Article

Forest and land use mapping using Remote Sensing and Geographical Information System: A case study on model system

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Abstract
Remote sensing and geospatial technologies find tremendous application in rapid spatial and temporal monitoring as well as assessment of tropical forest resources and hence in formulation of concrete policy frameworks for their sustainable management. Present paper provides an overview on application of remote sensing in forestry and ecology with a case study which may be further extrapolated in other Indian Himalayan regions of North-East India. The case study used an IKONOS (2001) image, Arc View ver. 3.2, and ERDAS IMAGINE ver. 9.1 in order to investigate the forest/vegetation types/land cover mapping of Forest Research Institute campus (FRI), Dehradun, India (as model system) through visual image interpretation. In the present case study, Chir pine was the dominant vegetation type covering major area of plantation inside FRI campus followed by Sal, Teak, Cassia, *Cupressus* and mixed vegetation with intermittent built up areas. Since FRI consists of huge plantations, separated in a segmented way, the site was feasible for learners of vegetation or forest mapping in an effective and systematic way. In nutshell, vegetation type/land use mapping through visual interpretation may be a valuable tool in monitoring, assessment and conservation planning of forests.

Keywords remote sensing; biodiversity; sustainable development; vegetation mapping; visual image interpretation; land use.

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1 Introduction

Biodiversity possess many ecosystem services which are intimately linked with the welfare of human society as well as sustainable livelihood (Rai, 2012). Tropical forests biodiversity is the basis for an array of ecosystem services, which constitute the life support system for humans. The loss of tropical forest biodiversity actually constrains and counteracts economic development and ecology leading to perturbation in ecological economics of a region. Since tropical forests harbours about one third of floral and faunal diversity in less than 10% of geographical area, conservation of tropical forests may be considered synonymous with conservation of biodiversity. In current Anthropocene era, biodiversity loss and its impact on climate change is a matter of concern at the global scale. Forest resource utilization as well as consumption of non-forest produce is not in a sustainable as well as in an equitable manner leading to environmental degradation ((Singh et al., 2002; Rai, 2009; Rai and Lalramnghinglova, 2010 a; Rai and Lalramnghinglova, 2010 b; Rai and Lalramnghinglova, 2010c; Rai and Lalramnghinglova, 2011a; Rai and Lalramnghinglova, 2011b; Rai, 2012). Tropical forest resources occupy less than 10% of the geographical area, however, possess more than 70% of floral and faunal biodiversity and also act as a huge reservoir for carbon sequestration.

Forest is generally defined as a plant community predominantly of trees and other woody vegetation with a tree canopy cover of more than 10% and area of more than 0.5 ha (FAO, 2001; Singh et al., 2006). It is well known that forests are an integral component of economy as well as environment. Forests boost the economy by providing food, fibre, timber etc. while they maintain a healthy environment by sequestering the carbon and through regulation of gaseous and nutrient cycling (Rai, 2012). Forest is a major resource and plays a vital role in maintaining the ecological balance and environmental setup (Roy, 2002; Rai, 2012). Increasing realization of the fact that forests not only provide multiple benefits to mankind but also help in conserving the environment has created global concern for their protection and conservation. In this direction, vegetation mapping through remotely sensed images may be a primary requirement for various management and planning activities at the landscape level (Singh et al., 2002).

According to United Nation, the term Remote Sensing means the sensing of the Earth's surface from space by making use of the properties of electromagnetic waves emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resources management, land use and the protection of the environment. Thus, the technique of acquiring information about an object by a recording device (sensor) that is not in physical contact with the object by measuring portion of reflected or emitted electromagnetic radiation from the earth’s surface.

Satellite images are considered as a very useful tool to study forest since they provide a digital mosaic of the spatial arrangement of land covers. Satellite-derived vegetation map and various landscape ecological parameters (*viz*., patch shape, patch size, number of patches, porosity, fragmentation, interspersion and juxtaposition) were analyzed by various authors to characterize various habitat ecosystems (Roy and Behera, 2002). Further, satellite remote sensing data have been successfully used to estimate Leaf Area Index (LAI), based on the relationship between LAI and the Normalized Difference Vegetation Index (NDVI) (Kale et al., 2005). An accurate forest cover-type and/or land-classification system is essential to providing information for effective management of natural resources (Schriever and Russell, 1995).

The remote sensing technology in integration with Geographical Information System (GIS), helps in extracting maximum amount of vegetal information that describe vegetation diversity i.e. extent, structure, composition and condition. The availability of new high-resolution satellite image sources e.g., IKONOS provides an opportunity to map ground features that was not previously available using medium resolution imagery (e.g. Landsat, SPOT 4). The ground resolution of the IKONOS panchromatic band is about 1 m, the greatest of any satellite. High-resolution IKONOS data can be used to classify tree species from mixed stands (Katoh, 2004)

Vegetation mapping is a primary requirement for various management and planning activities at the regional and global level (Singh et al., 2002). Furthermore, mapping the distributions of vegetation types and human land uses provides critical information for managing landscapes to sustain their biodiversity and the structure and function of their ecosystems (Tiwari and Singh, 1984; Tiwari, 1994).

In the light of abovementioned facts present proposed work aims to investigate the forest/vegetation types/land cover mapping of FRI campus using IKONOS (2001) data. It consists of two main procedures i.e.

the preparation of forest cover and land use map by visual image interpretation using the IKONOS image of February, 2001 and second, is the creation of area statistics.

There are two types of image interpretation techniques i.e. visual and digital. The images contain raw image data. These data when processed by a human interpreter's brain become usable information. Since the time was limiting factor, I confined my quest towards the visual image interpretation only because e-cognition software for digital image interpretation (DIP) requires expertise and time.

Followings are the key elements which assist in visual image interpretation (Lillesand and Kiefer, 2000): *Shape* refers to the general form, configuration, or outline of individual objects. *Size* of objects on images must be considered in the context of the image scale. *Pattern* refers to the spatial pattern arrangement of objects. *Tone* refers to the relative brightness or colour of objects on an image. *Texture* is the frequency of tonal change of an image. Texture contains important information about the structural arrangements of surfaces and their relationship to the surrounding environment (Kushwaha et al., 1994). *Site* refers to topographic or geographic location and is particularly important aid in the identification of vegetation types. *Association* refers to the occurrence of certain features in relation to others (Lillesand and Kiefer, 2000).

Further, the image interpretation process can often be facilitated through the use of image interpretation keys (Lillesand and Kiefer, 2000).

2 Study Area

The study area Forest Research Institute (FRI) was established in the year of 1906. FRI, Dehradun is one of the oldest institutions of its kind and acclaimed the world over. The area is situated between 30°19'55" and 30° 21' 16" N latitude and 74° 58'40" and 78° 01'00" E longitude. The major vegetation area of FRI was taken as a study area. The blocks chosen for study were teak gate block, garden block, champion block, riding school block, research block and canal block.

3 Materials and Methods

Satellite image: IKONOS (2001) image data of model system was used for the present study. IKONOS image data has been proved to be useful for vegetation type and land use mapping (Kim et al., 2008). Earlier, stereoscopic interpretations of aerial photographs were developed in the late 1940s to facilitate systematic forest management (Stone, 1998). The specific and general description of IKONOS satellite is explained in following and Table 1 respectively.

Satellite	IKONOS 2
Sensor	Optical Sensor Assembly (OSA)
Data product	Standard IKONOS MS, PAN
Date	4 December 2001
Spatial resolution	4 meters
Swath Width	11 Km
Pointing capacity	± 30°
Revisit time	1-3 days

The IKONOS Satellite is a high-resolution satellite operated by GeoEye. Its capabilities include capturing a 3.2m multispectral, Near-Infrared (NIR)/0.82m panchromatic resolution at nadir. Its applications include both urban and rural mapping of natural resources and of natural disasters, tax mapping, agriculture and forestry analysis, mining, engineering, construction, and change detection. It can yield relevant data for nearly all aspects of environmental study. IKONOS images have also been procured by several institutions for use in the media and motion picture industries, providing aerial views and satellite photos for many areas around the world. Its high resolution data makes an integral contribution to homeland security, coastal monitoring and facilitates 3D Terrain analysis.

Softwares: Arc View ver. 3.2 and ERDAS IMAGINE ver. 9.1; *Hardwares*: Lenovo PC was used. Enlarged colored map of study area was used for assistance in ground truth collection.

A schematic diagram of the present study is shown in Fig. 1.

A bird's eye view of the whole of the study area acquired during 7-10th June 2010. During the aforesaid period, attempts were made to digitize the image into distinctly separable polygons. IKONOS, MS and PAN subscenes (already geo-referenced) have been used as base data fir on screen digitization for visual interpretation using Arc View GIS package. Although the satellite data was also already enhanced, limited enhancement has been attempted in ERDAS Imagine through histogram equalization for better discriminability of various vegetation units. Spectral reflectance (DN values) of vegetation types were assessed in different wavelength (BGRIR) using ERDAS. The attribute classes were generated completely during the reconnaissance survey and ground truth collection.

Table 1 IKONOS satellite system: general sensor characteristics.

Launch Date	24 September 1999 at Vandenberg Air Force Base, California, USA
Operational Life	Over 7 years
Orbit	98.1 degree, sun synchronous
Speed on Orbit	7.5 kilometers per second
Speed Over the Ground	6.8 kilometers per second
Revolutions Around the Earth	14.7, every 24 hours
Altitude	681 kilometers
Resolution at Nadir	0.82 meters panchromatic; 3.2 meters multispectral
Resolution 26° Off-Nadir	1.0 meter panchromatic; 4.0 meters multispectral
Image Swath	11.3 kilometers at nadir; 13.8 kilometers at 26° off-nadir
Equator Crossing Time	Nominally 10:30 AM solar time
Revisit Time	Approximately 3 days at 40° latitude
Dynamic Range	11-bits per pixel
Image Bands	Panchromatic, blue, green, red, near IR

Field survey work was done in two phase viz. reconnaissance survey (on 11th June, 2010) and final field work (15th June, 2010) in order to have information of various vegetation type and correlated with the satellite data. Information was documented for assigning different attribute classes and finally preparation of vegetation type map was done. Corrections were done in order to remove any discrepancy.

4 Results

Spectral reflectance (DN) values of major vegetation types were plotted against different wavelength bands. Fig. 2 revealed that there was maximum reflectance for Sal followed by Chir pine, Teak and Chir pine gaps. Maximum reflectance between R and NIR region was recorded for vegetation when compared with settlement/built up features.

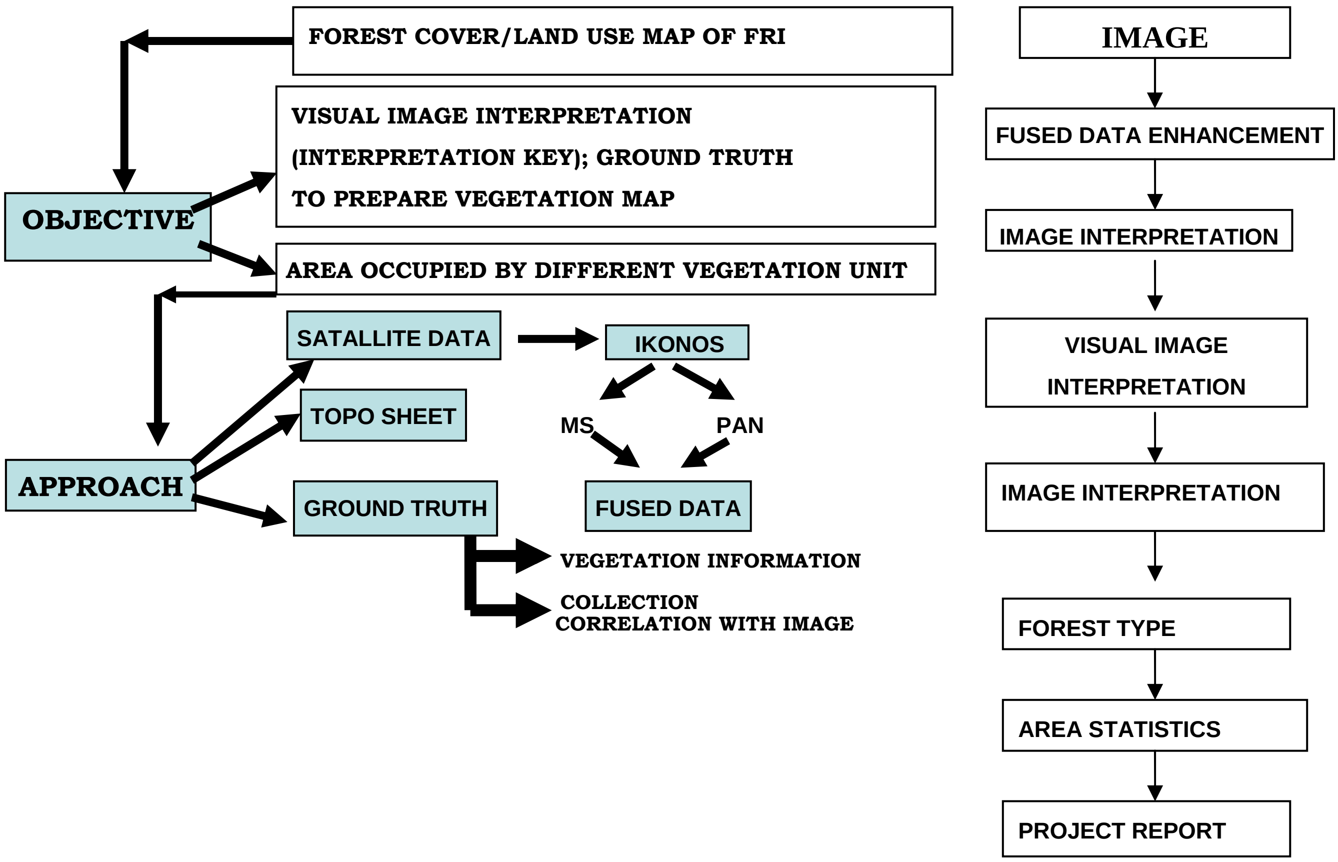

Fig. 1 Paradigm of study.

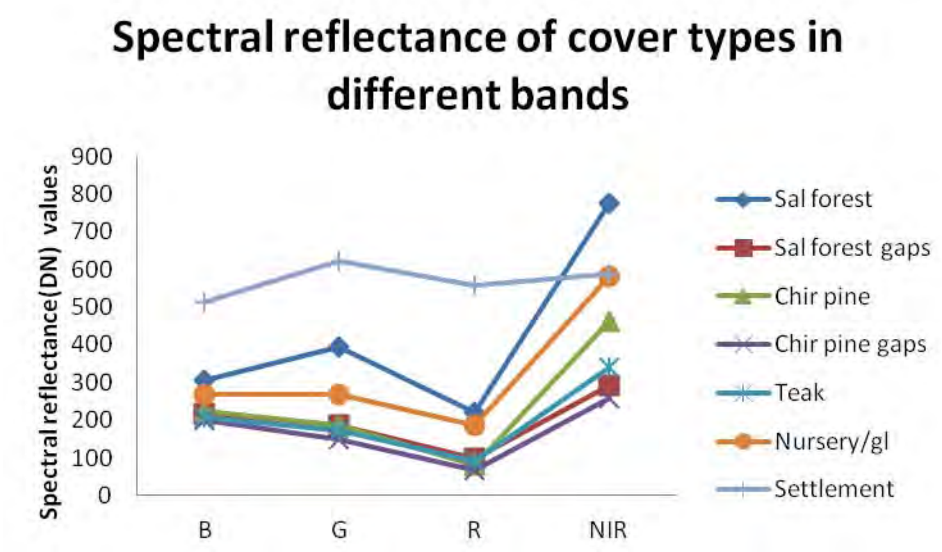

Fig. 2 Spectral reflectance of cover types in different wavelength bands.

False colour composite (FCC) image of the AOI is presented in Fig. 3. Image interpretation key for ready visual identification of vegetation type is shown Table 2. Chir pine, which was observed to be major vegetation type, has shown distinct blood red tone with medium pattern and regular texture while Chir pine mixed reflected reddish green tone with rough texture. Nursery has shown green tone with smooth texture while *Populus* nursery showed light red tone with rough texture. Healthy Sal reflected dark pink tone with regular pattern and coarse texture while senescent or diseased Sal was light pink with greenish tinge. Further, another important component of forest cover i.e. Teak has shown greenish blue tone with regular pattern and rough texture. Bamboo has shown pink/gray tone (yellowish tinge) with irregular pattern and coarse texture. Mixed vegetation has shown light red-red tone with irregular rough texture.

Fig. 3 False color composite (FCC) image for vegetation mapping (a part of FRI campus as model system).

Table 2 Image Interpretation key.

No	Forest cover type	ID	Tone	Pattern	Texture
1	Chir pine mixed	2	Reddish green	Regular	Rough
2	Chir pine	6	Blood red (with intermingled green shade)	Regular	Medium
3	Nursery	10	Light pink	Regular	Smooth
4	Sal spp.	5	Dark pink for healthy and pink with greenish tinge for senescent ones	Regular	Coarse
5	Teak	9	Greenish blue	Regular	Rough
6	Mixed (*Agathis*+*Cupressuss*+Mango+Others)	1	Light Red-Red	Irregular	Rough
7	*Eucalyptus*	22	Bright Red	Regular	Smooth
8	*Taxodium* sp.	8	Red	Regular	Smooth
9	Settlement/built up	4	Blue/Light green	Regular	Smooth
10	Chir pine gaps	7	Red	Irregular	Smooth
11	Open areas	4, 11	Light green with intermittent reddish tinge	Regular	Smooth
12	*Populus* nursery	10	Red	Regular	Rough
13	Bamboo	16	Pink with yellowish tinge	Irregular	Coarse
14	*Michelia champaca*	18	Light red	Regular	Coarse
15.	*Cassia* sp.	20	Bright red	Irregular	Medium

Forest cover and land use map of a part of FRI campus is shown in Fig. 4. Total area of selected portion came out to be 138.60 ha. Further, area statistics presented in Table 3 and Fig. 5 clearly indicated that Chir pine covered major portion (37.478%) together with Chir pine mixed (13.131%) and mixed Chir pine (0.0675%). Mixed vegetations which were scattered throughout the selected portion of FRI comprised 15.468% of the total area under investigation. Teak comprised (5.551%) followed by Sal (4.035%), *Cupressus* mixed (3.129%), Botanical garden-mixed (1.389%) and open area/grass land/built up (0.475%).

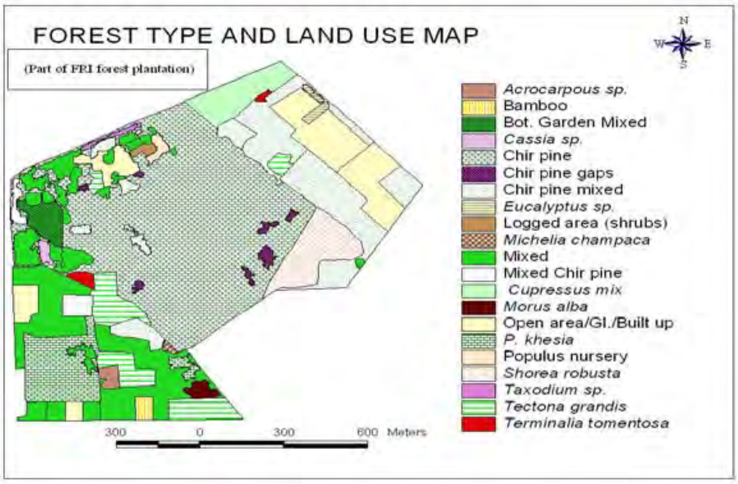

Fig. 4 Forest type and land use map (a part of FRI campus comprising vegetation).

Table 3 Area statistics and percentage distribution of vegetation types.

Vegetation/land cover types	Area (ha) of varying land covers	Percentage distribution
Acrocarpous sp.	0.604	0.436
Bamboo	0.612	0.442
Bot. Garden mixed	1.925	1.389
Cassia sp.	0.349	0.252
Chir pine (*P. roxburghii*)	51.945	37.478
Chir pine gaps	1.033	4.132
Chir pine mixed	18.199	13.131
Eucalyptus	0.542	0.391
Logged area (shrubs)	0.329	0.237
Michelia champaca	0.154	0.111
Mixed	21.438	15.468
Mixed Chir pine	0.935	0.675
Cupressus mixed	4.337	3.129
Morus alba	0.658	0.475
Open area/Gl./Built up	13.338	9.623
P. khesia	7.511	5.419
Populus nursery	0.510	0.368
Sal (*Shorea robusta*)	5.593	4.035
Taxodium sp.	0.319	0.230
Teak (*Tectona grandis*)	7.694	5.551
Terminalia tomentosa	0.575	0.415
Total Area	138.600	100.000

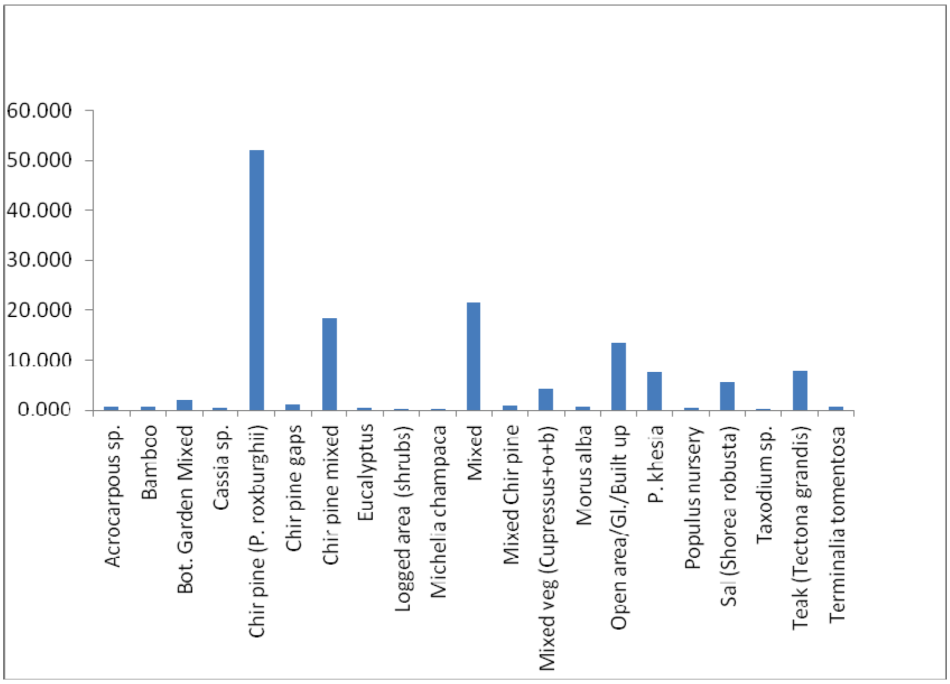

Fig. 5 Area wise distributions of vegetation types in FRI campus (Area in Ha).

5 Discussion

As per Convention on Biological Diversity (CBD) of 1992, Diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, 1992). Use of satellite remote sensing, geographic information system (GIS) and global positioning system (GPS) techniques for assessing the disturbed or polluted and biologically-rich sites by many researchers have enriched the literature (Bierregaard, 1992; Schriever and Russell, 1995; Menon and Bawa, 1997; Fuller et al., 1998; Nagendra and Gadgil, 1999; Behera et al., 2000; Behera, 2000; Roy and Tomar, 2000; Franklin, 2001; Helmer et al., 2002; Kushwaha and Roy, 2002; Roy and Behera, 2002; Porwal et al., 2003; Kale et al., 2004; Das et al., 2007). The biodiversity at landscape level can be characterized by measures of species richness, species diversity, taxic diversity and functional diversity (Behera, 2000; Roy and Behera, 2000; Roy and Behera, 2002). In view of grimy status of biodiversity conservation, landscape level strategies for biodiversity conservation should be adopted (Heywood and Watson 1995; Behera et al. 2005). Aforesaid statement has resulted in paradigm shift in conservation efforts focused towards the intricate interaction among species, instead of considering single species (Orian, 1993; Edwards et al., 1994; Behera et al., 2005).

In the present study, Chir pine was the dominant vegetation type covering major area of plantation inside FRI campus followed by Sal, Teak, Cassia, *Cupressus* and mixed vegetation with intermittent built up areas. Henceforth, vegetation type/land use mapping through visual interpretation may be a valuable tool in monitoring, assessment and conservation planning of forests. Also, remote sensing and geosptial technologies have been used for gathering the information on physical parameters of the wildlife habitats and geospatial modeling for wildlife habitat evaluation as an integral component of forest ecosystems (Kushwaha & Roy, 2002).

6 Conclusions

Present study may be extrapolated to north eastern Himalayan regions of India and adjoining countries. An environmental assessment approach through the remote sensing or geospatial techniques on different environmental issues of hotspot regions is the need of the hour as they are one of the most threatened habitats, lost more than 70% of their vegetation and importantly rich in endemic species (Rai, 2009; Rai and Lalramnghinglova, 2010 a; Rai and Lalramnghinglova, 2010 b; Rai and Lalramnghinglova, 2010c; Rai and Lalramnghinglova, 2011a, 2011a; Rai and Lalramnghinglova, 2011b; Rai, 2012). Shifting cultivation in North-East India is no more sustainable, thus, causing serious threat to the local flora and fauna (Rai, 2009; Rai, 2012). Since vegetation type can link to species composition or habitat types, vegetation maps provide crucial information for change detection as well as biodiversity conservation planning (Kushwaha, 1990; Tiwari, 1994). Moreover, mapping of vegetation is particularly relevant in context of global hotspots like Himalayan regions of India (Rai and Lalramnghinglova, 2011b; Rai, 2012) and its sustainable development in totality (Ramakrisnan and Kushwaha, 2000; Rai, 2012).

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