use/cover change within the 10-year time intervals. The Landsat 7-ETM (Enhanced Thematic Mapper) for 2000, Landsat 5-TM (Thematic Mapper) for 2010, and Landsat 8-OLI (Operational Land Imager) for 2020, images with same 30m spatial resolutions were downloaded from the United States Geological Survey (USGS) (https://glovis.usgs.gov/app) geoportal. A total of six scenes of satellite images of two from each successive year 2000, 2010 and 2020 were downloaded (Table 1). The entire Landsat images of 2000, 2010 and 2020 was around 3-10% of cloud cover but it was less than 1% in the intensive study area. We also used the topographic maps of 1:25000 and 1:50000 scales developed by the Department of Survey, Government of Nepal. They were also verified by using the maps developed by Google Earth. and classified map of 2010 developed by International Centre for Integrated Mountain Development (ICIMOD) (http://rds.icimod.org) was used as a reference image for verification. The reference field data were collected using a Global Positioning System (GPS) during the field study and used as ground-truthing points during classification of images and accuracy assessments (Table 1).

Image pre-processing

The Landsat image of each band was checked using metadata and each Landsat was georeferenced to the WGS_84 datum and Universal Transverse Mercator (UTM) Zone 44 or 45 North coordinate system. The details of bands and resolution are mentioned in Table S1. We used the bands with 30m resolution for further analysis. Landsat 5 TM images has seven bands, Landsat 7 ETM images have eight spectral bands, and Landsat ETM has 8 bands in which 1 to 7 bands have 30m resolution (Barsi et al. 2014). Similarly, Landsat 8 OLI images have 11 bands in which eight bands 1 to 7 and 9 have 30m resolutions. (https://www.usgs.gov) (Table S1). For the natural color composite for Landsat 8 OLI images, band 4 (red), 3 (green) and blue (2) were combined for the natural color, whereas bands 7, 6, 4 were used for false color (urban) similarly, bands 5, 4, 3 for vegetation composition, bands 6. 5, 2 for agriculture, 5, 6, 4 for land and water (Acharya & Yang 2015; Barsi et al. 2014).

The image was processed in ERDAS IMAGINE 9.2. Bands of each satellite image (2000, 2010 and 2020) were stacked within Raster main icon with layer stack function as a single layer. The images of each scene were masked using the AOI of the study area using mask function (Fig. 2).

Ground-truthing

The field survey from 2018 to 2020 provided a clear idea about the field, forest types and land cover types of the study area. The ground-truthing points were collected during the sign survey of large mammals including leopard and their prey using GPS (Garmin eTrex 10). A total of 1350 points were collected from various parts of the study area such as forest types, grasslands, barren lands, developed areas, water bodies and cropland. Among them half of the points were used for supervised classification and the remaining points were used for accuracy assessment. Besides this, printed versions of topographic maps were used to locate the different land cover types including changes over there through participatory GIS (pGIS) techniques. pGIS studies consider that the local people are familiar and experience ~~with~~ change to their surroundings and provide the greater spatial information of the area (Brown 2012; Zolkafli et al. 2017). For this purpose, group discussions were performed with members of community forests and elderly people who inhabited long time to that area and easily felt the changes to their surroundings.

Image classification

The land cover classification was established by the help of published literatures (Khanal et al. 2020; MoLRM 2015; Thapa 2011; Uddin et al. 2015; Zomer et al. 2001). In this study, we classified land cover patterns of Chitwan-Annapurna Landscape into eight major classes (Table 2).

Unsupervised classification

In the beginning, the unsupervised classification of the multi-temporal Landsat images of 2000, 2010, 2020 was performed. The nearer livelihood algorithms with 10 iterations were used to group the pixels having similar features (Duda & Canty 2002). The images were classified into 40 classes with a convergence threshold 0.90. Then, the similar classes were merged into eight different classes using recoding of classes (Table 2 and Fig. 2). The unsupervised classification of images was used for the planning of field data collection that provided the basic field knowledge. The unsupervised classes were revised after the collection of ground-truthing points.

Supervised classification

The supervised classification was performed using the widely used parametric classification algorithm Maximum Likelihood Classification (MLC) (Chamling & Bera 2020; Rai et al. 2018). The signature classes or training sets were prepared by ground-truthing points for 2020 and Google earth map of 2000 and 2010 were used to prepare signature classes for supervised classification. Two separately classified Landsat images were mosaicked to make a single image. Finally, the images were filtered fixing the pixels 3×3 for smoothing the image and avoid the errors of misclassification. The images were again recoded based on field knowledge to minimize the errors of misclassification.

Accuracy assessment

Accuracy assessment increases the quality of the remotely sensed data in classified thematic maps. It compares the classified image with ground truth points (Congalton 2001; Rai et al. 2018; Siddique et al. 2020; Song et al. 2001; Thapa 2011) and another most common method to assess the accuracy of the classified map is to generate stratified random points as the classified class and compare it with the Google Earth and topographic maps as reference points for

verification (Crowley & Cardille 2020). In this study, ground-truthing points (683 points) were used as reference points for the accuracy assessment of classified images of 2020. For Landsat images of 2000 and 2010, 500 stratified random points were generated and compared them with references such as google earth maps, topographic maps developed by the Department of Survey, Government of Nepal. The evaluation was performed computing confusion matrix or error matrix and Kappa Coefficient (Congalton 2001; Foody 2002). The user's accuracy, producer's accuracy, overall accuracy was obtained from the error matrix. The user's accuracy provides the reliability that the classified pixels of the map match with the ground-truthing points (equation 2), similarly, the producer's accuracy determines the probability of correctly classified reference pixels (equation 3). The overall accuracy was calculated by dividing the correctly classified pixels by the total number of reference points (Equation 1) (Congalton 2001; Foody 2002). Kappa Coefficient ($\hat{K}$) is used to measure the agreements between model prediction and reality (Congalton 2001). It is the multivariate analysis technique to evaluate the accuracy of the classified map statistically. The Kappa Coefficient ($\hat{K}$) ranges from 0 to 1. If the value of $\hat{K}$ is 0, this reflects there is no agreements, 0-0.2 signifies as slight, 0.2-0.41 as fair, 041-0.60 as moderate, 0.60-0.80 as satisfactory or good and 0.81 to 1 as almost perfect agreements (Maingi et al. 2002). Statistically, the $\hat{K}$ was calculated using equation 4.

$$\text{Overall accuracy} = \frac{Total\ number\ of\ correctly\ classified\ pixels}{Total\ number\ of\ reference\ pixels} \times 100 \quad (1)$$

$$\text{User's accuracy} = \frac{Number\ of\ correctly\ classified\ pixels\ in\ each\ category}{Total\ number\ of\ classified\ pixels\ that\ category\ (row\ total)} \times 100 \quad (2)$$

$$\text{Producer accuracy} = \frac{Number\ of\ correctly\ classified\ pixels\ in\ each\ category}{Total\ number\ of\ classified\ pixels\ that\ category\ (column\ total)} \times 100 \quad (3)$$

$$\text{Kappa coefficient } (\hat{K}) = \frac{N\left(\sum_{i=1}^{r} X_{ii}\right) - \sum_{i=1}^{r}(X_{1+} \times X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} \times X_{+i})} \quad (4)$$

Where, r= Number of rows in the error matrix
Xii= number of observations in row i and column i (on the major diagonals)
Xi+ = Total number of observations in rows i
X+i= Total number of observations in column i
N= Total number of observations included in matrix

Results

Land cover classes

Out of eight land cover classes, mixed forest was the most dominant category (44.95%) followed by cropland (28.3%), sal forest (15.4%) and developed area (4.13%) (Table 3, Fig. 3).

Land cover change

The temporal patterns of the LULCC analysis showed the direction of land cover changes with respect to the initial land cover (land cover of 2000) as a reference. The results indicated that there was decrease in barren land, grassland and cropland by 7.7%, 6.2% and 16% respectively from 2000 to 2010 whereas build-up or developed area, sal forest and the mixed forest were increased by 19.1%, 12.4% and 18.2% respectively. Similarly, from 2010 to 2020, water bodies,

sal forest, developed area and mixed forest were increased by 2.54%, 3%, 10.3% and 16.3% respectively; and barren area, cropland and grassland area were decreased by 13.3%, 46.9% and 16.3% respectively (Table 4, Fig. 4). Overall, from 2000 to 2010, barren area, cropland and grass land were drastically decreased whereas developed area, mixed forest and sal forest were in increasing trends (Table 4).

The separate analysis of land cover change between 2000 to 2020 in old Padampur and associated areas (low land) clearly showed that more than 93% of the total cultivated land was changed into the grassland and forest. Similarly, the barren area (flood plain of Rapti River) was reduced by 74.67%. However, grassland, riverine forest and mixed forest in the old Padampur and associated areas were increased by 94.45%, 91.26% and 62.5% respectively (Figs. 6, 7, Table S2).

The trend of land cover change from 2000 to 2020 in new Padampur and associated areas (low land) indicated that the riverine forest, sal forest and grassland were synergistically reduced by 61.21%, 54.14% and 64.88% respectively whereas the cropland and developed areas were increased by 88.17% and 1433.33% respectively (Figs. 7, 8, Table S2).

Byas area is an example of developed urban area of the Midhill of our study area. The land cover change from 2000 to 2020 in Byas and associated areas found the cropland was significantly reduced by 40.86% whereas developed area and mixed forest were increased by 86.55% and 62.14% respectively. The trend of land cover change in Byas and associated areas was more between 2010 to 2020 than 2000 to 2010 (Figs. 10, 11, Table S2).

Panchase and associate area is an example of rural area of the Midhill and consists of Panchase Protected Forest. The results of land cover change analysis of Panchase and associate area between 2000 to 2020 found 51.92% of cropland, 43.22% of grassland were reduced whereas mixed forest and sal forest were increased by 68.1% and 23.29% respectively (Figs. 12, 13 Table S2).

A part of Annapurna Conservation Area (ACA) that covered Birethanti, Ghandruk, Landruk, Australian Camp area is an example of Mountain area. The results of land cover change analysis of a part of ACA between 2000 to 2020 clearly showed the increment of mixed forest and developed area by 14.93% and 166.66% respectively whereas cropland, barren area and grassland were decreased by 40.97%, 24.09% and 19.94% respectively (Figs. 14, 15 Table S2).

Accuracy assessment

Overall accuracy of classified images of 2000, 2010 and 2020 was 81%, 81.6% and 84.77% respectively. The user's accuracy ranged from 73.33% to 87.09% in 2000, 73.68% to 83.33% in 2010 and 80.26% to 90.69% in 2020. The low range of user's accuracy in barren land in 2000 (73.33%), in a developed area in 2010 (73.68%) indicated confusion during land cover classification (Tables 5). Riverine forest in 2000, mixed forest in 2010 and sal forest in 2020 were more reliable with user accuracy of 87.09%, 83.77% and 90.69% respectively (Tables 5, supplementary tables S3-S5). The Kappa coefficient for the years 2000, 2010 and 2020 were 0.76, 0.79 and 0.82 respectively.

Discussion

Land cover classification

~~The Landsat image of 30m resolution and extensive fieldwork for collecting ground truth points help to classify the land cover into eight categories (water bodies, barren area, grassland, riverine forest, sal forest, mixed forest, cropland and developed area).~~ Similarly, the land resource mapping project of Nepal classified the land cover of Nepal into 6 classes, land use policy 2015 also categorized the land cover of Nepal into 11 classes (MoLRM 2015), ICIMOD developed 12 land cover classes for the development of a land cover database of the Hindu Kush Himalaya Region but there is lack of categorized of the forest types (Uddin et al. 2015). The Government of Nepal classified the land cover of Nepal using Google earth images into six classes (MoFE 2019). WWF (2013a) classified the whole Chitwan Annapurna Landscape (CHAL) area into seven categories. Most of the classification made by the different government and non-government organizations of Nepal categorized the land cover of Nepal into separate forest, non-forest, urban, mines areas only. The consistency of the land cover classes in national, regional and international level are not same. The land cover classification depended on the nature and purpose of the study that created the problems to land cover mapping and difficult to compare over time (Chettri et al. 2013; Uddin et al. 2015; Wang et al. 2020).

The present study attempted to categorize the major forest types such as sal forest, riverine forest, mixed forest and grassland. Among the land cover classes, sal forest was the most dominant in the Barandabhar Corridor Forest and some parts of Tanahun district. The sal was associated with *Terminalia alata*, *Adina cordifilia*, *Phylanthus emblica*, *Fiscus* spp. ~~etc.~~ The tropical and subtropical climate support the sal forest (Adhikari et al. 2019; Kunwar et al. 2020; Reddy et al. 2018). Similarly, the riverine forest was found at the flood plains of major river systems (Rapti, Narayani, Marshyandi, Kaligandaki, Seti river basin). In the midhill, most of the area was dominated by mixed forest. The high hills of the Tanahun were dominated by mixed forest of Chilaune (*Schima wallichii*), Katus (*Castanopsis tribuloides*) associated with Dhairo (*Woodfordia fruticose*), Kyamuno (*Syzygium cumini*), Utis (*Alnus nepalensis*). The high midhill of Kaski (Panchase, lower Annapurna Conservation Area such as Birethanti, Ghandruk, Landruk, Australian camp, Forest camp area) was dominated by Rakchan *(Daphniphyllum himalense)*, Rhododendron and oak (*Quercus* spp.), Utis (*Alnus nepalensis*), Champ (*Michelia champaca*), Paiyu (*Prunus cerasoides*), Lapsi (*Choerospondias axillaris*), Ritha (*Sapindus mukorossi*) and associate plants. The grassland was scattered and mostly found in the high hill and used by the local people as pasture land.

~~Our research followed the Barandabhar Corridor Forest, with a part of Chitwan National Park and associated areas of Chitwan; Seti Corridor of Tanahun and Kaski, Panachase and lower Annapurna Conservation Area.~~ LULCC analysis of the part of Chitwan Annapurna Landscape showed that more than 62% of total land was covered by forest area (mixed forest, sal forest and riverine forest) ~~(Table 2).~~ Hence, this landscape is one of the important landscapes for biodiversity conservation. However, this is human-dominated and highly fragmented landscape. The scattered settlements and croplands in this landscape made the forest fragmented. The river systems (Rapti, Narayani, Seti, Madi, Modhi, Kaligandaki, Marshyandi and other associates) and lakes (two Ramsar sites Beeshhazari Lake and Lake clusters of Pokhara Valley) are crucial for maintaining the ecosystems. Most of the grasslands (1.73% of total land cover) were scattered

inside the forest as a patch and provide the feeding grounds for herbivores. The rapid development of the roads, tracks, hydropower, industrial areas, airport and settlements in urban areas occupied 4.13% of the total land that made a barrier for wildlife movements. The settlement density was more in urban and plain areas than in hilly areas. Barren area (1.76% cover) includes gravels, sands, bare lands, landslide area. ~~Our study focused on midhill and mountain areas following the river system.~~ The landslide was very common in the study area. Besides, the major rivers (Seti, Trisuli, Rapti, Narayani) also deposited sands and gravels to their catchment area. The croplands and the forest area were closely associated in this fragmented landscape. The field study showed that most of the public lands also converted into the forest area, hence, only 28.13% of the land was covered by cropland. The water bodies (rivers, lakes, streams and reservoirs) occupied 1.97% of the total area. Land use and land cover are the principal sources of environmental change such as loss of biodiversity, habitat changes, destructions, loss of soil resources, landslides, flood, global climate change, the impact of invasive and alien plant species (MEA 2005; MoLRM 2015; Paudyal et al. 2019; Rather et al. 2020; Rimal et al. 2019; Wu 2019). Hence, land cover is ~~considered as~~ important issues in current scenario (Chamling & Bera 2020). Similar type of study based on the google earth map analysis of 2018 by MoFE (2019) found 44.47% of total area of Nepal was covered by forest. The land cover analysis of whole area of Chitwan Annapurna Landscape found 35.5% land covered by forest in 2010 (WWF 2013a) and more than 38% of the landscape covered by forest in 2016 (MoFSC 2016). These results also clearly showed increasing the forest area in Nepal and Chitwan-Annapurna Landscape.

Temporal change in land cover

Our classified images of a part of Chitwan Annapurna Landscape showed that cropland was decreased by 16% from 2000 to 2010, 16.3% from 2010 to 2020 and 29.87% from 2000 to 2020. But the mixed forest is synergistically increased by 18.2% from 2000 to 2010, 16.3% from 2010 to 2020 and 37.46% from 2000 to 2020. This is due to the shifting of the people from the hilly area to the urban area for better life and opportunities, hence, the cropland left by them gradually converted into the forest area. The results of increment of urban area from 2000 to 2020 (31.34% increment) also proved the out migration of the people from rural to urban area (~~Table 4)~~ but the area of barren area and grassland was decreased by 20.03% and 40.71% respectively, these areas were replaced by forest. The increment of the forest in our study area indicated the better habitats for wildlife especially large mammals. Forest cover inside the protected area (Chitwan National Park and Annapurna Conservation Area) was in increasing trends. Old Padampur area is an example of it. After resettlement of the village Padampur and included this area inside the CNP, the crop land was changed into the grassland and riverine forest. The land cover change analysis showed that more than 94% grassland was increased from 2000 to 2020 in Old Padampur area. The forest was cleared and the Padampur village was relocated to the New Padampur area. Hence, the cropland area was increased by 137.78% from 2000 to 2010 whereas developed area was increased by 1433.33% from 2000 to 2020. During the period of 2010 to 2020, the mixed forest area was comparatively increased due to the community forest program. Regeneration of the forest inside the Annapurna Conservation Area increased during this period. The people abandoned the marginal agriculture land due to low production, shortage of labors for agriculture work and high human wildlife conflict, hence these, area was converted into the forest area. Similar type of trends also found in Panchase and associated areas, where, the local people left their productive land and migrated towards the city area for better life. ~~Hence, this cropland was~~

converted into the forest area. Beside this, large number of rural youth temporarily migrated to foreign countries for employments which made the shortage of labors for agriculture activities (WWF 2013a). The population density was increased in the city area. Byas area is an example of this, in which the developed areas (settlements, roads, hydropower and other developmental works) were increased by 86.55% within the duration of 2000 to 2020. People of the hilly rural area migrate to these city areas for better life, employments, education and other facilities.

The classified images of Nepal clearly showed 48.6% of the forest area lost within the duration of 1930 to 2014 (Reddy et al. 2018). But this loss was very low from 2005 to 2014 (only 4 km^2 per year). From 2005 onwards the deforestation rate is decreased due to the effective implementation of community forests by the government of Nepal (MoFSC 2016). The forest loss during recent years is due to developmental works only which is comparatively more in the Terai region (Reddy et al. 2018). But the land cover change analysis of the CHAL area (landscape includes 19 districts from Terai to high mountains) between 1990-2010 showed an increased in forest area by 0.3% while the grasslands are in slightly decreasing trends (WWF 2013a). The overall forest of mid-hill of CHAL area is increasing in trends while cropland and grassland are in decreasing trends. Land cover analysis of 2015 found that 48% of the Midhill, 62.6% of high mountain and 6.1% of the high Himalayan area covered by forest (MoFSC 2015). However, the forest area of the Midhill and high mountains is increasing in trends while the croplands are in decreasing trends (MoFSC 2015) similar to this study.

Conclusions

Land cover change/land use patterns are presented themselves as the determining factors on the spatial patterns of land cover in Chitwan Annapurna Landscape. With increasing in elevation from south to north, land cover classes in CHAL showed a vertical composition of riverine forest, barren land, croplands, developed areas, mixed forest, sal forest, grasslands. The land cover change analysis of 2000, 2010 and 2020 showed the clear scenario of land cover change in such human-dominated fragmented landscape. The results of the temporal and spatial analysis of the land cover provide the baseline data for the conservation wildlife habitats, landscape management, sustainable development of the landscape which is useful to managers, planners, conservationists and the government.

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Figure 1

Map showing the intensive study areas which links two biodiversity significant areas: Chitwan National Park (CNP) and Annapurna Conservation Area

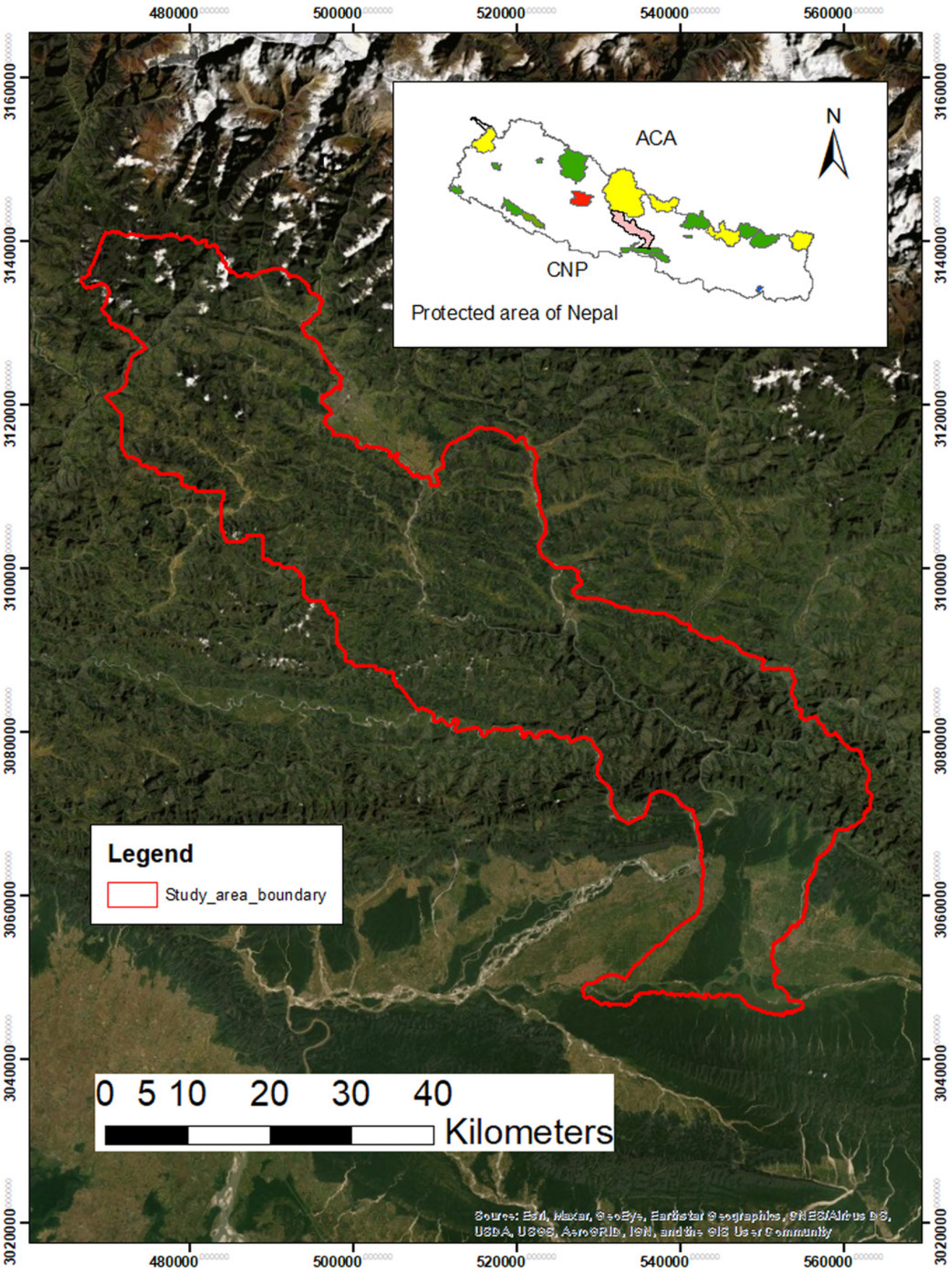
480000
500000
520000
540000
560000
3160000
3140000
3120000
3100000
3080000
3060000
3040000
3020000
ACA
CNP
N
Protected area of Nepal
Legend
Study_area_boundary
0 5 10 20 30 40
Kilometers
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 2

Figure 2. Flow chart of overall process of Landsat image classification

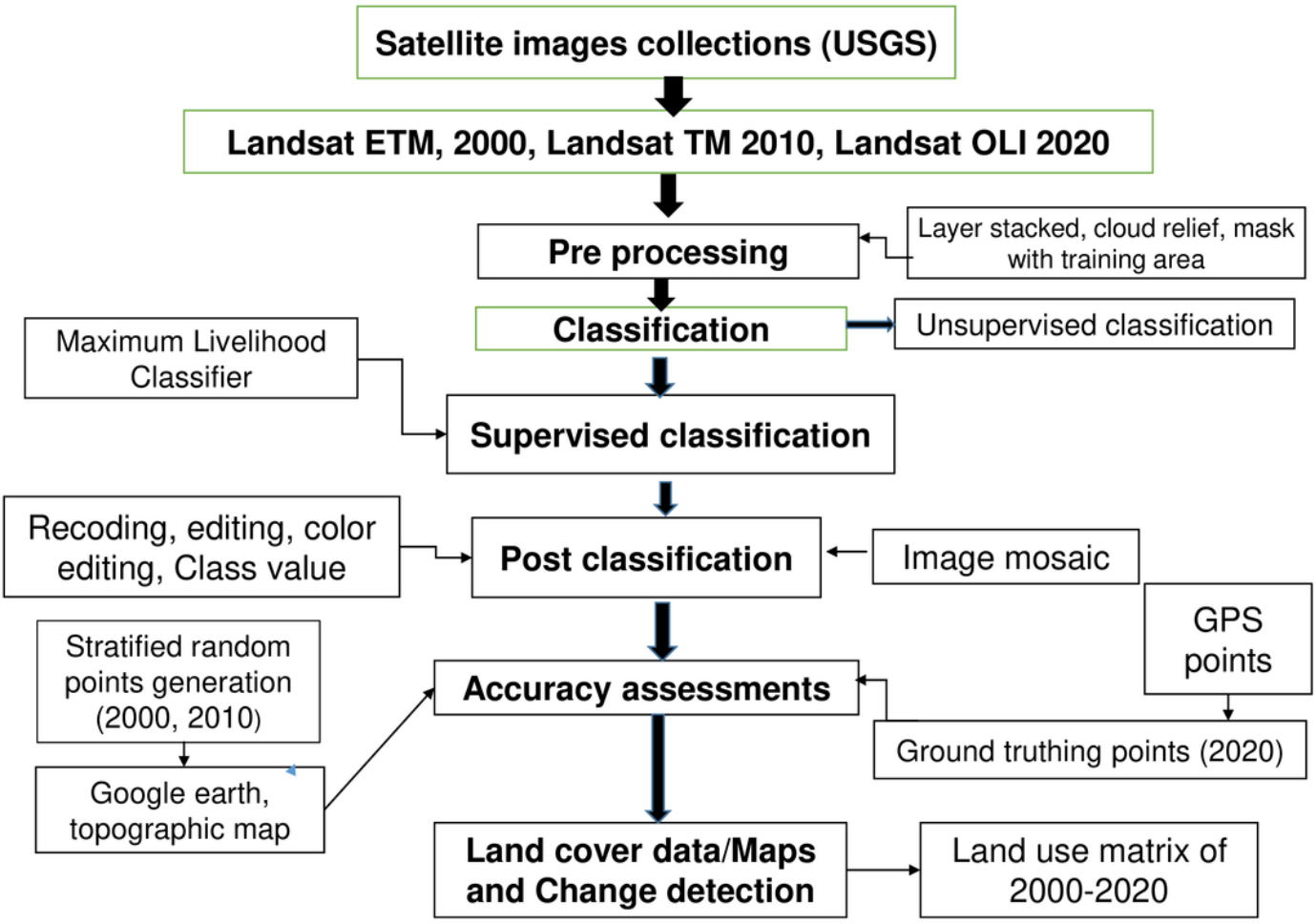

Figure 3

Land cover types of a part of Chitwan-Annapurana Landscape in 2020

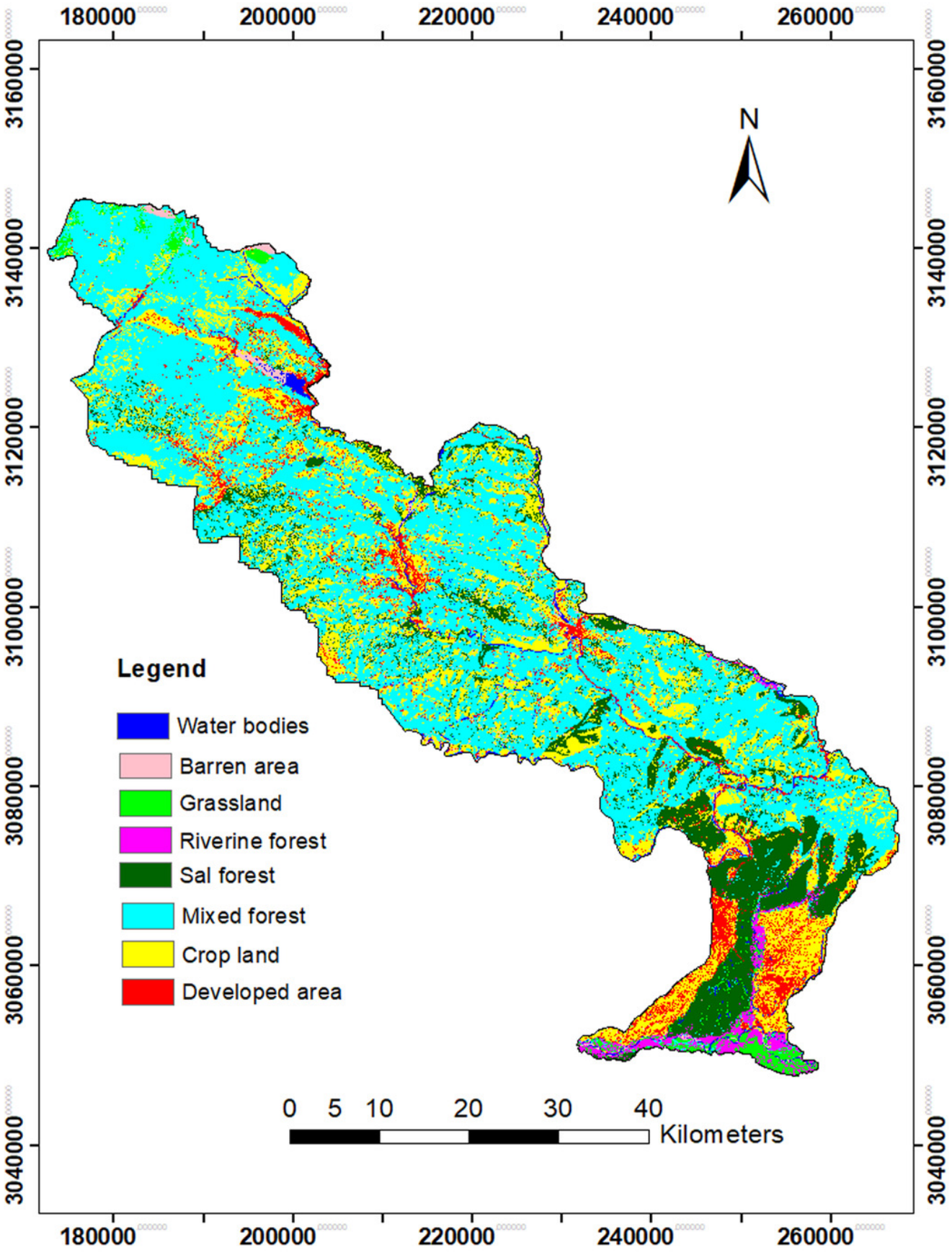
180000
200000
220000
240000
260000
3160000
3140000
3120000
3100000
3080000
3060000
3040000
N
Legend
Water bodies
Barren area
Grassland
Riverine forest
Sal forest
Mixed forest
Crop land
Developed area
0 5 10 20 30 40
Kilometers

Figure 4

The land-use / cover change in area during the period of 2000–2020

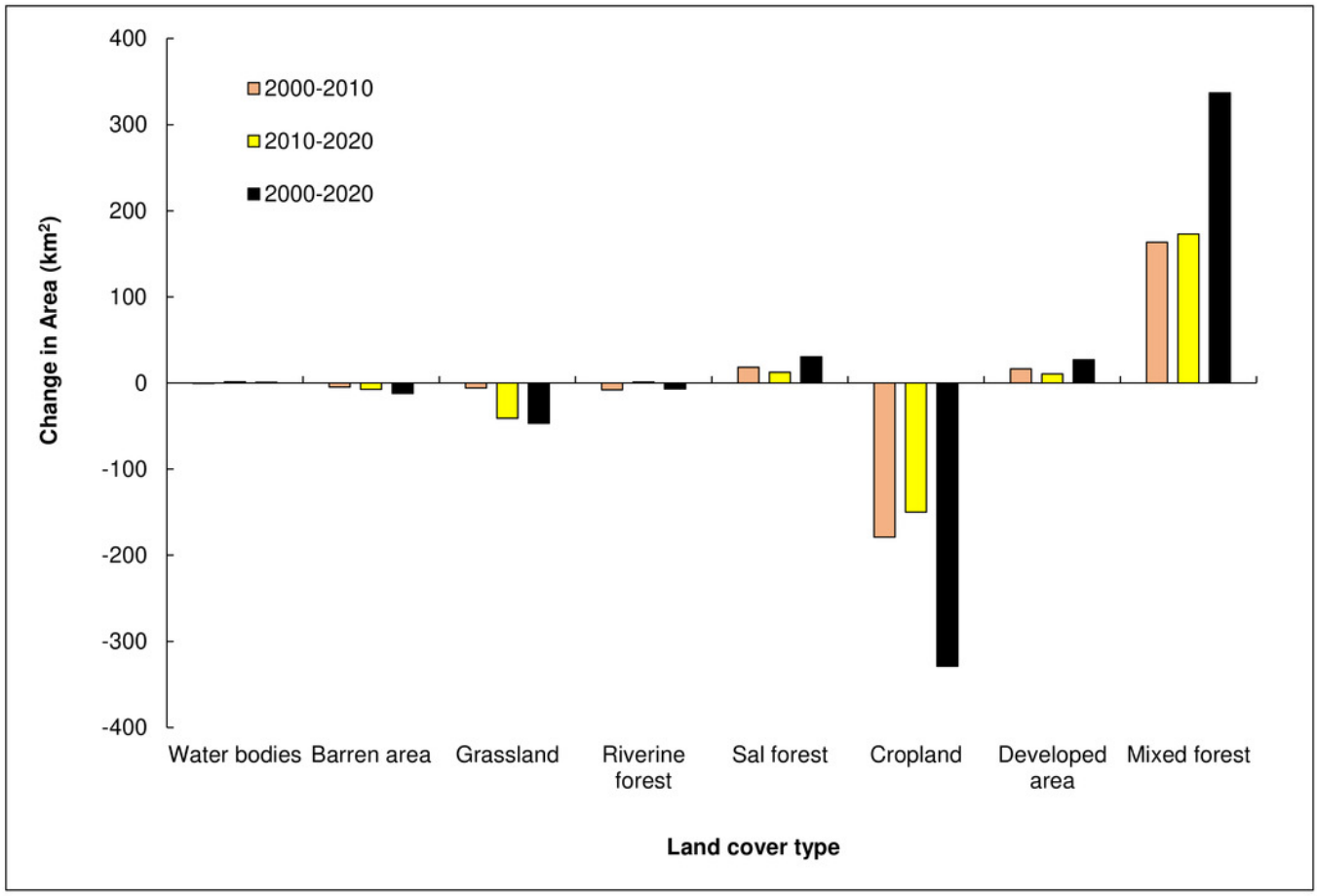

Figure 5

Land cover change between A. 2000, B. 2010 and C. 2020

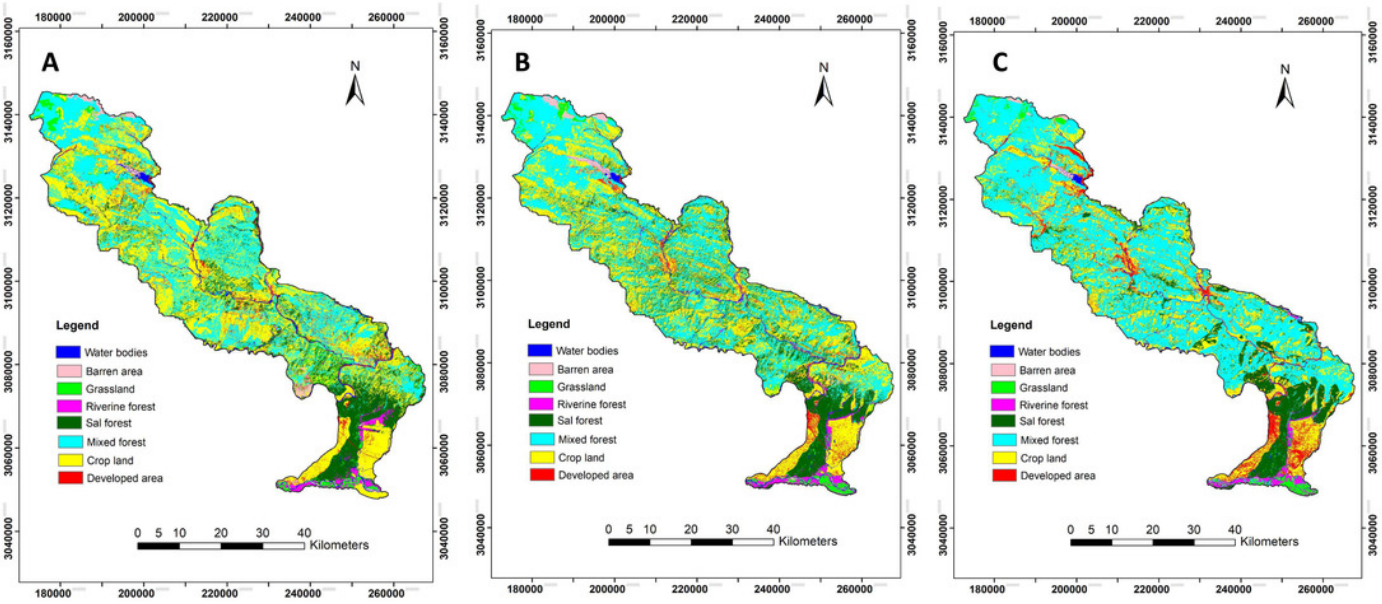

Figure 6

Percentage of Land cover change Old Padampur and associated areas from 2000 to 2020

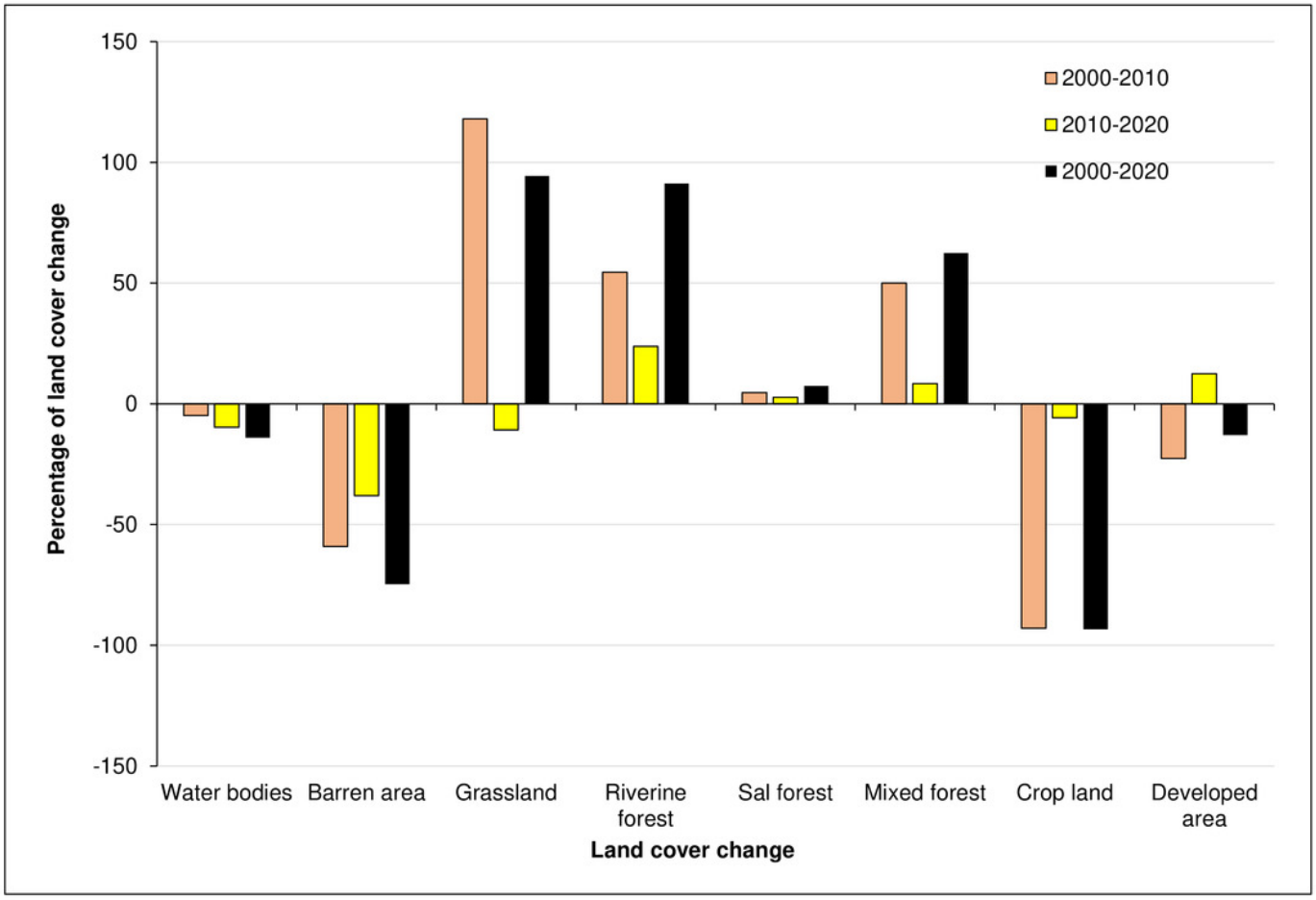

Figure 7

Synergic change in land cover of Old Padampur area A. 2000, B. 2010 and C. 2020

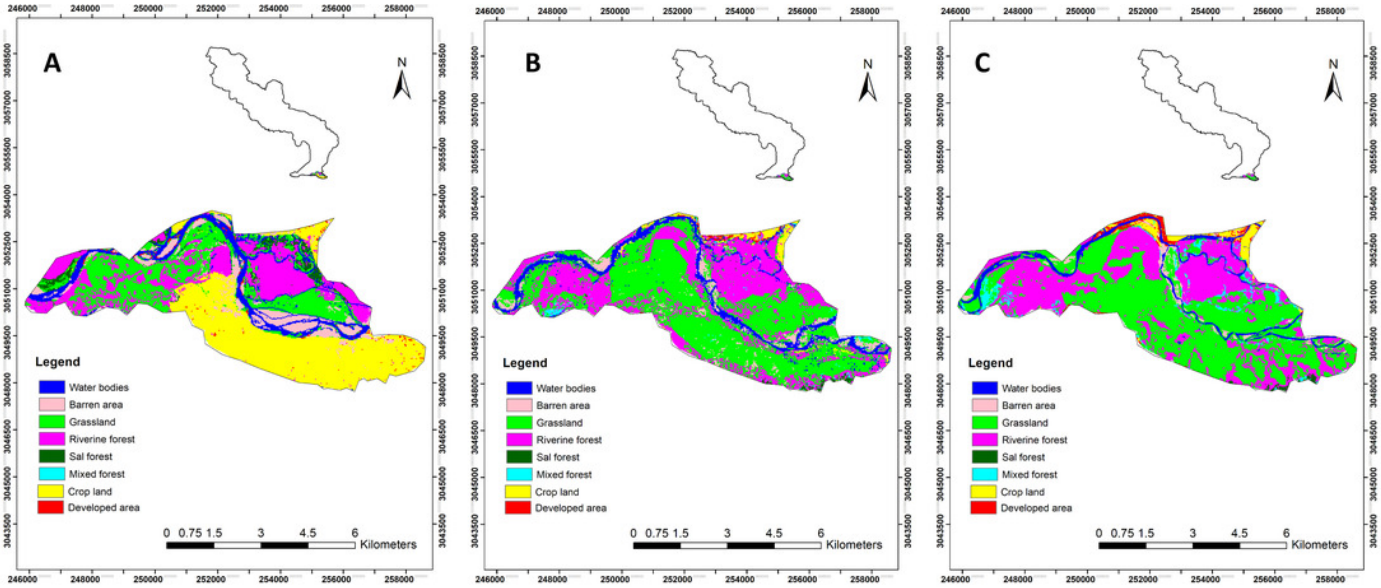

Figure 8

Percentage of Land cover change New Padampur and associated area from 2000 to 2020

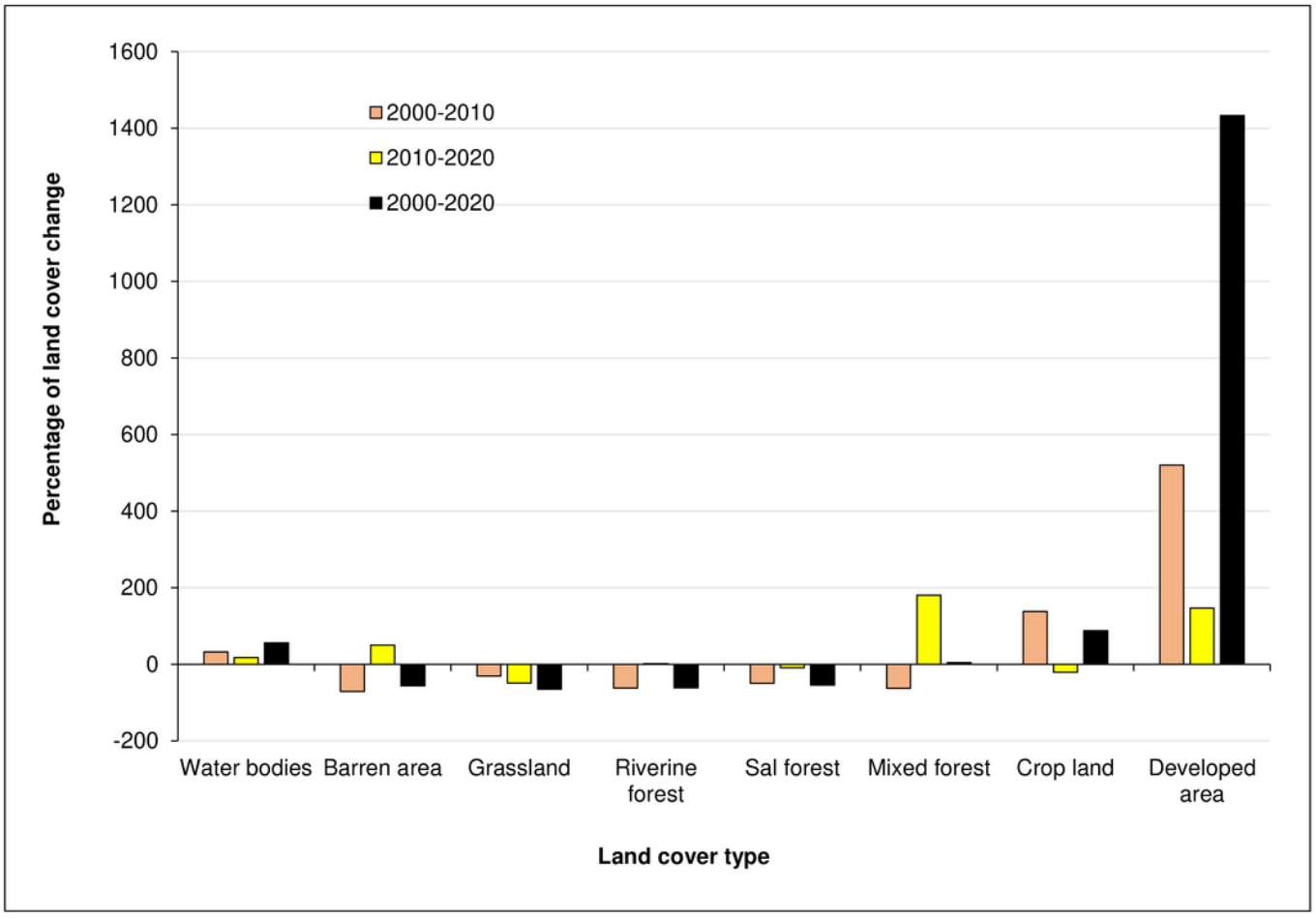

Figure 9

Land cover change in New Padampur area A. 2000, B. 2010 and C. 2020

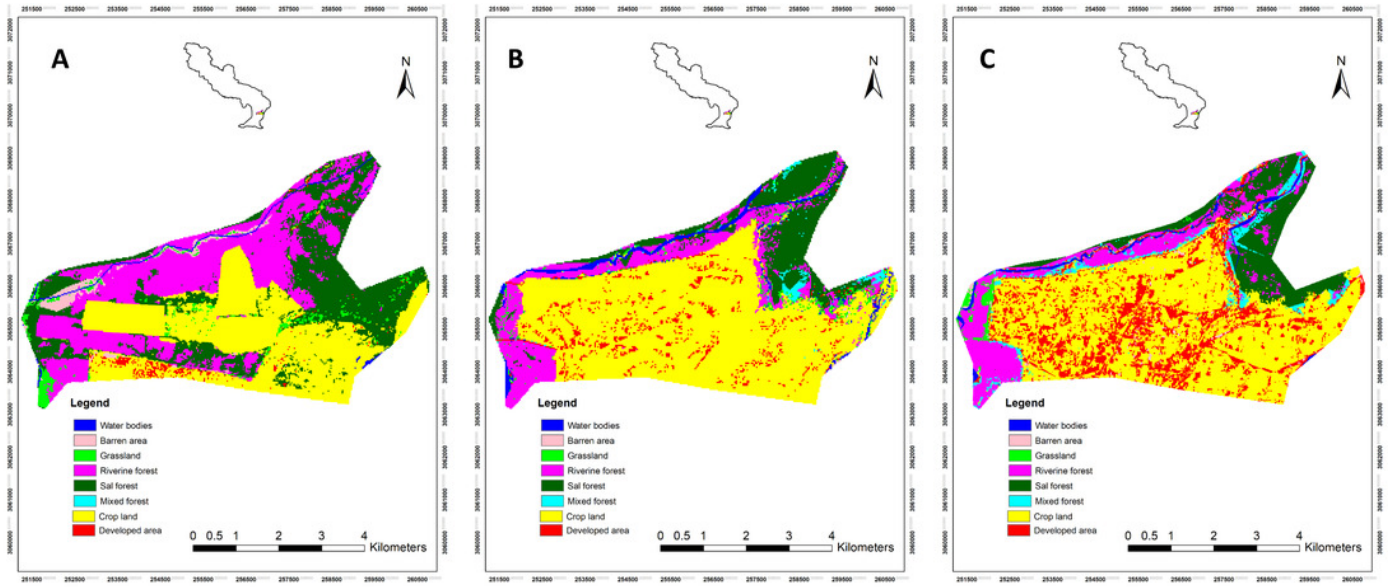

Figure 10

Percentage of land cover change of Byas and associated area (an example of urban area of Midhill) from 2000 to 2020

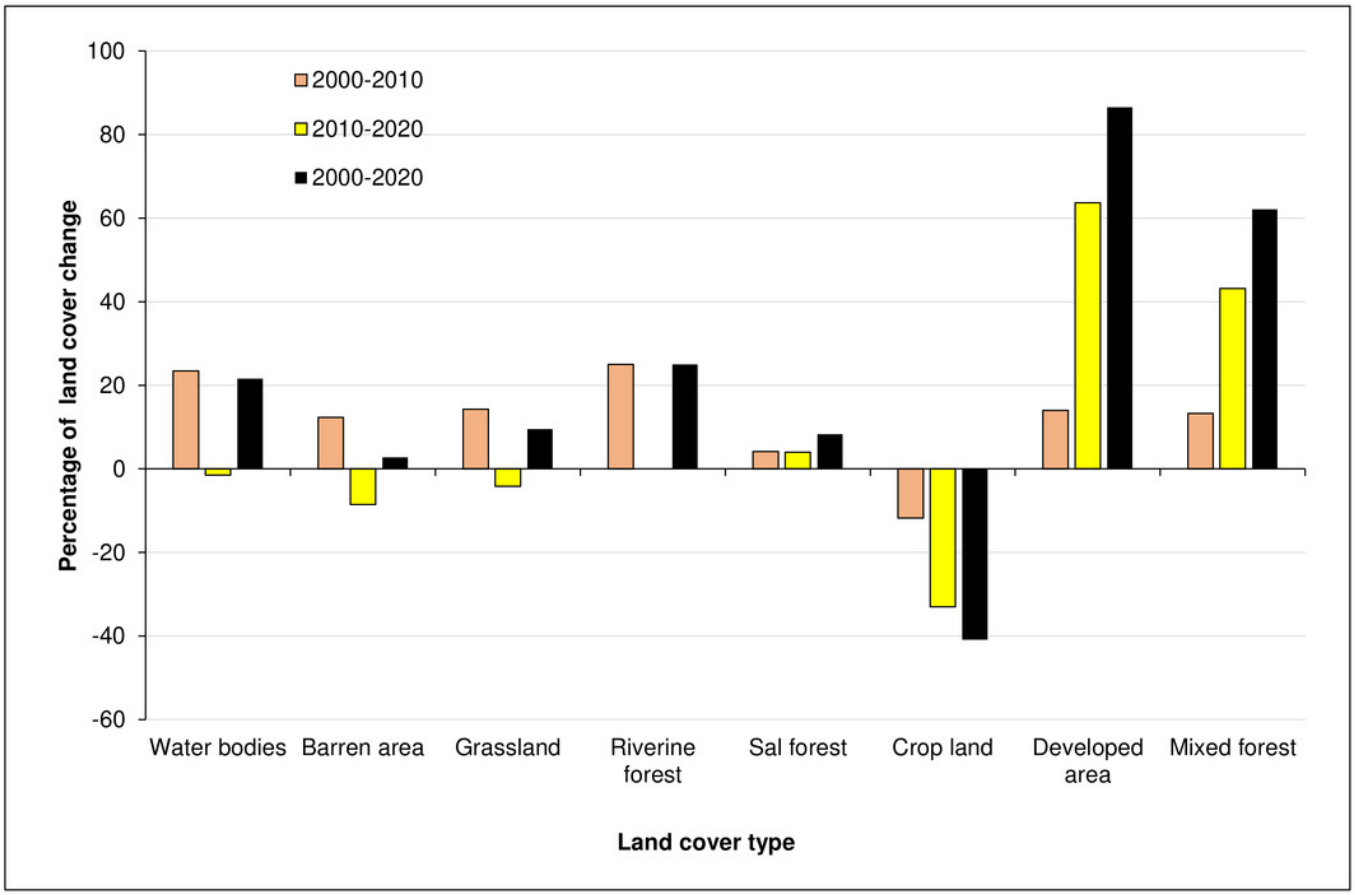

Figure 11

Land cover change in Byas area A. 2000, B. 2010 and C. 2020.

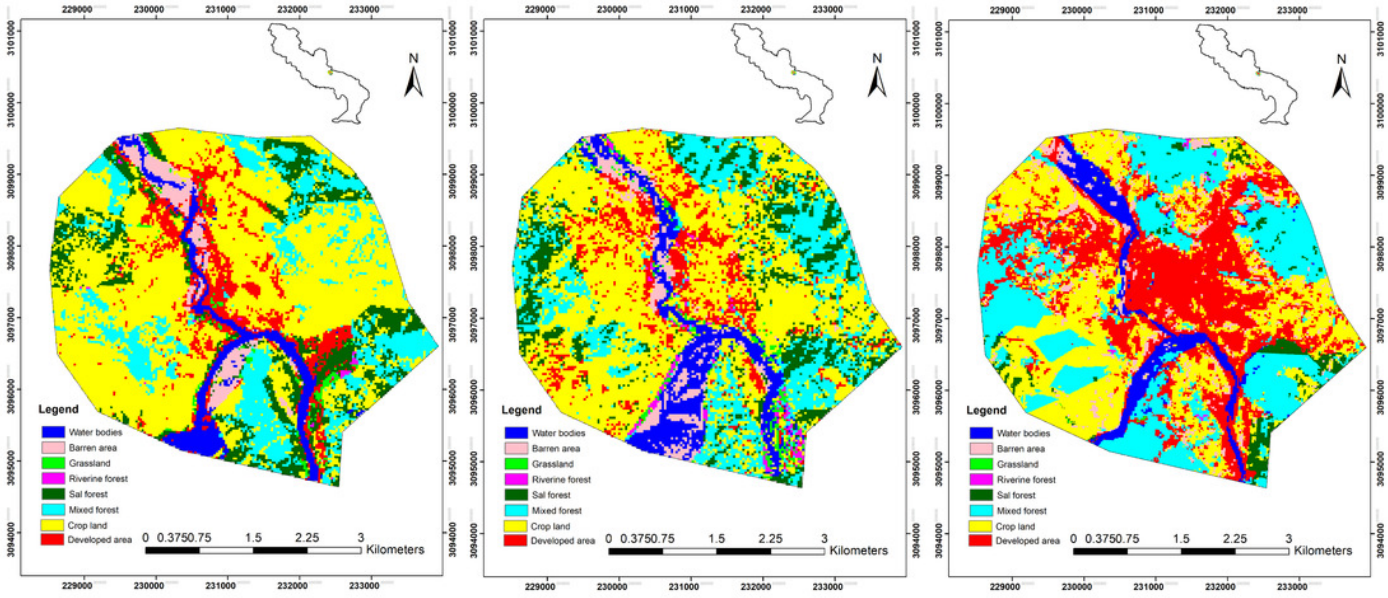

Figure 12

Percentage of land cover change of Panchase and associated areas (an example of rural area of Midhill) from 2000 to 2020.

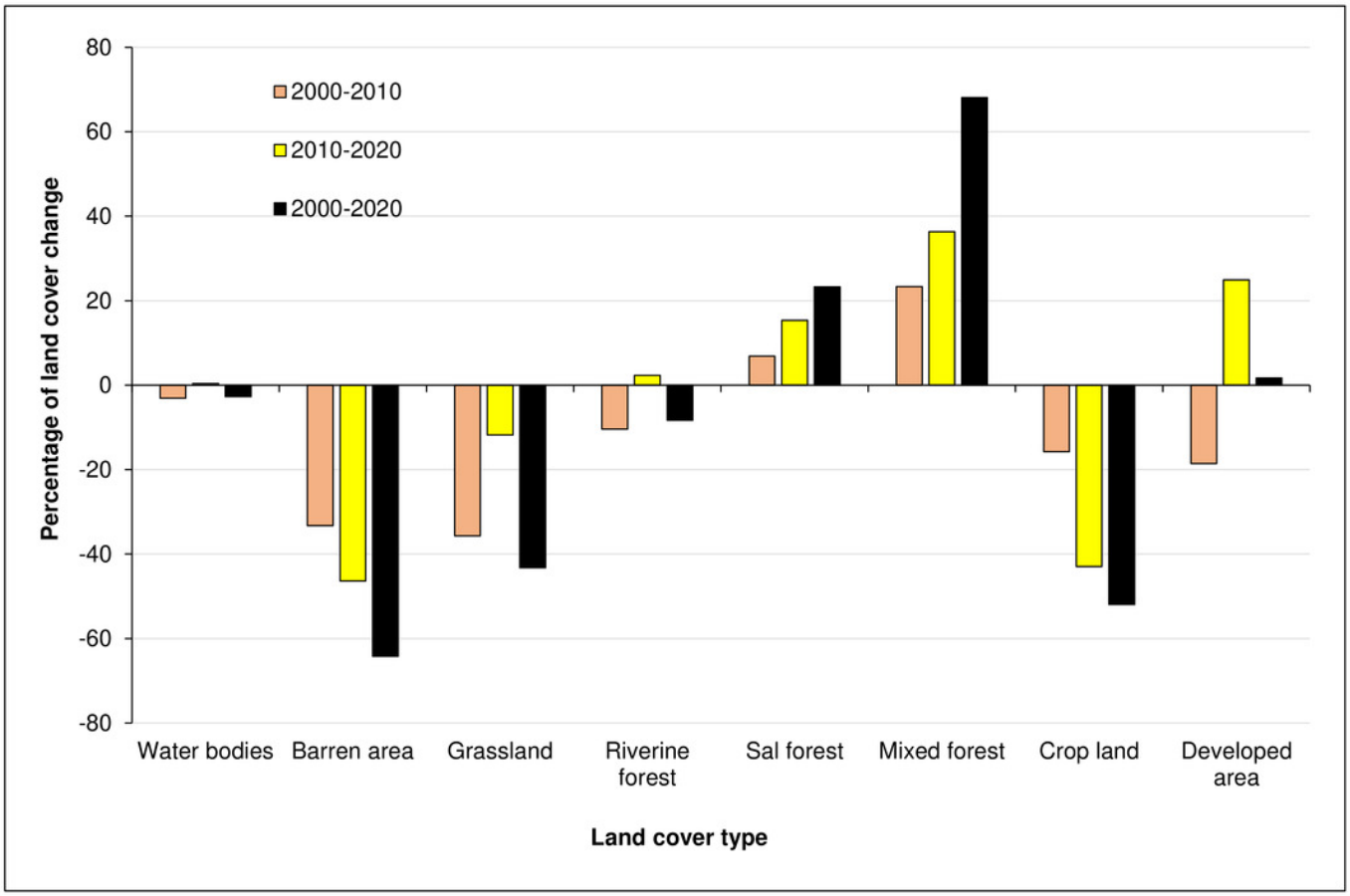

Figure 13

Land cover change in Panchase protected forest and associated area A. 2000, B. 2010 and C. 2020.

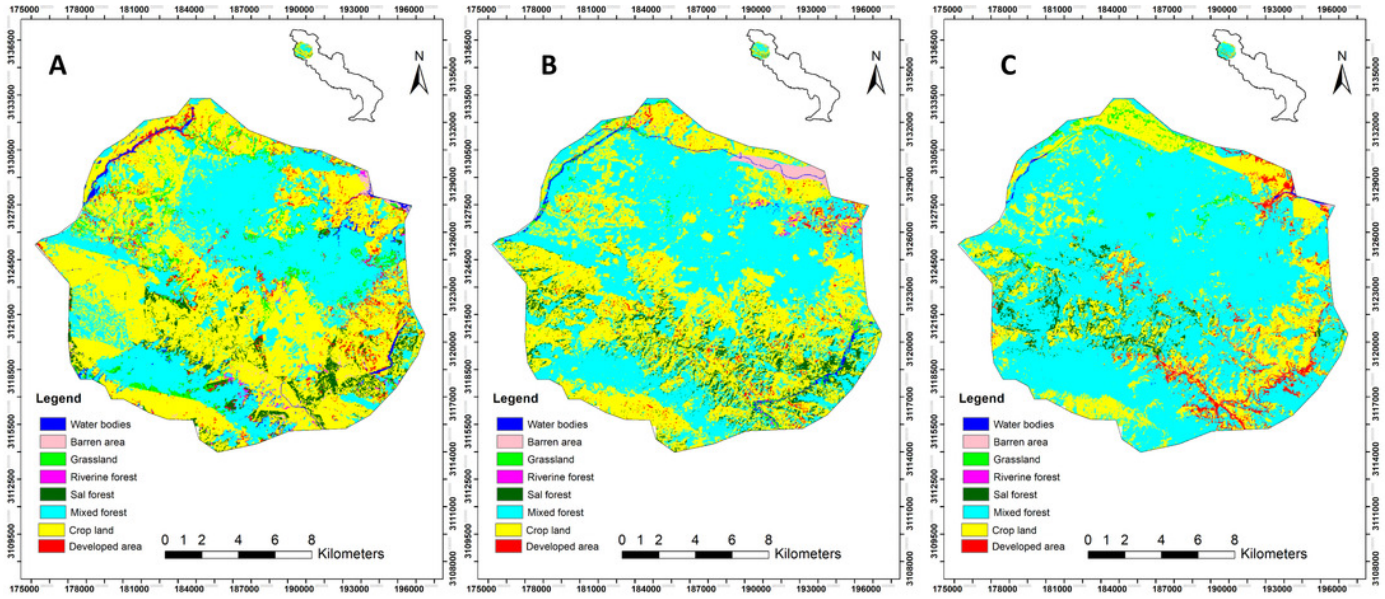

Figure 14

Percentage of land cover change of a part of Annapurna Conservation Area (an example of rural area of Mountain, inside the protected area) from 2000 to 2020.

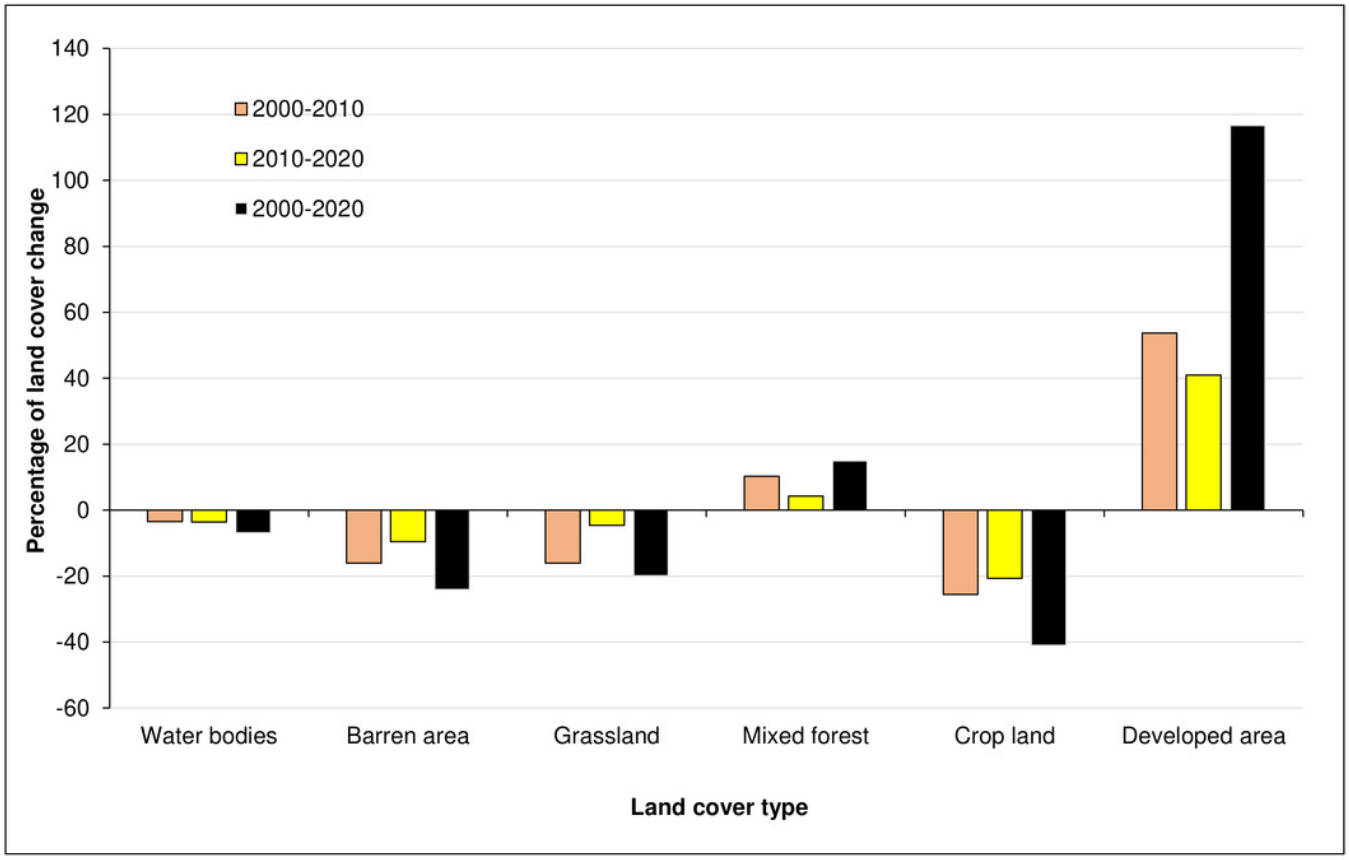

Figure 15

Land cover change in a lower part of Annapurna Conservation Area A. 2000, B. 2010 and C. 2020.

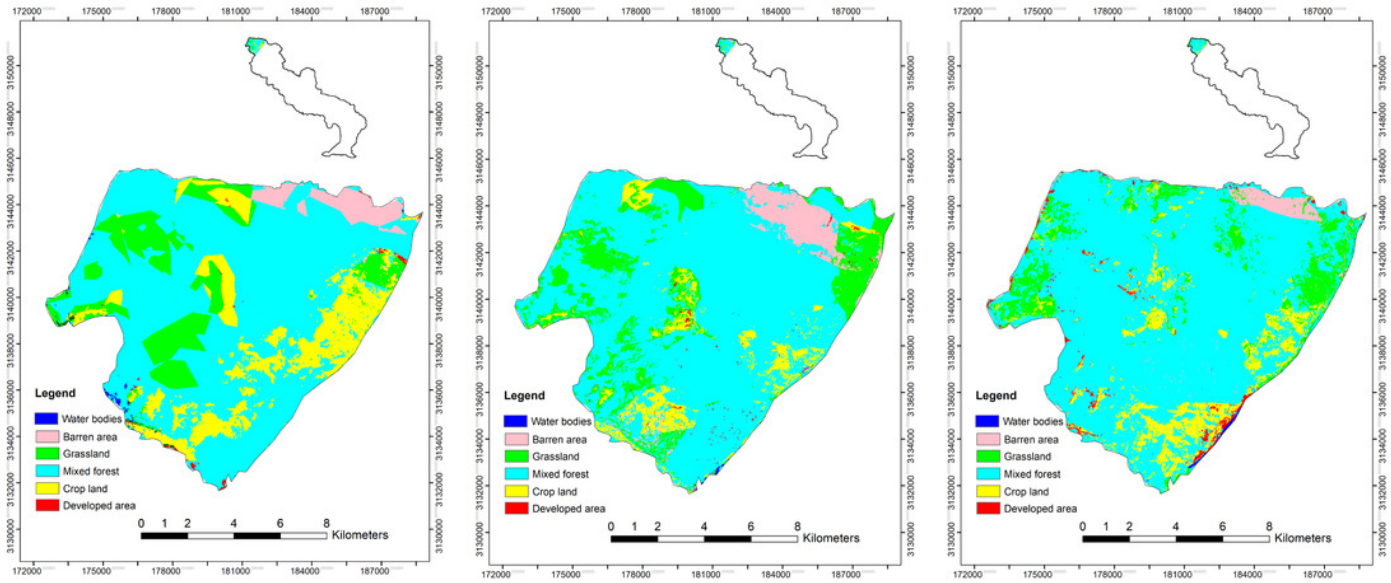

Table 1(on next page)

List of dataset used in the study.

Table 1

SN	Acquisition date	Data category	Spatial resolution	Band properties	Sources
1	3 April 2000	Landsat 7, Enhanced Thematic Mapper (ETM)	30m	Multispectral	https://glovis.usgs.gov/app
2	18 February 2010	Landsat 5, Thematic Mapper (TM)	30m	Multispectral	https://glovis.usgs.gov/app
3	17 March 2020	Landsat 8, Operational Land Imager (OLI)	30m	Multispectral	https://glovis.usgs.gov/app
4	1999/2000	Topographic map	1:25000 1:50000		Department of survey, Kathmandu
5	2018-2020	Ground truth (reference data)			Field survey- GPS
6	2000, 2010, 2020	Google earth pro			https://earth.google.com/web/
7	2010	ICIMOD		Classified	http://rds.icimod.org/

Table 2(on next page)

Major land use and land cover types in Chitwan Annapurna Landscape, Nepal.

Table 2

SN	Land cover types	Description
1	Water bodies	River, Lakes, ponds, marshy land, reservoirs
2	Barren area	Sand, gravel, flood plains without vegetation, landslide, snow feed area and no vegetation areas
3	Grassland	Grasslands, scattered shrub
4	Riverine forest	Simal (*Bombax ceiba*), Khair (*Acacia catechu*), Sisso (*Dalbergia sissoo*), Veller (*Trewia nudiflora*), Padke (*Litsea doshia*), *Litsea monopetala* and associates plants
5	Sal forest	Sal (*Shorea robusta*), Saj (*Terminalia alata*), Karma (*Adina cordifolia)* and associates plants
6	Mixed forest	Dhairo (*Woodfordia fruticose*), Kafal (*Myrica esculenta*), Kutmero (*Litsea monopetala*), Amaro (*Spondias pinnata*), Chilaune (*Schima wallichii*), Katus (*Castanopsis tribuloides*), Lapsi (*Choerospondias axillaris*), Kyamuno (*Syzygium cumini*), Rakchan *(Daphniphyllum himalense)*, Rhododendron and oak (*Quercus* spp), Utis (*Alnus nepalensis*), Champ (*Michelia champaca*), Paiyu (*Prunus cerasoides*), Lapsi (*Choerospondias axillaris*), Ritha (*Sapindus mukorossi*) and associate plants
7	Crop land	Crop lands
8	Developed area	Urban and rural settlements, commercial areas, industrial areas, hydropower project areas, roads construction, airport

Table 3(on next page)

Land cover classes in a part of Chitwan-Annapurna Landscape in 2020.

Table 3

SN	Land cover type	Area_2020 (Km^2)	Percentage
1	Water bodies	54.04	1.97
2	Barren area	48.62	1.76
3	Grassland	47.32	1.73
4	Riverine forest	53.25	1.93
5	Sal forest	423.65	15.4
6	Mixed forest	1235.9	44.95
7	Cropland	753.35	28.13
8	Developed area	113.35	4.13
	Total area	2749.48	100

Table 4(on next page)

Land cover changes in study area from 2000 to 2020.

Table 4

SN	Land cover type	Land cover area (km^2)			Change 2000-2010		Change 2010-2020		Change 2000-2020	
		2000	2010	2020	Area	%	Area	%	Area	%
1	Water bodies	53.2	52.7	54.04	-0.5	-0.9	1.34	2.54	0.84	1.57
2	Barren area	60.8	56.1	48.62	-4.7	-7.7	-7.48	-13.3	-12.2	-20.03
3	Grassland	94.1	88.24	47.32	-5.86	-6.2	-40.9	-46.4	-46.8	-49.71
4	Riverine forest	60.03	52.16	53.25	-7.87	-13	1.09	2.09	-6.78	-11.29
5	Sal forest	393.15	411.3	423.65	18.15	4.62	12.4	3	30.5	7.76
6	Mixed forest	899.1	1062.48	1235.9	163.38	18.2	173	16.3	337	37.46
7	Cropland	1102.8	923.7	773.35	-179.1	-16	-150	-16.3	-329	-29.87
8	Developed area	86.3	102.8	113.35	16.5	19.1	10.6	10.3	27.1	31.34
	Total	2749.48	2749.48	2749.48						

Table 5(on next page)

Accuracy assessment of the classified images from 2000-2020.

Table 5

Land cover	2000		2010		2020	
	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy
Water bodies	81.81	90	76.92	76.92	90	81.18
Barren area	73.33	73.33	80	72.73	82	69.49
Grass land	78.37	80.5	75	80	80.95	76.11
Riverine forest	87.09	81.8	76.92	71.4	84.61	84.61
Sal forest	84.21	80	83.11	80	90.69	95.9
Crop land	82.73	80.41	83.33	83.3	85.32	83.78
Developed area	77.77	72.41	73.68	66.67	84.62	80.88
Mixed forest	78.43	83.3	83.77	86.95	80.26	89.7
Over all accuracy	81		81.6		84.77	
Kappa coefficient	0.76		0.79		0.82	