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Vegetation cover and forest structure assessment in Rani and Garbhanga Reserve Forests, Assam using remote sensing and GIS

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Abstract

The information on forests can be assessed with the help of remotely sensed imagery, which can provide quantitative information on forest ecosystems at high temporal and spatial resolutions. Vegetation and forest structural features were mapped in Rani and Garbhanga reserve forests by integrating the Normalized Difference Vegetation Index (NDVI) from IRS P6 LISS III imagery and high-resolution IRSP6 LISS IV imagery. NDVI image depicted 5 distinct major classes land cover classes viz. closed moist deciduous forest, moist deciduous forest medium, open moist deciduous, scrub forest and non forest area. The vegetation pattern of the reserve forest is characterised by the first 4 land cover classes. The land cover classes derived from NDVI is evaluated using high spatial resolution LISS IV imagery. The maximum forest cover is reflected by closed moist deciduous forest (more than 40 % of the total area) and the lowest forest cover is reflected by Bamboo brakes (not more than 8 % of the total area). Further, the reserve forest showed a natural representation of the vegetation patterns. The method has helped for identifying vegetation types in areas with a great variety of plant communities and complex relief on real time.

Key words: Remote sensing, Forest structure, NDVI, vegetation mapping, *Shorea robusta*

INTRODUCTION

The assessment of vegetation cover and forest structure is possible using multi-spectral satellite imagery. It facilitates in establishing a relationship between spectral information from image and forest structural features. Remote sensing data have been used in identifying vegetation cover and density (Wu *et al* 1985; Roy *et al* 1990; McCloy & Hall 1991). Forest structural classification based on broad canopy density classes has been reported using Indian Remote Sensing Satellite Data IRS-1A LISS II (Roy *et al* 1990). The spectral response of a forest is determined the structure of the canopy such as biomass, age, density, mean tree height and basal area (Lee & Nakane 1996; Peterson *et al* 1987; Rock *et al* 1986). Several studies have compared the application of different satellite sensors for monitoring forest structural features (Brockhaus & Khorram 1992; Hyyppa *et al* 2000; Lefsky *et al* 2001). A significant relationship exists between spectral information and variables such as forest age, successional status, basal area, height, biomass, density and volume (Brockhaus & Khorram 1992; Foody *et al* 2001; Jakubauskas 1996; Olsson 1994; Puhr & Donoghue 2000; Steininger 2000).

There are several methods for analysing spectral information to assess vegetation cover and forest structure. One such method is Normalised Difference Vegetation Index

(NDVI) that is most commonly used vegetation indices amongst all the spectral indices and it provides an estimate of vegetation greenness or biomass (Goward *et al* 1985). However, the limitation of NDVI is that vegetation greenness within a pixel saturates at a threshold level, beyond which NDVI values are insensitive to increasing vegetation amount (Ripple 1985). Furthermore, NDVI provides measures of vegetation greenness and soil reflectance, which may be more sensitive to topographic variation than to actual soil or vegetation properties (Cohen & Goward 2004).

Any detailed survey of the forest covers in Rani and Garbhanga Reserve Forests using remote sensing and GIS has not been made so far. Both the reserves are dominated by sal (*Shorea robusta*) and illegal felling of trees for timber has been taking place in the inner regions of the reserve. Moreover, the reserves lie close to the Guwahati city facing threats also from encroachment. Therefore, assessment of the forest is of utmost importance and

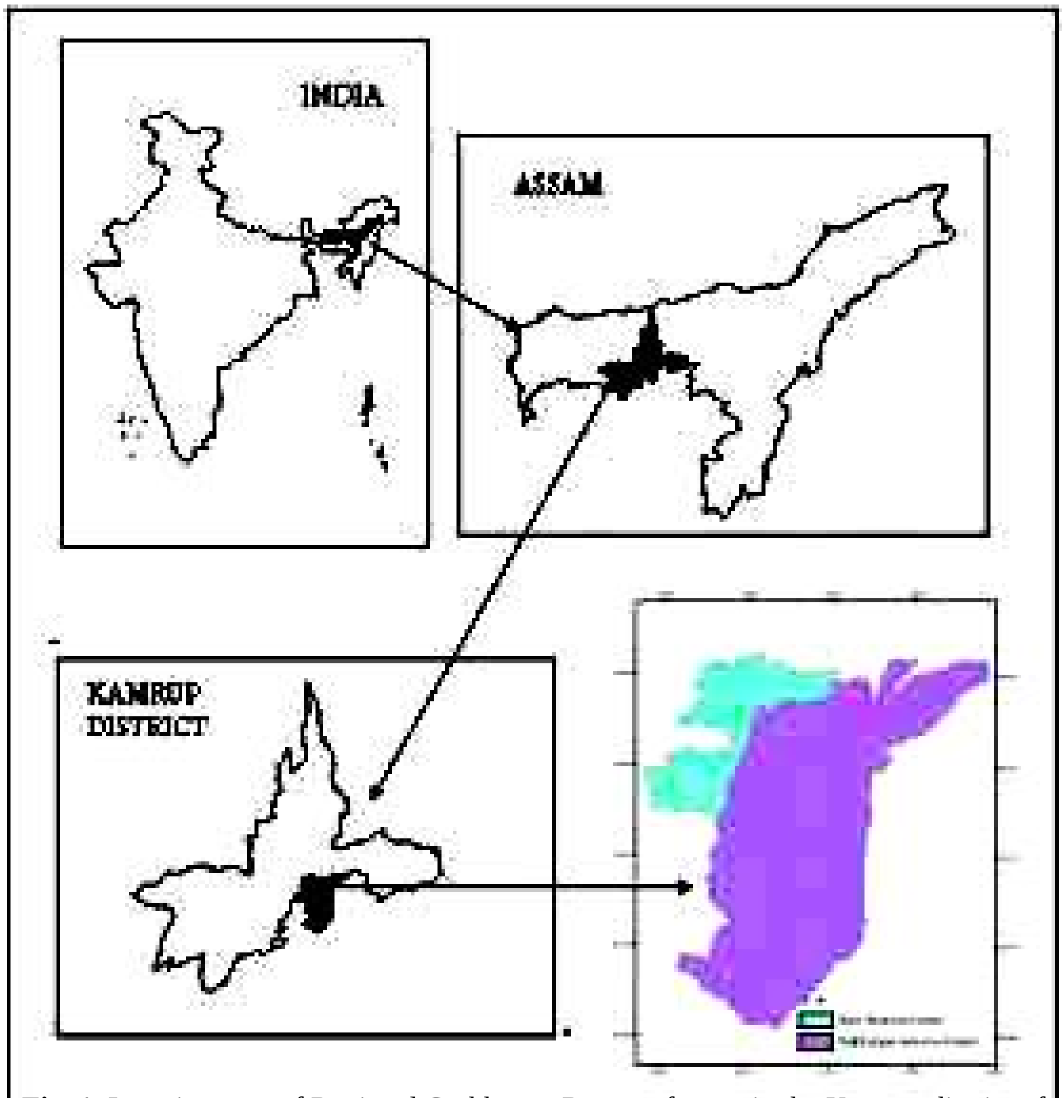

Fig. 1. Location map of Rani and Garbhanga Reserve forests in the Kamrup district of Assam

using NDVI from IRS LISS III imagery coupled with high resolution LISS IV data, an attempt has been made in the study to assess vegetation cover and forest structure in Rani and Garbhanga Reserve Forests.

Study area

Rani and Garbhanga Reserve Forests (Fig. 1) are located in Kamrup district of Assam and the state of Meghalaya lies toward the southern portion of both the reserves. Rani Reserved Forest is located between 91° 35'16" E to 91° 42'24" E Longitude and 26° 06'41" N to 26° 01'15" N latitude, while Garbhanga Reserve Forest is located between 91° 36 25" E to 91° 47'45" E longitude and 26° 05'31" N to 25° 54'12" N latitude (Fig. 1).

Rani Reserved Forest is situated at a moderate altitude ranging from 60 m to 401 m above mean sea level and Garbhanga Reserved Forest with altitude ranges from 80 m to 670 m above the mean sea level. Both the Reserved Forests fall on the Eastern part of the Kamrup district of Assam state. The rock types in around Rani and Garbhanga Reserved Forests derived form gneiss, quartzite or conglomerate. The soils are gravely on crests and upper slopes, deep red and clayey in the foot hills and alluvial lower down.

The forests are mainly of sub-type (B) moist deciduous forests (Champion & Seth 1968) and are dominated by sal (*Shorea robusta* (Linnaeus) Gaertner *f.)*. It is an important habitat for many wild animals including Asian elephant. Some common plants of these forests are *Schima wallichii* Choisy, *Adina cordifolia* Bentham & Hooker *f.*, *Gmelina arborea* Roxburgh, *Lagerstroemia parviflora* Roxburgh, *Dillenia pentagyna* Roxburgh, *Vitex peduncularis* Wallich *ex* Schauer, *Terminalia bellerica* (Gaertner) Roxburgh, *Phyllanthus emblica* Linnaeus, *Premna latifolia* Roxburgh, *Aporosa roxburghii* Baillon, *Aphanamixis polystachya* (Wallich) R.N. Parker, *Garcinia* sp., *Careya arborea* Roxburgh, *Dendrocalamus hamiltonii* Munro, *Desmodium* spp., *Eupatorium odoratum* Linnaeus, *Zizyphus mauratiana* Lamarck, *Microstegium ciliatum* (Trinius) A. Camus, *Imperata cylindrical* (Linnaeus) Beauverd, *Thysanolaena latifolia* Honda, *Carex baccans* Nees, *Zizyphus oenoplia* Miller, *Entada phaseoloides* Merrill, *Butea parviflora* Roxburgh *ex* G. Don, *Artocarpus chaplasha* Roxburgh, *Michelia champaca* Linnaeus and *Amoora spectabilis* Miquel.

Secondary moist bamboos brakes also occurs which are formed by *Dendrocalamus hamiltonii* with its characteristic low spreading habit, also holds tenaciously to ground once occupied. Under a closed bamboo crop the floor is usually almost devoid of tree saplings but with scattered shrubs and few grasses. Scrub forest has usually come into existence in old village clearings in Sal forest.

METHODS

IRS P6 LISS III imagery with 23.5 m spatial resolution and high-resolution IRS P6 LISS IV data with spatial resolution of 5.8 m were used for mapping forest structure and vegetation cover in Rani and Garbhanga reserve forests. Data analysis was carried out using ERDAS and Arc GIS softwares. The LISS III data was acquired on November 2010 (path 110 and row no 53) while that of LISS IV was acquired on April 2009. NDVI was generated from IRS LISS III using RED band = 620 – 680 nm, and NIR band =770–860 nm. To obtain maximum NDVI value, November data-set was selected for the analysis.

The formula for NDVI is given as:

$$\mathbf{NDVI = (NIR - RED)/\ (NIR + RED)}$$

The land cover in the study area was classified into five major classes based on NDVI. This classification has facilitated in gathering information on vegetation composition and structure. NDVI values ranges from –1 to +1 in which the negative values correspond to non-vegetated surfaces and positive to vegetated areas. IRS LISS IV is a high-resolution available imagery that provides useful information to validate course resolution satellite data, making possible to delineate vegetation cover and density. Based on visual interpretation of LISS IV image aided by field knowledge, different vegetation cover types were also identified. These samples were used to extract the corresponding NDVI values. Vegetation was sampled in such a way as to reflect the internal variability in canopy closure. The vegetation-NDVI samples were analyzed in order to identify ranges in NDVI that correspond to the specific vegetation classes. Accuracy assessment for all the classes mapped by the NDVI was also carried out using the Kappa coefficient, which measures accuracy that for chance agreement between classes in an error matrix (Landis & Koch 1997).

RESULTS AND DISCUSSION

The reserve forest is characterised by moist deciduous forest type. Bamboo brakes and scrub forest were also found to occur in the reserves. Scrub forest has resulted due to degradation of primary moist deciduous forest which is significantly high (approximately 9 % of the total area) in both the reserves. NDVI image (Fig.2) depicts a meaningful picture of the vegetation patterns. It was segmented into five major land cover classes:

1. closed moist deciduous forest
2. moist deciduous forest medium
3. open moist deciduous
4. scrub forest
5. non-forest area

The spatial distribution of NDVI values has been dominated by the high values in October and December. The senescence stages in April and May for deciduous forest can been clearly demarcated by the spatial distribution of NDVI values. The NDVI values are high in October and December (Joshi *et al* 2001) and the highest NDVI range in the study area being +0.51. Closed moist deciduous forest corresponds to canopy closer >70 %, medium is 40 to 70 % and that of open moist deciduous forest is <40 %. It is easy to distinguish the transition from the more vigorous vegetation, where deciduous forest tends to occur, to the less vigorous vegetation, characterized by scrub. Forests openings are visible, particularly in the southern part of Garbhanga reserve forest. The northern part is distinguishable by the greater proportion of high NDVI values, represented by the occurrence of closed moist deciduous forest. Distribution of NDVI in all the categories showed distinctive ranges of NDVI values, decreasing as the canopy opens and exposed lands. Nevertheless, there were instances of shared NDVI values between vegetation types. An increas in NDVI value is observed in dense canopy cover (Oza *et al* 1996; Feeley *et al* 2005) and the value tends to decreased as vegetation changed from closed forest to open forest and finally to forest scrub. NDVI > +0.4 corresponds closed moist deciduous forest and moist deciduous forest medium ranges from +0.3 to +0.2. NDVI value for open moist deciduous is from +0.1 to +0.2 while that of scrub forest is between +0.062 to +0.093.

The result from NDVI segregated classes were correlated with the vegetation density classes derived from visual interpretation of LISS IV (Table 1) and it was observed that a positive relationship was found between tree density and NDVI (Cintrón & Rogers 1991; Gillespie *et al* 2006).

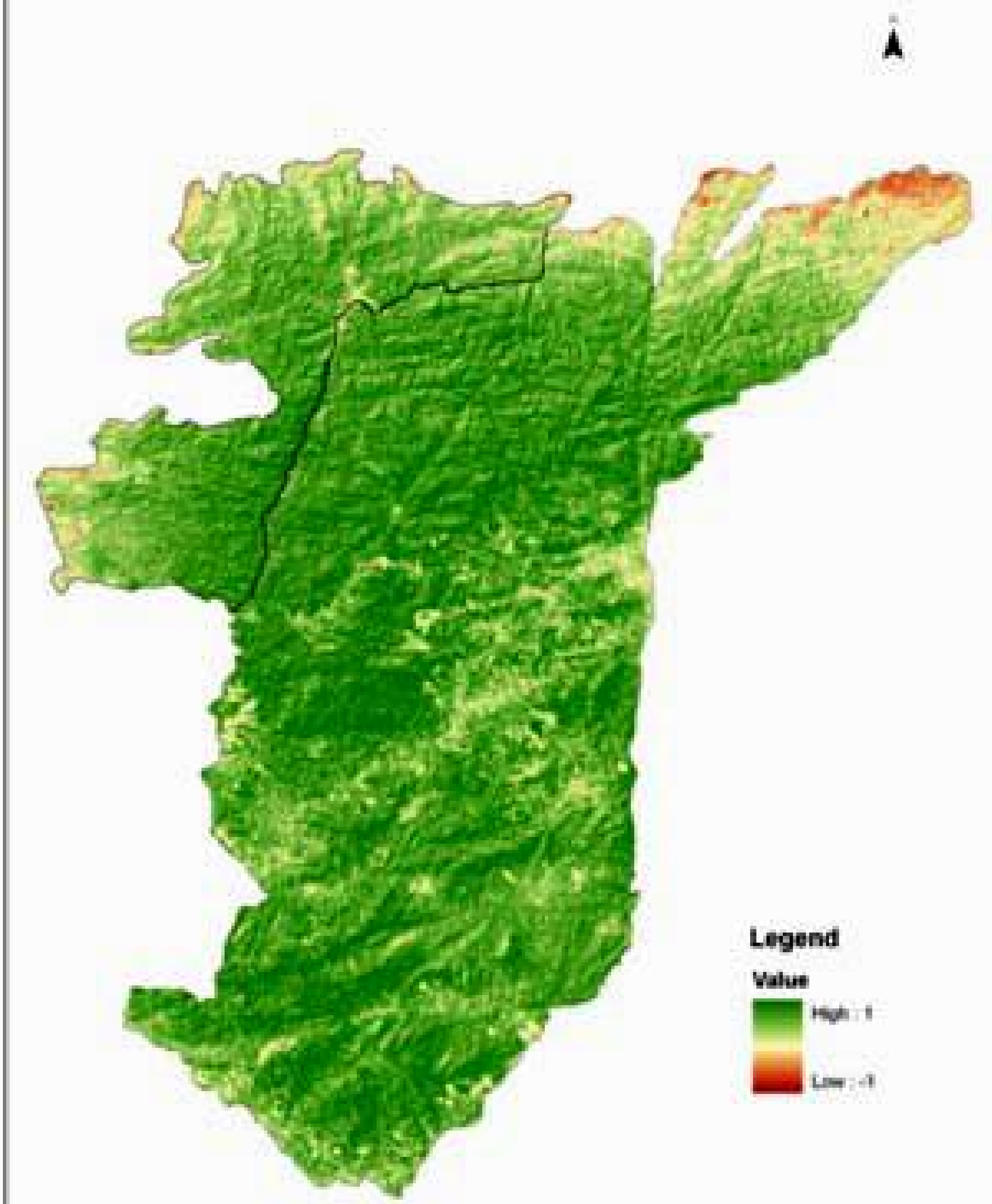

Fig. 2. Map showing NDVI range in the study area

The closed moist deciduous forest could not be detected purely in the NDVI image, which can be identified from high resolution data due to saturation of NDVI value. Only a small fraction of the closed moist deciduous forest was represented. It was also observed that open forest is predominant in Rani Reserve Forest that is supported from the interpretation from LISS IV data.

Table 1. Land cover categories derived from IRS P6 LISS IV imagery

CLASS	RANI RESERVE FOREST		GARBHANGA RESERVE FOREST	
	Area (ha)	**Area (%)**	**Area (ha)**	**Area (%)**
Moist deciduous Forest-Closed	1794.34	40.37	7497.74	40.85
Moist deciduous Forest-Medium	501.81	11.29	3191.40	17.39
Moist deciduous Forest-Open	1397.88	31.45	3148.94	17.16
Bamboo Brakes	195.39	4.40	1364.56	7.43
Forest-Scrub Forest	397.64	8.95	1880.71	10.25
Forest Blank	32.87	0.74	748.96	4.08
Agriculture land	73.03	1.64	343.55	1.87
Built-Up area (Rural)	48.10	1.08	169.06	0.92
Waterbodies-River	4.04	0.09	8.91	0.05
Total	**4445.09**	**100**	**18353.83**	**100.00**

Bamboo break that occurred in a very small patch could not be identified in the NDVI image. Accuracy assessment yielded a kappa coefficient of substantial agreement equal to 80 %.

CONCLUSION

NDVI and high-resolution imagery together provides a valuable tool for mapping forest structure and vegetation pattern. It has allowed separating the major vegetation by capturing their differences in canopy closure. The different classes of vegetation exhibited a variable range of NDVI. A positive relationship was found between forest density and NDVI. It was also seen that forest cover with a higher forest density tends to have a higher NDVI values. However, NDVI alone was not sufficient to separate the entire vegetation types. The combination of high-resolution imagery with field knowledge represented a useful tool in separating classes that showed similar NDVI values in the LISS III imagery. Although some plant communities exhibited variable coverage that can include bare soil, the accuracy assessment demonstrated that this problem was confined to certain transition areas. In summary, the combination of NDVI and high-resolution imagery results in a useful tool for mapping vegetation and forest structure. This is of special value under the great need for remote sensing applications and information able to support conservation and monitoring strategies in these ecosystems.

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