Using Landsat data for assessing forest cover change and fragmentation in Laljhadi corridor of Kanchanpur district, Nepal

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The study, carried out at Laljhadi corridor in Kanchanpur district of Nepal, aimed at assessing forest cover change and fragmentation using multi-temporal Landsat data. Post classification change detection was applied on temporal forest cover class datasets obtained by supervised classification technique with maximum likelihood algorithm. The overall change analysis indicated a decreasing trend in forest cover. Statistics on selected landscape metrics were generated to quantify the change in spatial structure resulting from fragmentation. The analysis of the landscape metrics depicted increase in fragmentation over the analysis time period along with progression of deforestation.

Key words: Fragmentation, forest cover change, Landsat, Laljhadi corridor

Information on human induced disturbance like deforestation has gained much importance particularly in the present global context of climate change and biodiversity conservation challenges. Satellite remote sensing methods have been widely used to map area and patterns of deforestation as well as to analyze the rates of forest cover change (Apan and Peterson, 1998; Franklin *et al.,* 2002; Hall *et al.,* 1991; Mas, 1999; Mas *et al.,* 2004). Forest loss and fragmentation process through habitat loss, fragmentation and isolation of forest patches alter the landscape structure and functions, and ultimately have several ecological effects on ecosystem (Matsushita *et al.,* 2006, McGarigal and Cushman, 2002). Therefore, it is important for deforestation analysis to include spatial dynamics of the forest, landscape which provides information on the temporal change in the patch metrics such as size, number, shape, adjacency and the proximity of patches in a landscape. Previous studies have observed forest cover change in the Terai, a physiographic region of Southern Nepal, which is important from both biodiversity conservation as well as rich forest resources (DFRS, 1999; DoF, 2005; Kandel *et al.*, 2010; Khanal, 2009). This study analyses the spatial and temporal pattern of forest cover change using multi-temporal Landsat Satellite imageries and uses FRAGSTATS, a spatial pattern analysis program to analyze characteristics of landscape fragmentation in Laljhadi Corridor forest of Terai Arc Landscape in western Nepal.

Materials and methods

Study area

Laljhadi forest, a biological corridor lies in Kanchanpur district of the far western region of Nepal. The corridor which encompasses four Village Development Committees (VDCs) (Raikar Bichawa, Baisi Bichawa, Shankarpur and Krishnapur) (Fig. 1), which are located between Dudhwa National Park of India and Shukla Phanta Wild Life Reserve of Nepal. It is a very important corridor as it connects Nepal's Churia forest in the North to India's Dudhuwa national park in the South. Geographic positions are 80° 20'E to 80° 33'E and 28° 38'N to 29° 10'N approximately.

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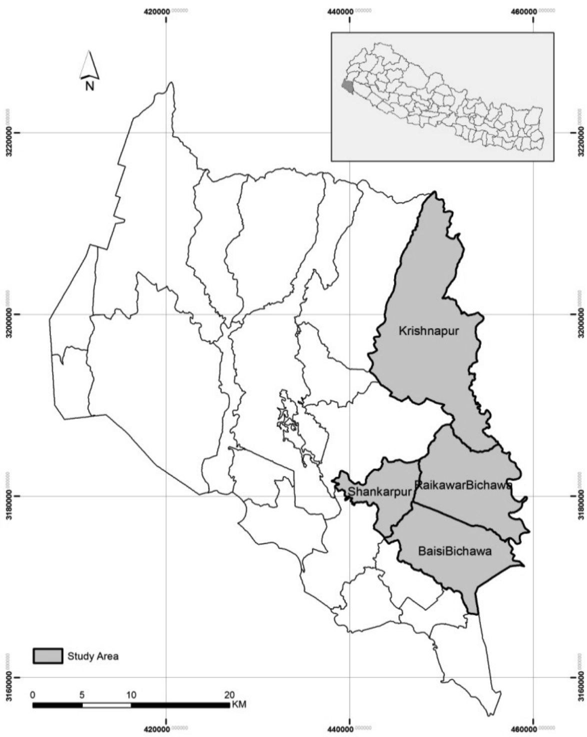

Fig. 1: Study area in kanchanpur district, Nepal

Data

Four Landsat images (Table 1) were downloaded from the United States Geological Service (USGS), Global Land Cover Facility (GLCF) (http:// glcf. umiacs.umd.edu/) web sites on 10 November 2010. All scenes correspond to the peak of the growing season of vegetation, with 9 to 13 years in between acquisitions. Ancillary datasets included 1964 aerial photographs from the Department of Forest Research and Survey , 2010 Rapid Eye image from Forest Resource Assessment Project Nepal as well as 1:25,000 topographic sheets from Survey Department. Landsat Multi Spectral Scanner (MSS) and Thematic Mapper (TM) satellite imageries selected for forest cover change analysis had covered a period of 33 years (1977 - 2010).

Table 1: Name and character of the images

Satellite Type	Sensor	Date	Spatial Resolution (m)
Landsat 2	MSS	1977 Jan 23	57
Landsat 5	TM	1990 Oct 23	30
Landsat 5	TM	1999 Nov 09	30
Landsat 5	TM	2010 Oct	30

Image preprocessing

Histogram matching was applied so that the histogram of multi-temporal imageries resembles each other and aid classification and change detection. All images were geo-referenced using Survey Department's Topo Layers and projected to Universe Transverse Mercator (UTM) zone 45. To match the pixel size with Landsat TM, re-sampling of MSS data to 30 m pixel was done using cubic convolution.

Image classification

The image classification was carried out using ERDAS Imagine 9.2. A supervised classification technique with maximum likelihood algorithm was applied. Landsat images of all the required data were classified into three broad classes: forest cover, water body and others (cultivated land, settlement, barren land). Training samples using ancillary datasets were taken as signature classes for classification. For classifying the image of 1977, 1990, 1999 and 2010, the aerial photo of 1966, topographic map of scale 1: 25000, Rapid Eye image of 2010 were used as reference along with Google Earth. After the classification filtering was done filtering out patches less than one hectare. After classification in ERDAS 9.2, the classification maps were exported to Arc GIS 9.2 for further processing.

Accuracy assessment

Typical accuracy assessment approach was applied, which involved verification of the randomly generated locations using reference data. For the quantitative analysis of the image classification, Kappa statistics was applied. Kappa statistics is a measure of agreement between image data and reference data (Jensen, 1996). Overall classification accuracy and Kappa coefficient statistics were derived for each image date as presented in table 2.

Table 2: Result of Kappa and accuracy assessment

Dates of image	Overall kappa coefficient	Overall classification accuracy
1977	0.9081	95.33%
1990	0.8942	93.33%
1999	0.9439	96.67%
2010	0.8494	91.33%

Forest cover change and fragmentation analysis

Post-classification techniques are considered to have limitations as comparison of land cover classification does not allow detection of subtle change within land cover categories (Macleod and Congalton, 1998). However, in the present study, since Landsat which is a coarse resolution image, was used focusing on only one forest class with threshold of more than one hectare size, change detection was performed using post-classification comparison method which produced acceptable results. The post classification technique of image differencing was applied on subsequent pairs of the classified single date images so that image difference data were obtained for the three time interval. The classified multi-temporal image with forest and non forest classes were analyzed using spatial statistics of FragStats 3.3 (McGarigal and Marks, 1995) interface inside Patch Analyst 4.2.13 (Rempel *et al.*, 2008) using metrics as listed in table 3.

Table 3: List of metrics

Landscape metrics	Description
CA	Class area (ha) sum of areas of all patches belonging to a given class.
NumP	Number of patches for each land use class
MPS	Mean patch size (ha)
MedPS	Median patch size (ha) the mpatch size, or 50th percentile.
PSCoV	Patch size coefficient of variance, coefficient of variation of patches.
PSSD	Patch size standard deviation (ha), standard deviation of patch areas.
TE	Total edge (m) sum of perimeter of forest class
ED	Edge density (m/ha) amount of edge relative to the landscape area.
MPE	Mean patch edge (m/patch) average amount of edge per patch (TE / NumP).

Results and discussion

Forest cover change

Landsat MSS Images and TM images of 1977, 1990, 1999 and 2010 were used to produce forest cover maps of the study area (Fig. 2). It was revealed that a considerable amount of forest (4581.72 ha) had decreased during the entire study period. Table 4 depicts the statistics on total forest area and the equivalent percentage of area changed during the time intervals. Highest loss of forest cover (2500 ha) took place between 1999 and 2010.

Table 4: Total Forest area in ha, percentage and change

Year	Forest area(ha)	Percent	Change area (ha)
1979	25902.42	72.66	-
1990	24573.78	69.26	-1328.64
1999	23866.32	67.26	-707.46
2010	21320.70	60.09	-2545.62

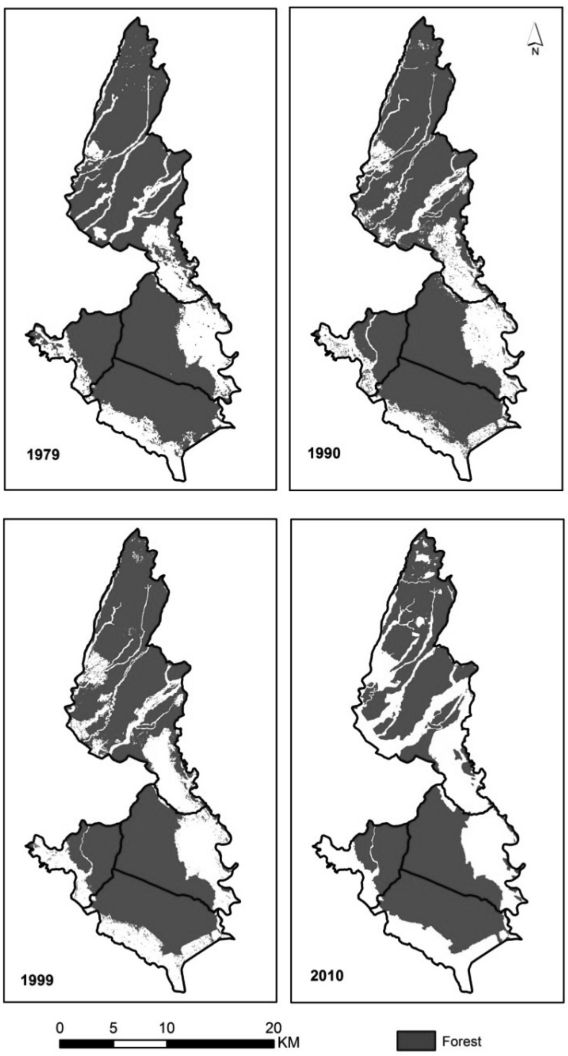

Fig. 2: Forest cover map of the study area in different time period

Forest fragmentation analysis

The analysis of selected landscape metrics depicted increase in fragmentation over the analysis time period along with progression of deforestation (Table 5). The sum of areas of patches belonging to forest class or the class area (CA) showed trend of deforestation. The number of forest patches (NumP) increased heavily in 1990s and declined sharply in 2010. Field observation as well as the interpretation of secondary data revealed that this may have happened because of many disturbances in forests due to road construction, deforestation and migration in 1990s. By 2010, most of the smaller forest patches had already been converted to other land use classes.

Table 5: Selected landscape metrics for forest class

Metrics	1979	1990	1999	2010
CA	25902.42	24573.78	23866.32	21320.70
NumP	113	153	95	52
MPS	229.22	160.61	251.22	410.01
MedPS	2.70	2.67	3.54	13.47
PSCoV	597.22	695.68	539.93	411.62
PSSD	1368.99	1117.35	1356.45	1687.72
TE	482975.2	656808.8	524871.1	393510.05
ED	18.64	26.72	21.99	18.46
MPE	4274.12	4292.87	5524.96	7567.50

Mean patch size (MPS) and Median patch size (MedPS) showed overall increment from 1979 to 2010, indicating disappearances of small sized patches. Patch size coefficient of variation (PSCoV) increased in 1990 but later decreased in subsequent time slices. Patch size standard deviation (PSSD) which measures absolute variation in patch size and is affected by the average patch size also showed the identical. Total edge (TE) which is sum of perimeter of patches showed decline trend in number of patches, while edge density (ED) remained almost static in the same time interval. However, the average amount of edge per patch, and the mean patch edge (MPE) almost doubled in 2010 as compared to 1979. It is interesting to note that for 2010, MPE is higher which is obtained by dividing total edge by number of patches though while both values are smaller than other time slices.

Conclusion

The multi-temporal forest cover change analysis revealed the important changes both in the areas of deforestation and fragmentation of forests. A very clear trend toward forest fragmentation was observed with a continuous trend over time of decreasing forest cover as indicated by increase in the number of forest patches and ultimately decreasing following the conversion of smaller patches to other land use types. The use of multi-temporal Landsat images to monitor spatial pattern of forest cover change further supports the potential applicability of Landsat sensor products for monitoring other land use dynamics in Nepalese terrain. However, it is recommended that to understand more detailed dynamics of landscape fragmentation, future research should use higher resolution datasets and encompass wider landscape units rather than part of a small corridor.

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