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Land use and land cover change analysis for Kosi River wildlife corridor in Terai Arc Landscape of Northern India: Implications for future management

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Abstract: This study is an attempt to characterize spatial and temporal patterns of land use land cover (LULC) changes, rate of deforestation, and develop future scenarios for Kosi River wildlife corridor using geospatial tools. One of the key corridors of Terai Arc Landscape, in the Himalayan foothills of northern India, Kosi River corridor provides crucial linkage between the Jim Corbett Tiger Reserve and the Ramnagar Forest Division. Growing anthropogenic disturbances in the landscape have led to fragmentation of existing wildlife habitats. The changes were mapped using remotely sensed multi-date satellite images (2009 and 2014) in geographic information system. Land Change Modeler was used to predict LULC distribution for 2020 and 2030 using current disturbance scenarios. The predicted map showed that if the current probability of change persists, dense forest would witness a decline of about 8.5 km^2 in area, while area under plantation would occupy 4.31% (27.9 km^2) of the total area by 2030. These changes are significant given the fact that the area is under protected area status. The study indicates that manmade obstructions, in the form of construction of resorts, buildings and residential houses, all along the Kosi River are the major reasons for increasing deforestation. Loss in forest cover outside Corbett Tiger Reserve may lead to loss of important connectivity between the core protected ecosystems, breaking the continuity of genetic exchanges amongst spatially isolated wildlife populations.

Key words: Change prediction, corridor, Corbett tiger reserve, habitat fragmentation, land change modeller, protected areas, transition probabilities.

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Introduction

Increasing biotic pressure in peripheries of protected areas (PAs) has resulted in fragmentation, and degradation of wildlife habitats (Kushwaha & Hazarika 2004; Ravan *et al.* 2005). Most of the PAs in India average 200–250 km^2 and are surrounded by dense human populations (Marcot 1992). These habitat fragments individually are too small to support viable populations of large mammals over the long term and isolated populations of large vertebrates in such refuges have a high probability of local extinction (Wikramanayake *et al.* 2004). Preservation and restoration of wildlife 'corridors' is one of the most widely accepted methods for moderating

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the negative effects of habitat loss and fragmentation (Beier *et al.* 2008; Marcot 1992; Ravan *et al.* 2005; Venkataraman 2005). Wildlife movement corridors also called dispersal corridors or landscape linkages are linear features whose primary wildlife function is to connect at least two significant habitat areas (Beier & Loe 1992). Corridors are meant to increase landscape connectivity, by facilitating exchange of genetic materials and movement of organisms between habitat fragments (Beier & Noss 1998; Ravan *et al.* 2005; Venkataraman 2005) and thus minimize the risk of inbreeding and extinction (Khanna *et al.* 2001).

As populations of large vertebrates like tiger and elephants are being confined to isolated habitat patches (Johnsingh *et al.* 2004; Singh *et al.* 2005; Wikramanayake *et al.* 2004), conservation biologists have identified landscapes where breeding tiger populations are linked by corridors, allowing interactions between spatially separated and isolated tiger populations (Sanderson *et al.* 2010; Wikramanyake *et al.* 1999).

The Terai-Arc Landscape (TAL), located along the Himalayan foothills in northwestern India, is identified as one of the global priority tiger conservation landscapes (Dinerstein *et al.* 2006). The human population density in TAL exceeds the national average (Johnsingh *et al.* 2004); consequently, tiger populations are confined to forest patches interspersed within a matrix of PAs, multiple-use forests (forest divisions), agricultural land and human habitation (Harihar *et al.* 2009). Potential tiger habitat in the landscape is fragmented into nine disjunct forest blocks referred as Tiger Habitat Blocks (THB), with poor or no connectivity (Johnsingh *et al.* 2004; Harihar *et al.* 2009). In response conservation biologists have identified about 10 corridors that are crucial for enabling movement of tigers between the THBs and thus have significant management implications (Easa 2005; Johnsingh *et al.* 2004).

Satellite imageries combined with geographical information systems (GIS) proved to be effective tools in adopting landscape level spatial analysis (Beier *et al.* 2008; Ravan *et al.* 2005; Wikramanayake *et al.* 2004). Synoptic and repetitive coverage of space borne imagery are useful for detection of changes at various resolutions and thereby generate information for sound planning and cost-effective decision making (Joshi *et al.* 2006; Ricketts 1992). Keeping this in view the study was conducted to assess the impacts of anthropogenic disturbances on Kosi River corridor, which provides physical linkage between Corbett tiger reserve (CTR) and Ramnagar forest division (Johnsingh 2006). Increased tourism activities around CTR have raised serious concern on the existing biological diversity in the area. Through this study an attempt was made to assess the magnitude and direction of land use land cover (LULC) changes in the corridor area using satellite images of 2009 and 2014, and model the future changes for 2020 and 2030.

A number of land use change prediction have been developed, however it is difficult to compare which one gives more accurate representation (Wu & Webster 2000). Among the number of modelling tools and techniques, the commonly used models are the modelling techniques embedded in IDRISI (Clark Labs 2006). These are Land Change Modeler (LCM), Cellular Automata, Markov Chain, CA_Markov, GEOMOD and STCHOICE (Eastman 2006). But LCM is widely used modelling technique. The LCM module works on neural network and needs to reach higher accuracy, but accuracy depends much on influencing variables. In LCM, two options of modelling algorithms that are used to model selected transition variables, viz. logistic regression and Multi-Layer Perceptron (MLP) neural network. MLP uses minimal parameters and it is more easily approachable. Also MLP neural network has been extensively enhanced to offer an automatic mode that requires no user intervention (Mishra *et al.* 2014). Hence, MLP network was used in this study.

Materials and methodology

Study area

The study area extends from Ramnagar town in the south to Kunkhet in the north, covering an area of 529 km^2 along the bank of Kosi River in TAL (Fig. 1). Kosi is one of the largest tributaries of River Ramganga, and from Mohan through Dhikuli till Ramangar, the river forms the eastern boundary of CTR.

Wild animals from CTR use it for drinking especially during pinch periods (Johnsingh *et al.* 2004; Singh 2002). Forest connectivity is available in four places within the corridor area, viz. (a) for a stretch of 5 km between Mohan and Kumaria; (b) 1.5 km between Dhangari gate and Sundarkhal; (c) 100 m between the two blocks of Sundarkhal and 6 km between Infinity Resorts and Bijrani

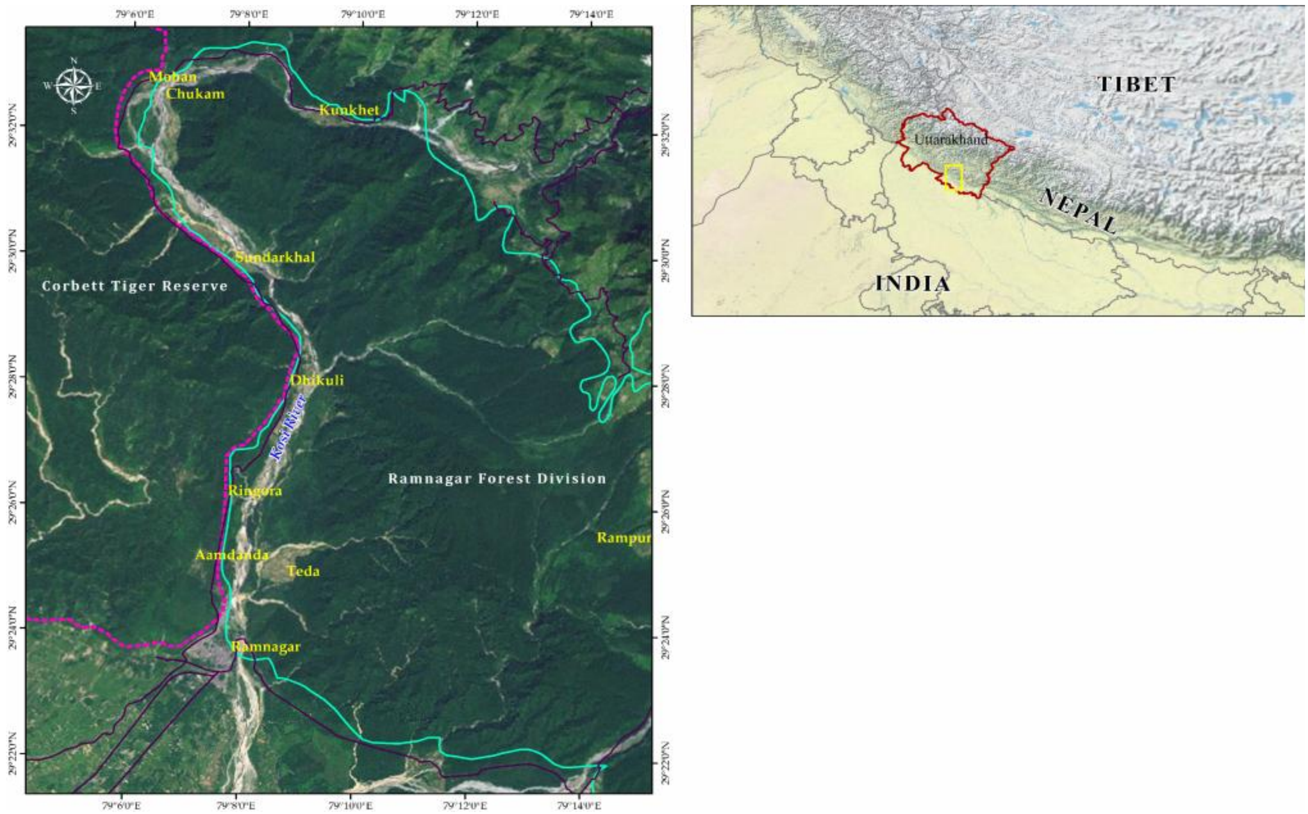


Fig. 1. Map showing location of Kosi River corridor.

(Johnsingh 2006). CTR is presumably among the best habitat for tiger in the Himalayan region, rich alluvial grasslands spread over hundreds of hectares offers excellent habitat for tigers (Singh 2002). The major problem facing the CTR is human population growth around the area. In addition, a state highway runs along the eastern boundary of CTR from Ramnagar to Marchula (Singh *et al.* 2009). Besides, the presence of Indian Medicines Pharmaceutical Corporation Limited (IMPL), Garjia Chemical factory and resorts at prominent locations (Johnsingh 2006) within the corridor area has added to the problems. Most of the people living in surrounding areas of the reserve are engaged in agriculture however with development of tourism a section of the population is engaged in the tourism industry (Johnsingh *et al.* 2004).

Data used

The changes in LULC were mapped using IRS-P6 LISS IV satellite images for 2009 and 2014, procured from National Remote Sensing Centre, Hyderabad. The procured images were geometrically corrected using 1: 50,000 Survey of India (SOI) toposheets for the given area and was referenced to geographic coordinate system, WGS84 datum. The two time period satellite data were then subsetted to obtain the study area. Digital Elevation Model (DEM) of the area was downloaded from the Advanced Spaceborne Thermal Emission and Reflection (ASTER) Global DEM website (http://gdem.ersdac.jspacesystems.or.jp/). State Forest Department (Government of Uttarakand) reference maps and SOI toposheets were used to generate ancillary database on road network and settlements. Three software were used in the study, viz. ArcGIS (ESRI 2011) for paper map digitization, data overlay and map preparation, ERDAS Imagine for satellite image processing and IDRISI Andes for change analysis and prediction modelling.

Land use land cover classification

The processed satellite images of 2009 and 2014 were on-screen visually interpreted and classified using unsupervised classification (ISODATA technique). The produced maps were compared with the respective satellite images and were cleaned by recoding. Built-up areas and water bodies were captured separately using Area of Interest (AOI) tools and subsequently recoded (Areendran *et al.* 2013a). After classification the LULC datasets were re-projected to the UTM coordinate system (Zone 44, WGS 84 datum) for calculation of area statistics and modelling. Field verification of the final output was carried out to calculate the accuracy of 2014 LULC. Field survey was done in the post-monsoon season. Random points were selected and at each location the existing LULC and the coordinate information was noted using Global Positioning System (GPS).

Change analysis

Post-classification comparison method, which is the most common approach in change detection studies (Miller *et al.* 1998; Zhou *et al.* 2004), was applied in this study. Change analysis was done using LCM of IDRISI Andes. Changes in LULC were computed by comparing maps of 2009 and 2014, pixel by pixel to show the changes from one class to another. The generated change

$$r = \frac{\left(\ln\left(A_{t1}\right) - \ln\left(A_{t0}\right)\right)}{t1 - t0} \times 100 \qquad (1)$$

where, r is the rate of LULC change, and A_{t0} and A_{t1} are the forest cover at time t_0 and t_1 respectively (Puyravaud 2003).

Change prediction

The road, settlement and new developments (IMPL, chemical factory and resort location points) vector layers were converted to raster format. ASTER DEM was used to prepare slope and aspect maps. These six variable layers (road, settlement, new developments, DEM, slope and aspect) were converted to *.rst* format of IDRISI. Distance maps were prepared for road and settlement layers by calculating the Euclidean distance between the pixels and the target layer. Apart from these quantitative variables, a seventh qualitative variable, which is empirical likelihood to change map was also prepared. For preparing this, a map showing changes from all LULC classes to built-up area was prepared. The map was changed to probability (0–1) using evidence likelihood transformation (Munsi *et al.* 2012). It is based on the frequency of pixels of different categories to appear within the change area (Eastman 2009). The transition potential maps were prepared using seven variables as input, the transitions to be modelled were selected and the procedure used was based on MLP neural network using Back Propagation algorithm. MLP is an artificial neural network that learns non-linear function mappings. A typical Back Propagation network contains one input layer, one or more hidden layers and one output layer (Gautam & Panigrahi 2007; Munsi *et al.* 2012). In this case the seven explanatory variables were the input layers, and the transitions to be modelled were the output layers. The training of the model is completed in a successive number of iterations when the change in error is sufficiently small (or less than the user defined limit) (Gautam & Panigrahi 2007). After completion of training in MLP, transition potential modelling is used to prepare transition maps. Each of the transition maps were given weight on the basis of transition probabilities obtained from Markov transition matrix for 2020 and 2030. The process analyzes two LULC images from different dates and produces a transition probability matrix, which calculates the transition from one class to another. Then the transition probabilities generated from past and present changes were applied to predict future change (Wijanarto 2006). On the basis of the transition probabilities hard prediction modelling was carried out. The hard prediction process is based on multi-objective land allocation. It looks through all transitions and creates a matrix of host classes (classes that will lose some amount of land) and a list of claimant classes (classes that will acquire land) for each host (Eastman 2009). Finally, the results of the reallocation of each host class are overlaid to produce prediction maps.

Validation

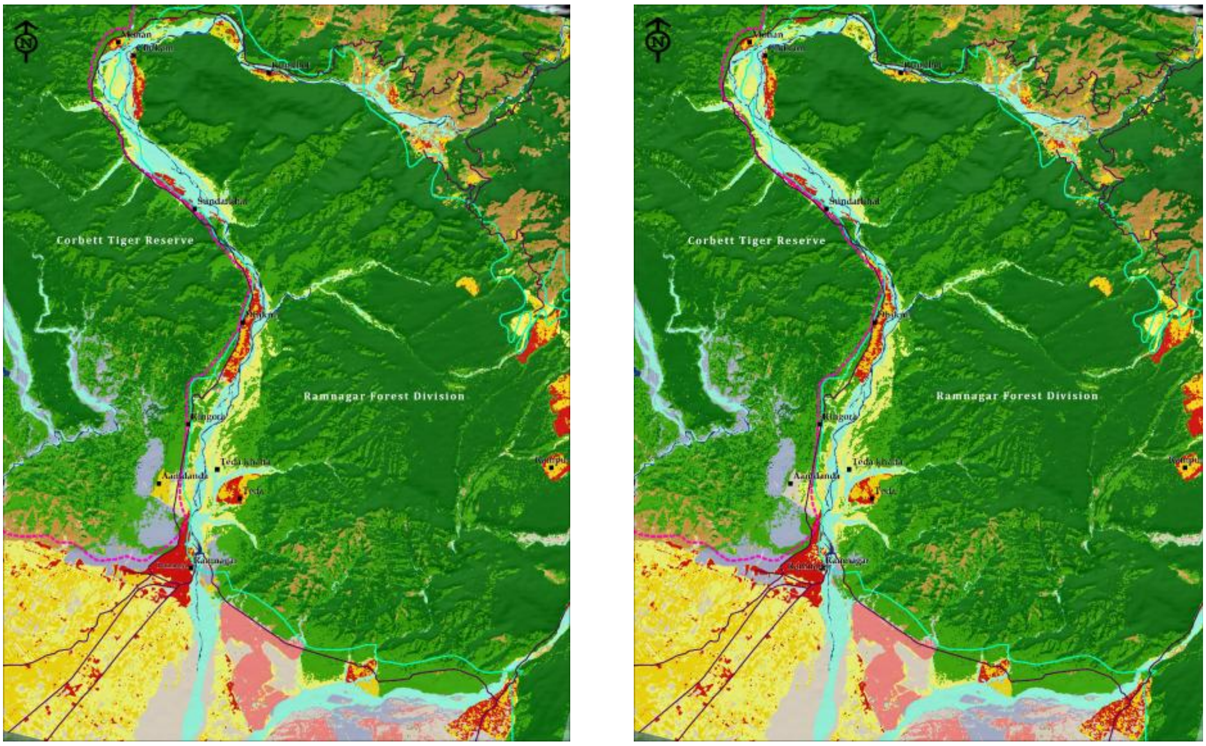
For validating the model, a LULC map was predicted for 2014 using archived LULC data of 2005 for the same area extent. The VALIDATE module of IDRISI Andes was used to compare the predicted 2014 LULC with the actual 2014 LULC. This module compares the two LULC maps and measures the agreement of cells and location of cells in each class (Eastman 2009).

Results and Discussions

Land use land cover mapping

The LULC maps depicting eleven classes were prepared for 2009 and 2014 (Fig. 2). Area covered by various LULC classes and the changes in area are given in Table 1. Three forest density classes, viz. dense forest (canopy density of more than 40%), open forest (canopy density between 10 and 40%) and scrubs (canopy density less than 10%; FSI 2010), along with water bodies, sandy river bed, rocky exposure, plantation, open/barren land, built-up area, cropland and agricultural fallow land were derived from remote sensing data.

Grasslands, which are typical to CTR, have been merged with scrubs in the classification. The spatial distribution of forest cover indicated that dense and open forests are confined to the Reserve areas, which are the hilly tracts to the north of Ramnagar town, and are largely composed of *Sal* (Singh *et al.* 2009). Cropland and agricultural fallow land covered majority of the plain area in



(a) (b)

Fig. 2. Land use land cover maps for 2009 (a) and 2014 (b).

Table 1. Estimated area under different land use land cover classes.

LULC class	2009		2014		2020 (predicted)		2030 (predicted)	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Dense forest	300.00	46.15	298.51	45.92	297.38	45.75	290.00	44.61
Open forest	130.27	20.04	130.71	20.11	131.17	20.18	134.56	20.70
Water body	3.17	0.49	3.17	0.49	3.17	0.49	3.16	0.49
Built-up	10.16	1.56	10.75	1.65	11.41	1.75	14.33	2.20
Cropland	26.60	4.09	27.27	4.19	27.74	4.27	29.85	4.59
Fallow land	36.59	5.63	36.23	5.57	35.89	5.52	33.83	5.20
Sand	29.49	4.54	29.48	4.54	29.55	4.55	29.56	4.55
Grass/ Scrubs	12.94	1.99	13.43	2.07	13.97	2.15	16.44	2.53
Open/Barren land	37.65	5.79	37.31	5.74	36.73	5.65	35.30	5.43
Rocky exposure	35.26	5.42	35.26	5.42	35.03	5.39	35.01	5.39
Plantation	27.92	4.29	27.92	4.29	27.99	4.31	27.99	4.31

the southern part. Some of the cropland and agricultural fallow land can also be seen along the Kosi River bed. Plantations are mainly found in the southern part, mostly along the fringes of Ramnagar Forest Division. Scrubs/grasslands were found all along the river bed and other small channels draining the area. Built-up areas are mostly concentrated in the low lying areas in the southern part and along the river. Ramnagar, Dhikuli, Sunderkhal, Chukam and Kunkhet are main human habitations located within the corridor area.

Dense forest has decreased over the period, whereas open forest and scrubs have increased owing to the contribution from dense forest. This can largely be attributed to deforestation and degradation. Dependence on forest for fuel, timber, livestock grazing by Gujjar and Bhotia camps, and conversion of natural forest into monoculture, and tea and eucalyptus plantations (Panwar 1985; Singh *et al.* 2005) have all contributed towards forest degradation and fragmentation. Area under cropland and built-up areas increased during the time period. Human encroachment is one of the key problems of this corridor (Panwar 1985). The encroachment of Sunderkhal was primarily forest land which was encroached by small farmers for small gains but over the years it has grown almost into a village and hits right across the corridor (Khanna *et al.* 2001; Panwar 1985). This encroachment, which stretches over a length of three km in a narrow strip along the river, is also an impediment to animals moving to Kosi River for water (Johnsingh 2006; Panwar 1985). Increase in tourism activities led to a spurge of hotels and resorts all along the Kosi between Ramnagar and Dhangarhi (Khanna *et al.* 2001), resulting in increase in built-up areas and cropland. Moreover, establishment of IMPL and Garjia chemical factory (Johnsingh *et al.* 2004) have also resulted in increase in human population and consequent built-up areas.

The field data were used to calculate the accuracy of the LULC map of 2014 using the common 'confusion matrix' method (Areendran *et al.* 2013b). The overall accuracy of the map was 79.09% with a Kappa coefficient of 0.77.

Change analysis

Change matrix (Table 2) shows the change in area from one LULC class to another. The diagonal cells of the matrix represent the area that has remained same in both the time periods. Other cell values represent the area that has changed from one class to another class.

Within a period of five years (2009–2014) 1.45 km^2 of area under dense forest was transformed into open forest. Open forest was transformed into scrubs, though the change was < 1 km^2. Similarly, change matrix showed conversion of forests to non-forest LULC classes. Open forest and scrubs were transformed to cropland during 2009–2014. About 57 ha of forested area got converted to agricultural land (cropland and agricultural fallow land) in the mentioned period. Huge biotic pressure posed by large scale conversion of forested tracts and grassland into cropland has resulted in reduction of forest density, habitat fragmentation, shrinkage and degradation of wildlife habitats (Areendran *et al.* 2011; Singh 2002). This is one of the prime reasons for increased human-animal conflict. As humans have moved into the wild lands, spaces required by the large mammals are isolated into small patches of forests that are surrounded by cropland. When forced to share habitat with humans, the wild animals become rogue and even occasionally attack people (Khanna *et al.* 2001).

The dense forest decreased, open forest and scrub/grassland areas increased at a positive rate (Table 3). The growth in grass/scrubland areas was quite significant for the period. The montane forests have become highly fragmented and rich alluvial grasslands are mostly cleared for agriculture. Expanding human populations, increased development, and extraction of firewood and fodder are the principle causes of disturbance and degradation within forests (Kanagaraj *et al.* 2011). This is evident from the increase in cropland and built-up areas, with the later growing at a rate of 1.90 km^2 per year.

Change prediction

Markov transition probabilities for 2020 and 2030 are given in Tables 4 and 5 respectively. The diagonal cells represent the probability that an area will remain under the same class. By comparing the two matrices, it can be concluded that probability of dense forest remaining in the same class has reduced in the next time period (2030). It has the highest probability of conversion to open forest which in turn has the highest probability of getting converted scrubs/grassland and also to cropland. Similarly, scrubs/grasslands have the highest probability of being transformed to cropland. Changes in LULC within the corridor area have altered the existing tiger habitats in the

Table 2. Land use land cover change matrix for 2009–2014 (area in km²).

2009	2014										
	Df	Of	Wb	Bu	Cl	Fl	Sa	Gr/Sc	Ol/Bl	Rex	Pl
Df	298.51	1.45	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Of	0.00	129.26	0.00	0.00	0.15	0.06	0.00	0.79	0.00	0.00	0.00
Wb	0.00	0.00	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bu	0.00	0.00	0.00	10.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.00	0.00	0.00	0.45	26.14	0.01	0.00	0.00	0.00	0.00	0.00
Fl	0.00	0.00	0.00	0.20	0.26	36.12	0.00	0.01	0.00	0.00	0.00
Sa	0.00	0.00	0.00	0.00	0.01	0.00	29.48	0.00	0.00	0.00	0.00
Gr/Sc	0.00	0.00	0.00	0.00	0.32	0.04	0.00	12.59	0.00	0.00	0.00
Ol/Bl	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	37.31	0.00	0.00
Rex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.26	0.00
Pl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.92

Df–dense forest; Of–open forest; Wb–water bodies; Bu–built-up land; Cl–cropland; Fl–fallow land; Sa–sand; Gr/Sc–grass/scrub area; Ol/Bl–open land/barren land; Rex–rocky exposure; Pl–plantation

Table 3. Rate of land use land cover change during 2009–2014.

LULC class	Rate of change
Dense Forest	–0.17
Open Forest	0.11
Water Bodies	–0.01
Built-up Land	1.90
Cropland	0.83
Fallow land	–0.33
Sand	0.00
Grass/ Scrubs	1.23
Open/Barren land	–0.30
Rocky exposure	0.00
Plantation	0.00

subtropical forest that once extended all along the Himalayan foothills is now highly fragmented, and along with it, the resident tiger and elephant populations (Singh *et al.* 2005; Wikramanayake *et al.* 2004). The reduced and narrow corridors deter the movement of large animals across these corridors (Khanna *et al.* 2001). The likelihood of scrubs and cropland getting transformed to built-up areas has increased over time. Comparing predicted 2014 LULC map and actual LULC map validated the model. This gave an accuracy of 66.14%, which is acceptable as the number of classes is high and accuracy decreases with number of class (Munsi *et al.* 2012).

Table 4. Markov transition probabilities for 2020.

2014	2020										
	Df	Of	Wb	Bu	Cl	Fl	Sa	Gr/Sc	Ol/Bl	Rex	Pl
Df	0.84	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Of	0.00	0.79	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Wb	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bu	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Cl	0.00	0.00	0.00	0.02	0.98	0.00	0.00	0.00	0.00	0.00	0.00
Fl	0.00	0.00	0.00	0.01	0.01	0.99	0.00	0.00	0.00	0.00	0.00
Sa	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Gr/Sc	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.97	0.00	0.00	0.00
Ol/Bl	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.99	0.00	0.00
Rex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Pl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Df–dense forest; Of–open forest; Wb–water bodies; Bu–built-up land; Cl–cropland; Fl–fallow land; Sa–sand; Gr/Sc–grass/scrub area; Ol/Bl–open land/barren land; Rex–rocky exposure; Pl–plantation

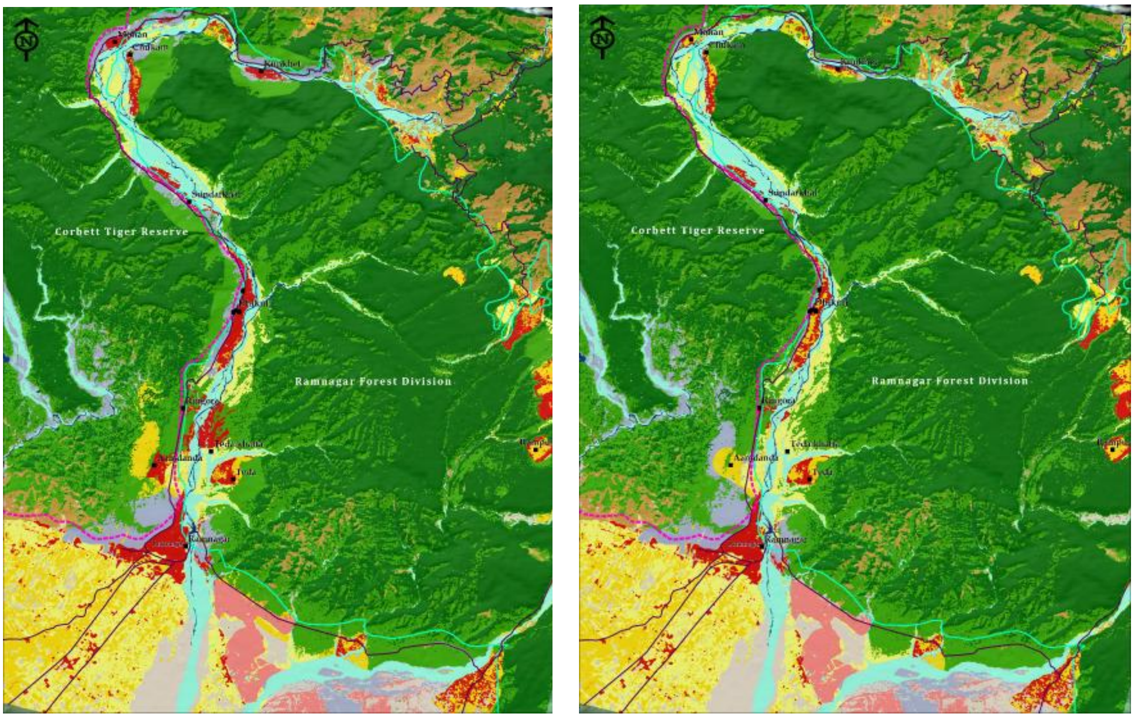
Table 5. Markov transition probabilities for 2030.

2014	2030										
	Df	Of	Wb	Bu	Cl	Fl	Sa	Gr/Sc	Ol/Bl	Rex	Pl
Df	0.81	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Of	0.00	0.70	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.00	0.00
Wb	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bu	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Cl	0.00	0.00	0.00	0.11	0.89	0.00	0.00	0.00	0.00	0.00	0.00
Fl	0.00	0.00	0.00	0.04	0.04	0.92	0.00	0.00	0.00	0.00	0.00
Sa	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Gr/Sc	0.00	0.00	0.00	0.02	0.14	0.02	0.00	0.83	0.00	0.00	0.00
Ol/Bl	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.94	0.00	0.00
Rex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Pl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Df–dense forest; Of–open forest; Wb–water bodies; Bu–built-up land; Cl–cropland; Fl–fallow land; Sa–sand; Gr/Sc–grass/scrub area; Ol/Bl–open land/barren land; Rex–rocky exposure; Pl–plantation

The LULC maps of 2020 and 2030 are product of hard prediction model and show probable spatial distribution of various LULC classes (Fig. 3).

The predicted map showed that if the current probability of change persists, dense forest would witness a decline of about 8.5 km^2 in area, while area under scrubs/grass would increase to 2.53% of the total area (Table 1). These changes are significant given the fact that the area is under protected area status. These areas are dominated by forest monoculture plantations of softwood and hardwood which replaced the mixed forests and grassland habitats in the 1960s to meet industrial needs in the region (Johnsingh & Negi 2003).



(a) (b)

Fig. 3. Predicted land use land cover maps for 2020 (a) and 2030 (b).

Conclusions

The corridor along the Kosi River is very precious and need to be protected. This is a massive task as lots of economic interests of the people, local as well as outsiders, are involved. Clearing of this corridor from obstructions is a monumental task requiring stupendous political will and cooperation of the local people and administrative acumen (Singh 2002).

The study highlights the capability of remote sensing and GIS in analysing and predicting the LULC change dynamics. LULC distribution for 2009 and 2014 was analysed and based on the past and present probabilities of changes predicted the future (2020 and 2030) land cover distribution in Kosi corridor area. The area has undergone LULC changes during the period which is likely to affect the forest connectivity used by wildlife to move from one habitat to the other. The results of our LULC mapping show that major changes have occurred all along the Kosi especially in and around Ramnagar, Sundarkhal, Dikhuli, Chukam and Kunkhet (Johnsingh 2006). Loss in forest cover due to developmental activities is evident from the change matrix. Construction of resorts, buildings and residential houses between the state highway and along the Kosi River from Ramnagar to Mohan up to Marchula continues unabated (Bijoy 2011). The transition matrices suggest that the forested areas are prone to future transformations as well. Thus, it can be concluded from the study that man-made obstructions are coming in the way of free movement of wildlife across the river and lead to habitat isolation (Singh 2002). Studies like this one would help in planning, management and utilization of land and other natural resources. It can form potential tool at research level, policy formulation level and policy implementation level, which will help in proper management of landscapes.

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