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Research Article

HOW SECURE IS OUR RECORDED FORESTLAND? – A CASE STUDY OF DEHRADUN USING GEOSPATIAL APPROACH

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ABSTRACT
India has a huge population living close to the forest with their livelihoods critically linked to the forest ecosystem. People living in these forest fringe villages depend upon forest for a variety of goods and services like collection of edible fruits, flowers, roots and leaves for food and medicines; firewood; fodder and grazing of livestock in forest. Therefore, with such extensive dependence pattern, any over exploitation and unsustainable harvest practice can potentially degrade forest. The study aims to find 1) whether the land transformation into habitation or agriculture has occurred in recorded forestland area 2) use of LISS IV satellite data to map human intrusion 3) whether land transformation decreases along the altitude. This study highlights the area under recorded forestland that has undergone land transformation since 1965 to 2008 in Dehradun district. It is found that around 3336.34 ha of forestland have undergone land transformation, a major part of which lies all along the forest fringes indicating heavy human pressure of nearby communities. A monitoring plan along with people's awareness and their participation is advised to forest fringe communities to conserve and sustain the forest resources.

***Key Words**: Land Transformation, Remote Sensing, Recorded Forestland*

INTRODUCTION
Land Transformation (LT) is the process where changes in land use/cover are observed at different time periods and is one of the important fields of human induced environmental transformation. Land is in a continuous state of transformation as a result of various natural and man- made processes. An accurate and continuously updated resource data is a prerequisite for the present-day forest ecosystem management. Because of the synoptic and repetitive data acquisition capabilities, satellite-based sensors have the potential to detect, identify and map canopy changes that are important to the forest ecosystem managers (Coppin and Bauer, 1996). Timely and accurate change detection of earth's surface features provides the foundation for better understanding of the relationships and interactions between human and natural phenomena to better manage and use natural resources (Lu *et al.,* 2007). Kristensen *et al.,* (1997) have claimed that the forest change detection mapping from satellite imagery is the 'most powerful monitoring tool' for conservation practices. The change is usually detected by comparison between two or multiple-dates satellite images, or sometimes between old maps and a recent remote sensing images. Infact, the high resolution Digital Globe satellite data available on Google Earth application have been used as the ground truth data (Valožić and Cvitanović, 2011).
There are around 1.73 lakh villages located in and around forests (MoEF, 2006). Though no official census figures are available for the forest dependent population in the country, different estimates put the figures from 275 million (World Bank, 2006) to 350- 400 million (MoEF, 2009). Agriculture and livestock are two other major sources of livelihoods in the forest fringe villages, which in turn depend extensively on the forest for various inputs. Open grazing in the forest is the conventional rearing practices for forest fringe communities and has adverse impact on growing stock as well as regeneration capacity of forest when there is over grazing due to more livestock.
India is one of those few countries to have a robust and scientific system of monitoring forest resources by using remote sensing technology since 1987 (FSI, 2011). Over the past two decades the forest cover of India has remain more or less around 21% of total geographical area against the national forest policy which aims it to be around 33%. Because of India's forest protecting laws (MoEF, 2013), the forest area

doesn't seems to undergo large land use/cover changes, however the forest cover is not even rising as per expectation. The case study of Dehradun presented here demarcates the area under recorded forest (RF) that has undergone LT since 1965.

The forest of Doon valley is dominant by Moist Sal forest (Champion and Seth, 1968). Major loss in vegetation cover and substantial increase in habitation/ arable land area was reported in Dehradun by Richards (1987) due to rapid development of metropolitan area and massive population growth during the period 1880-1980. As per latest census 2011, Dehradun has noticed an increase of 32% population since 2001. The LT sites here indicate either habitation or agriculture. They actually represent the human intrusion, the nature of which is to be confirmed on ground i.e. they could be the construction activity of forest department or a nursery else encroachment/ agriculture field. There could be forestland diversion due to some development project. The RF are declared recorded forest area in the government records and belong to either protected forest or reserve forest where human activity is strictly prohibited or restricted. These forests remain more or less intact without anthropogenic pressure and usually increase in area or density because of conservation strategies. Mountain areas have always posed enormous challenges for human habitation. The productive activity is restricted by variations in altitude, slope, aspect, thermal regime and water availability. Moreover the unsustainability of mountain agriculture has caused large proportion of the population to migrate to more productive areas in the plain (Sati and Kumar, 2004). Therefore human activity is expected to decrease along the altitude.

Study Area and Climate

The Dehradun district lies between 77º37'49.75" to 78º01'22.81"E longitude and 30º58'30.63" to 30 º22' 36.04" N latitude. It possesses various types of physical geography from Himalaya to Plains. The district is bordered by the Himalayas in the north, Sivalik Hills to the south, river Ganges to the east, and Yamuna River to the west. This district is divided into two major parts, the main city Dehradun surrounded by Shivalik and the Himalayas, and Jaunsar Bavar, which is located in the foothills of Himalayas. The Doon valley has the Terai and Bhabar forests within it as well as the Shiwalik hills and Lesser Himalayan Range containing hill stations such as Mussoorie and Chakrata. Dehradun possess a population of 1,698,560 (Census of India, 2011).

The climate of Dehradun is generally temperate, although it varies from tropical; from hot in summers to severely cold, depending upon the season and the altitude of the specific location. The nearby hilly regions often get snowfall during winter. Summer temperatures can often reach 43°C whereas winter temperatures are usually between 2-20°C. During the monsoon season, there is often heavy and protracted rainfall. The weather is considered to be good during winter in the hilly regions. Agriculture benefits from fertile alluvial soil, adequate drainage and plentiful rain.

MATERIALS AND METHODS

The LT in RF was analysed from 1965 (SOI toposheets) to 2008 (satellite data belongs to this period). Since boundary of RF was not available, the greenwash area given in SOI toposheets was considered as proxy RF area. The toposheets used was at 1:50,000 scale. The high resolution LISS IV (spatial resolution= 5.8m) and moderate resolution LISS III (spatial resolution= 23m) data of Indian Remote Sensing satellite P6 from 2008 (Oct to Jan period) was used. LISS IV data covers 90% area, LISS III covers 5% and the remaining 5% area was considered via google earth (depicted in Figure 1) due to non-availability of any satellite data for corresponding area.

The Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model data (spatial resolution= 30m) used to carry out geospatial analysis along terrain was downloaded from http://www.jspacesystems.or.jp/ersdac/GDEM/E/ website. The geo-referencing of SOI toposheets were done using *ERDAS IMAGINE* 9.3 software.

They were all mosaic and subset using district boundary. The greenwash layer and forest fringe villages were digitized using Geographical Information System software (ArcGIS 9.1). The pre-processing of satellite data includes first order radiometric corrections done by dark pixel subtraction technique (Chavez *et al.*, 1977). Well distributed 30-50 ground control points were considered for geo-rectification and images were resampled using first order nearest neighbour interpolation model with an error less than one pixel. Standard product (False color composite) with its pre-specified lookup tables does not provide significant contrast discrimination of various features of interest.

Therefore, to facilitate the task of image interpretation, histogram equalization was used. Following projection parameters were adopted for preparing and carrying out geospatial analysis- Projection type: UTM, Spheroid and Datum Name: WGS 84, UTM zone: 44, North. The satellite data was visually interpreted in the RF area for delineating the area where habitation (distinguished on the basis of shape, size, tone) or agriculture (identified through tone, texture, pattern and association with nearby residential structures) was found.

The sites of LT area were marked by point layer after the name of nearest settlement using SOI toposheets. The ASTER GDEM data was classified into three altitudinal classes (< 1000m, 1000-2000m and > 2000m) and LT at each class was spatially analysed.

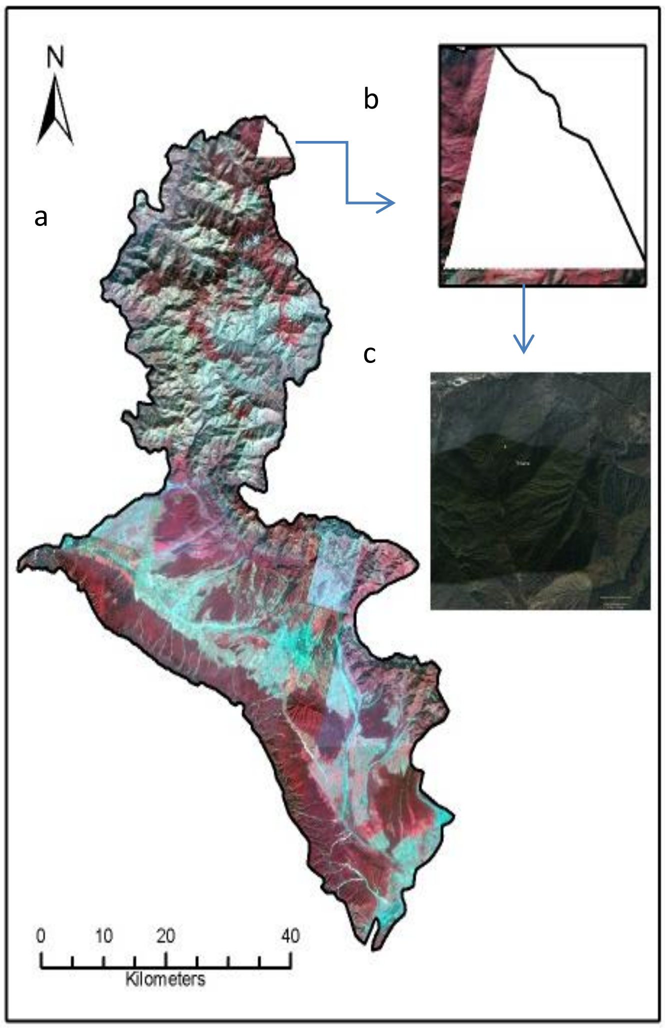

Figure 1: a) Mosaic False Color Composite of Dehradun. b) The area under no data c) Google Earth Digital Globe data corresponding to no data area in FCC, captured on 5 April 2012.

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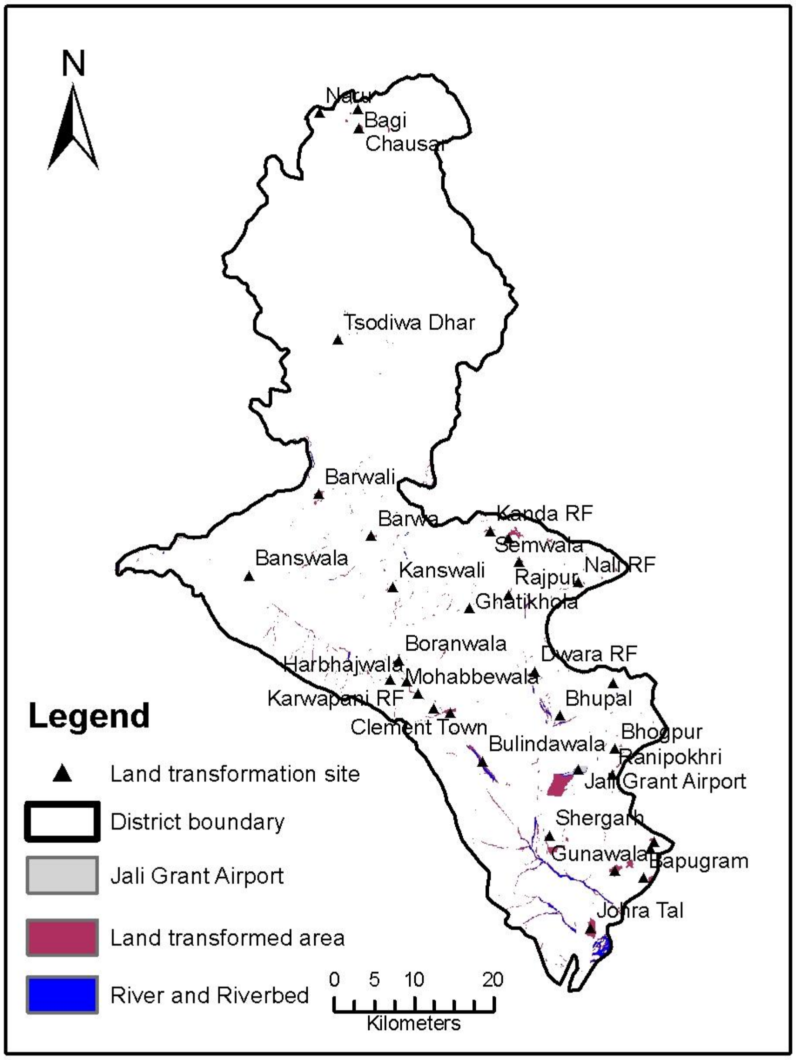

Figure 2: Map showing LT at various locations in Dehradun

RESULTS AND DISCUSSION

The study reveals that LT has occurred on wide scale within the boundary of RF. The high resolution LISS IV data is successful in detecting such LT occurring in small patches and sparse manner. The LT area under various altitudinal classes is given in table 1. The maximum LT area is found at below 900m category thus proving more human activity at lower altitude followed by higher altitude (above 1800m) while the least LT area lies between 900- 1800m class. The map showing the LT at various locations of Dehradun is shown in Figure 2. Overall around 3336.34 ha of forestland have undergone land transformation in Dehradun.

Table 1: Area statistics of various classes in different altitudinal zones

S No	Altitudinal class	District area (ha)	RF area (ha)	Land transformation (H\A)
1	< 900m	163803.61	90452.81	2671.48
2	900 - 1800m	92323.06	23747.19	256.74
3	> 1800m	52673.33	31482.56	408.13

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The LT sites resulted from satellite data of 2008 dataset were compared with the higher resolution Quick Bird images (dated from September -March 2009-2013) available on Google Earth application that served as the ground truth data. 48 out of 55 sample locations matched the ground truth locations. Of the remaining 7 sites, degraded forest was found on 3 sites while grassland was found on rest of the 4 cases. Field visit was also made to get complete assurance of results at few locations. People were seen grazing their cattle and collecting fodder & fuelwood within the RF area.

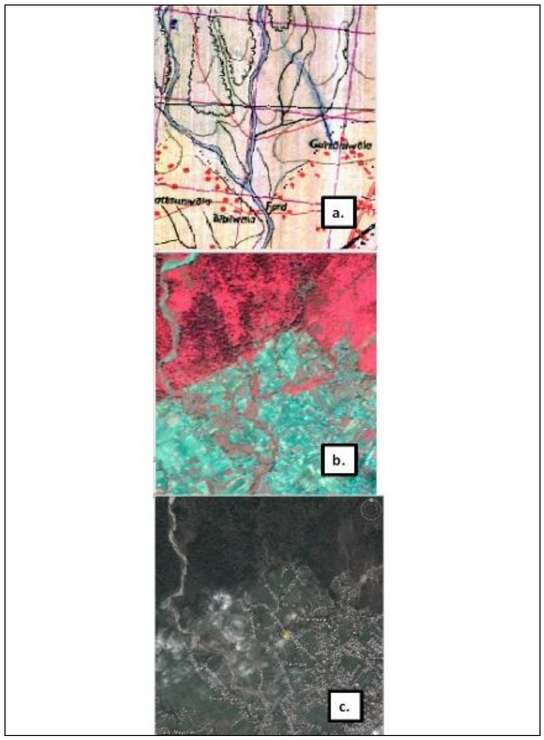

Figure 3: Compared area of the LT sites at below 1000m altitudinal class, as seen in a) SOI toposheet (scale 1:11000) b) FCC (scale 1:11000) c) Google Earth (scale 1:500m, alt eye = 2.51km)

The maximum conversion was found in Thano RF area due to LT into habitation and establishment of an airport in around 2008. The verification done using Google earth seems to be satisfactory and can be used wherever very high resolution digital globe data is available (Figure 3). One unique pattern observed is an edge effect leading to the loss of forest all along the boundary of RF, a case especially observed in Malhan RF. The LT sites are sparsely distributed in rest of the district.

Conclusion

Based on these results it seems that even the forest within RF boundary is not secured. The land transformation is occurring at minute scale which is not caught by FSI's regular monitoring because of the use of moderate resolution LISS III data. The reasons responsible for these LT are a) If forest department is involved, it must be purposefully done for making Forest Rest houses or nursery. b) If forest department is not involved then it is possibly the increasing population pressure forcing people's dependency on adjacent forestland for agriculture/ habitation. Since habitation is also found in RF area, the possibility of encroachment cannot be ignored. c) The need of airport in the vicinity of city is another reason for LT. A further study is suggested on assessing socio-economic status and dependency of forest fringe communities on adjacent forest resources which may complement these findings for better understanding of whole scenario. The society's progress demands infrastructural development but at what cost it takes place is something to be thought and planned for lasting ecological services. People's participation in addition to landuse planning around the RF may help in stopping illegal LT. Being a mountainous and eco-sensitive region, focus should be given to green development. Since LT are mostly habitation/ agriculture, it takes time for such change to occur. Therefore a period of five year sounds good for cost effective space based monitoring plan. The need is to take every possible step and formulate a policy which would increase the safety and integrity of forest unit.

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