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Original Research Paper

Application of Remote Sensing in Detection of Forest Cover Changes Using Geo-Statistical Change Detection Matrices – A Case Study of Devanampatti Reserve Forest, Tamilnadu, India

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ABSTRACT

The continuous observations on forest cover through the spaceborne technology known as remote sensing provide relative accuracy for temporal variation, changes and spatial distribution of forest biodiversity. The present study describes the temporal changes in forest cover and their spatial distribution in Devanampatti Reserved Forest in Tiruvannamalai District of Tamilnadu using change detection matrices technique by integrating remote sensing and GIS. Remote sensing technology provides satellite imagery with synaptic coverage on large area and high spatial resolution to identify individual species in biodiversity and delineating various forest types at national, regional and local level, and that facilitates to manage and conserve the forest biodiversity worldwide. The present study carried out using Landsat TM and ETM+ imageries acquired in 1977, 1991 and 2006 during the same seasonal period. The present study has brought the view of temporal variation of forest cover and its distribution in various periods. This also revealed the changes and spatial distribution of particular forest types into what types of spatial feature from the past period to present. The study showed rapid changes of forest cover between the two decades; the result of change detection analysis reveals that the deciduous forest cover spatially distributed to about 57.35 km^2 in 1977 and it tremendously decreased to 29.60 km^2 in 1991 and 23.56 km^2 in 2006. The decreasing rate per year between 1977 and 2006 was estimated at 0.65 %. The area of mixed forest cover was estimated to be about 35.30 km^2 in 1977, which decreased to 41.75 km^2 in 1991 and 18.96 km^2 in 2006 with the decreasing rate of 0.018% per year. Unfortunately, the rich forest biodiversity degraded into sandy gravel or eroded landform, and range of area cover was about 18.93 km^2 in 1977 and 24.30 km^2 in 2006 and rocky exposure increased in its area from 44.67 km^2 in 1977 to 77.79 km^2 in 2006. The changing rate of these landforms increased per year to about 0.11 % and 0.63 % respectively.

INTRODUCTION

Biodiversity includes flora and fauna, covering of about 1,60,400 species all around the world. Indian subcontinent is rich in species biodiversity with high heritage of flora and fauna, and world's twelve hot spots are located in this esteemed region. On an average, about 6% of the world species are present in India and the areal extent of both forest cover and mangroves in the country include 67.83 M.ha which covers 19.39% of the total geographical area in India (MoEF Report 2001). The biodiversity richness and its area of distribution is not uniform throughout the surface of the earth and that determined by the local geo-physical structures and climatic phenomena of a fussy area. Present days, there is an increase in threatening of spatial distribution and species biodiversity due to anthropogenic activities, population growth and industrialization (Panigrahy 2006). Due to the growth of human and cattle population, and widespread rural poverty, forest cover throughout the world is subjected to deforestation and degradation. As a result, there is significant loss of forest cover at an alarming rate. Depletion of forest causes many ecological, social and economic problems such as loss of biodiversity, soil erosion and increase of global warming (Roy & Joshi 2002). It is believed that the natural vegetation in the sub-tropical regions worldwide is experiencing loss of biodiversity at significant rates, so it is necessary to call for immediate management and conservation of forest biodiversity in this region through advanced technologies. Large-scale changes in land cover and repeated monitoring of forests have popularized remote sensing technology as an essential tool. Forest cover change detection has been done through visual interpretation of satellite data by Unni et al. (1985). Forest cover changes have been estimated from satellite imagery through computer assisted digital image processing (DIP) techniques. The basic principle of change detection through remote sensing is that

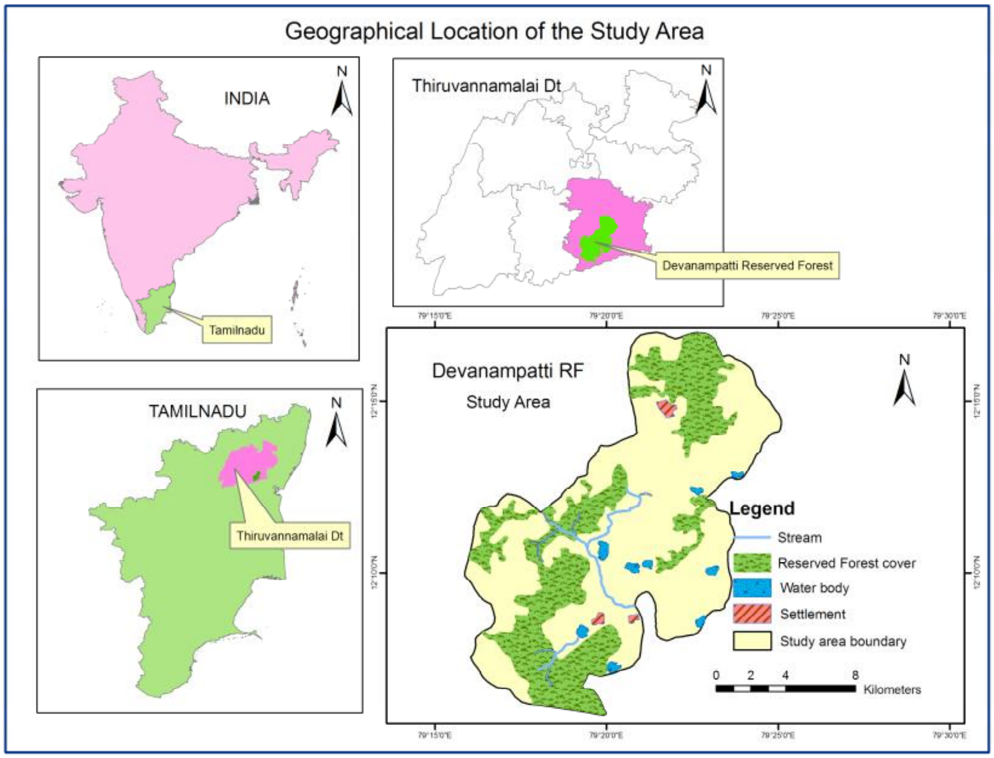

Fig. 1: Location of the study area.

the changes in spectral signatures commensurate with the change in land cover (Okeke & Karnieli 2006). The process of change detection is premised on the ability to measure temporal impacts (Sabins 1987). According to Alwashe & Bokhari (1993), Landsat TM data have been used to monitor vegetation changes under the aspects of urban planning in Saudi Arabia. In their study, Landsat TM image of Al Madinah city was chosen for two different acquisition dates and image were merged IHS based image processing techniques to obtained the bi-temporal variations within one image product that could be integrated into a possible operational vegetation monitoring system of selected regions are outlined. Change detection is useful in such diverse applications as land use change analysis, monitoring of shifting cultivation, assessment of deforestation, study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring snow-melt measurements, day and night analysis of thermal characteristics and other environmental changes (Singh 1999).

REMOTE SENSING AND GIS TECHNOLOGY IN BIODIVERSITY CONSERVATION

Remote sensing and GIS have capability to analyze and monitor the periodical changes of spatial distribution forest resources and its diversity conditions. GIS is an innovative tool in which, it combines spatial data (maps, aerial photographs, satellite images) with the other quantitative, qualitative and descriptive information databases. The analytical work carried out for data synthesis combines a system capable of data capture, storage, management, retrieval, analysis and display. Remote sensing is a technique of imaging the earth surface by capturing the electromagnetic radiation (EMR) reflected or back scattered from the features present on the earth's surface without any human intervention. The onboard sensor on satellite with multi-spectral bands is to observe all resources on the earth surface based on reflection characteristics. Each feature on the surface has unique reflection characteristics in electromagnetic spectrum (EMS) and this is a primary principle in remote sensing technology (Lillisend & Keifer 1994). There were radiometric differences among the images in both space and time, but the noise associated with temporal radiometric differences is minimal relative to the signal from stand replacement forest disturbance (Cohen et al. 2002). The temporally acquired remote sensing and GIS data are used to explore the area to indentify the species types and to estimate their changes periodically (Coppin et al. 2004). A study on the detection and estimation of changes in biodiversity in an inaccessible area was made possible with a higher accuracy through this technological intervention, which is not feasible by the conventional methods (Zheng et al. 1997).

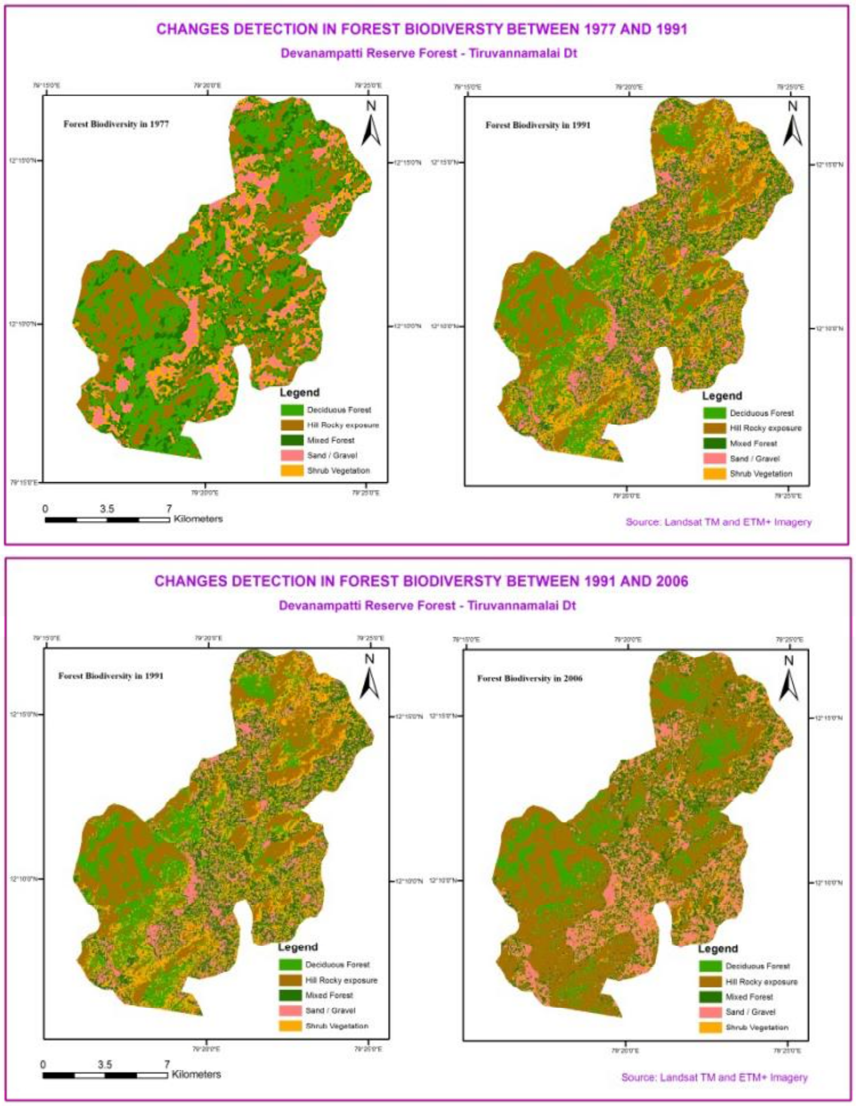

Fig. 2: Forest cover changes between 1977-1991 (a) and 1991-2006 (b).

In the forest cover assessment studies, the following essential factors are rates of depletion, reason for the deterioration and remedial measures to restore and assess the forest cover in any terrain. Forest cover assessment and change detection in the rugged topography or hill sector is not an easy task and it is a time-consuming process in conventional approach. This can be made easier only through the high spectral, spatial and temporal resolution qualities of remote sensing techniques. Indeed, the precise database pertaining to forest cover information is an imperative input of formulating various management plans and also remote sensing technology can be effectively utilized for change detection and monitoring activities (Jessica et al. 2001).

THE STUDY AREA

The study on spatial distribution and temporal variation of forest cover was carried out in Devanampatti Reserve Forest in Tiruvannamalai District of Tamilnadu, India. The total area is about 181.450 km^2 with the geographical longitude extension of 79°15’47.12’E to 79°25’05.64’E and latitude extension of 12°06’09.93’N to 12°16’58.38’ N. The area is located 10 km south-east from Tiruvannamalai and about 70 km north-west from Villupuram township, and nearly 32 km south-west from Nangilikondan village. The study area is covered with hilly vegetation and rural settlements.

Physiographical structure: The forest cover of the study area can be categorized into deciduous forest, mixed forest,

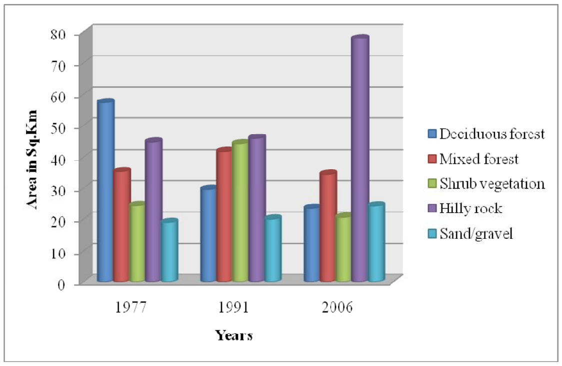

Fig. 3: Area of different types forest cover during 1977, 1991 and 2006.

shrub, and scrub vegetation based on the field observation and distribution of tree types. The area is a hilly terrain with the altitude of about 429 m to 440 m MSL at central west and north-west, that is covered by the deciduous forest in south and south-eastern portion. North-west is roofed with mixed forest. The foothills of the region consist of shrub and scrub vegetation covers. A number of streams and small tributaries flow from west towards south-east. Sand and gravel are found along foothills and water bodies. Normally, this is sub-tropical climatic condition. The annual average rainfall is 22cm. Rainfall varies from 31cm in the north-east monsoon from November-December and 26cm during south-west monsoon from June to October. The optimum temperature is 27°C and the humidity ranges from 69 to 78% during the summer and winter season respectively.

MATERIALS AND METHODS

The primary data product of the Landsat sensors TM and ETM+ have provided the satellite imagery with longest time series with and temporal coverage of the same area much suitable for monitoring changes in the vegetative cover at high spatial resolution. The estimation of forest cover changes in the study area was carried out into two flavors. Using image classification technique, the Landsat TM and ETM+ imageries were classified into number of classes to delineate the spatial distribution of different types of forest covers. Change detection matrix technique comprises the attributes of each forest type in rows and columns of matrix table for the year of 1977 and 1991, 1991 and 2006 and 1977 and 2006. The matrix table was used to correlate specific class in row with the all classes in column to estimate the spatial differences of each class of the forest types and particular classes of forest changed into what types and how much areal extent of increasing or decreasing from 1977 to 2006. The supervised classification technique Maximum Likelihood Classification (MLC) was applied to classify the different types of forests from the multispectral imagery (30m) based on spectral signature characteristics. Using classification tool in ERDAS Imagine 9.1, the spectral signature file was created from the imagery with the ratio of 1:10 that mean each 100 pixels of feature classes participate to prepare 10 pixels spectral signature file. The number of signature files were inputted to classify the imagery to identify different types of forest covers. The raster feature classes were converted into polygon vector using ESRI ArcGIS 9.3.1 geo-processing processing tool, and they have verified geometrically by removing of overlapped adjacent layers and tiny polygons. The area of each feature class was estimated and tabulated. Image differencing of the DN values to be considered were estimated by the temporal changes of forest types between different periods.

Data products used: The data products used are given in Table 1.

Table 1: the data products used in the study.

Sl. No.	Data product	Date of acquisition	Spectral bands	Spatial resolution
1.	Landsat TM	27-1-1977	Blue, Green, Red, IR	30 m
2.	Landsat TM	29-1-1991	Blue, Green, Red, IR	30 m
3.	Landsat ETM+	24-1-2006	Blue, Green, Red, IR	30 m

Forest species identification and classification: Digital image interpretation technique is applied on the Landsat imagery acquired for the years 1977, 1991 and 2006 to identify the location and spatial distribution of different types of forests by applying ground-sampling points collected from field survey with the help of handheld GPS. As per the spectral behavior of forest types, the DN values of pixels from each feature class was derived to create spectral signature for different training sets and cluster analysis executed using Maximum Likelihood Classification technique to classify the image into five classes such as deciduous forest, mixed forest, shrub vegetation, rocky exposure and sand/gravel deposits.

Deciduous forests were emerged as dark reddish in color, coarse to medium pattern, irregular in shape and spread over among the hilly top. Mixed forests were emerged as pale red to pink color, medium to coarse pattern and associated with periphery of deciduous forest. In satellite imagery, dark brown colored features with coarse textures indicate the rocky exposures. Sand and gravel deposits were emerged as white to yellowish white with medium texture, irregular shape, and associated with water bodies.

Changes detection matrix: According to Singh (1989), change detection is the process of identifying differences in the state of an object or phenomenon by observing it in different times (multi-temporal variations). The each classified Satellite imagery of the different types of forests was con-

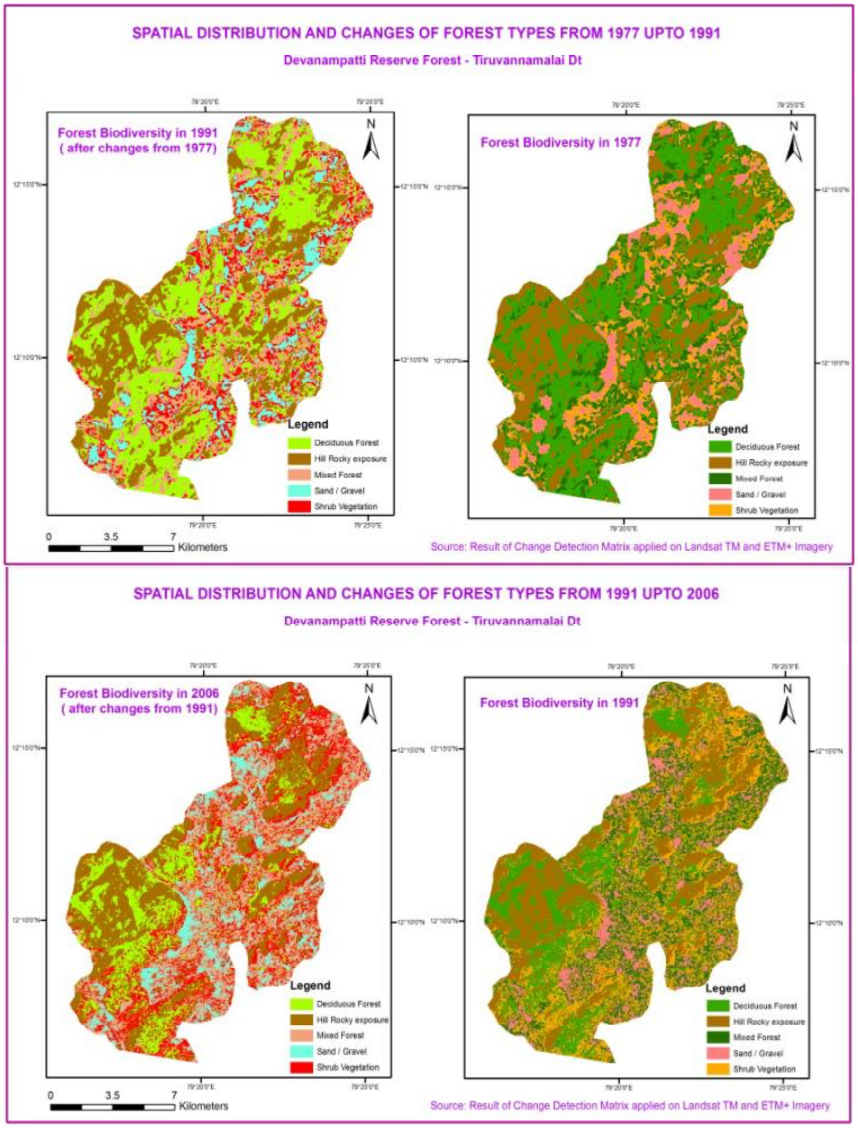

Fig. 4. Spatial changes of forest cover (a) changes between 1977 and 1991, (b) changes between 1991 and 2006.

verted into vector layer with appropriate geo database using Arc GIS 9.3 software. From the vector layer, every feature was extracted into separate layer and overlaid into one another to detect the changes and differences in the specified area, then computed and tabulated.

RESULTS AND DISCUSSION

Forest feature classification and area estimation: The spatial distribution of area was evaluated from Landsat TM and ETM+ satellite imageries acquired for January 1977, 1991 and 2006. The forest types, such as deciduous forest, mixed forest, shrub and scrub vegetation with different species of forest biodiversity were delineated from image based image classification technique.

In 1977, the spatial distribution of deciduous forest occupied an area of about 57.85 sq. km, and in 2006, it was decreased to 29.60 sq. km. The mixed forest is situated at the periphery of deciduous forest at lower elevation of hilly region and the total area of this was 35.30 sq.km in 1977 and this increased to about 41.75 sq.km in 1991, but in 2006 it again decreased in to 34.41sq.km. Shrub vegetation is widely distributed at the periphery of foothills and its area was 24.41sq.km in 1977 which increased to 41.75 sq.km in 1991, but again declined to 34.41 sq.km in 2006. The area of extent of hilly rocky exposure was 44.67sq.km in 1977 which increased to 77.79 sq.km in 2006. Sand and gravel deposits accumulated at the bank of tributaries and foothills with an area of 18.93 sq.km in 1977 which increased to about 24.80

Table 2: Estimation of area of forest cover during 1977 to 1991 and 1991 to 2006.

Forest Types	1977		1991		2006	
	Area (sq. km)	Percentage	Area (sq.km)	Percentage	Area (sq.km)	Percentage
Deciduous forest	57.3515	31.929	29.6052	16.3271	23.5647	13.158
Mixed forest	35.3083	19.4871	41.7571	23.6288	34.4111	18.9645
Shrub vegetation	24.4145	13.4747	44.1255	24.3349	20.5647	11.3335
Hill rocky exposure	44.6768	24.6577	45.8349	25.2777	77.7913	42.8721
Sandy/Gravel	18.9366	10.4514	20.0031	11.0315	24.3079	13.6721
Total area	181.4501	100	181.3257	100	181.1877	100

sq.km in 2006 (Fig. 2). The result reveals that the significance changes exist in each type of forest biodiversity. The increase or decrease of the forest features and its spatial distribution area might be attributed to the fluctuating climatic factors like rainfall, soil erosion and land fertility degradation. A specific type of forest location and its area is reduced to certain level and the same level of land is comprised of other types of features between particular periods of interval (Fig. 2, Table 2).

Spatial distribution and changes detection among the forest features: The spatial distributions of specific forest types have dynamic changes between 1977 and 1991 as well as between 1991 and 2006. Each type of forest feature has undergone significant changes in its location and the area of distribution in year by year. The location and area of deciduous forest was occupied by the mixed forests and shrub vegetation. Similarly, most of the land cover under deciduous forest changed as rocky exposure and degraded landforms.

Estimation of changes of forest features between 1977 and 1991: The area of difference of deciduous forest is 42.99 sq.km from its total area of 57.85 sq.km between 1977 and 1991. There is no change in the 19.2 sq.km of the deciduous forest and the remaining 7.24 sq.km of deciduous forest is changed to mixed forest, and 17.11 sq.km area was turned into shrub vegetation. The large deciduous cover of forest of about 12. 36 sq.km area was converted into rocky exposure in 1991. The total changes of each type of forest features

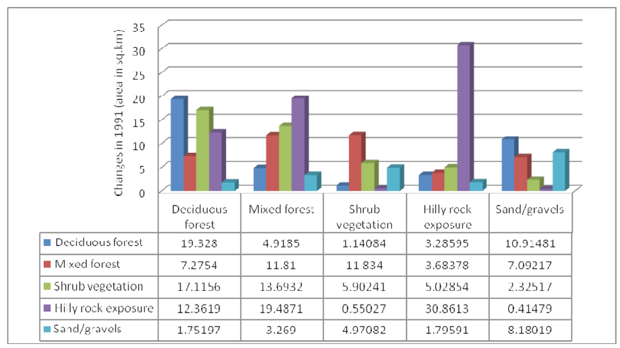

Fig. 5: Spatial changes of forest cover between 1977 and 1991.

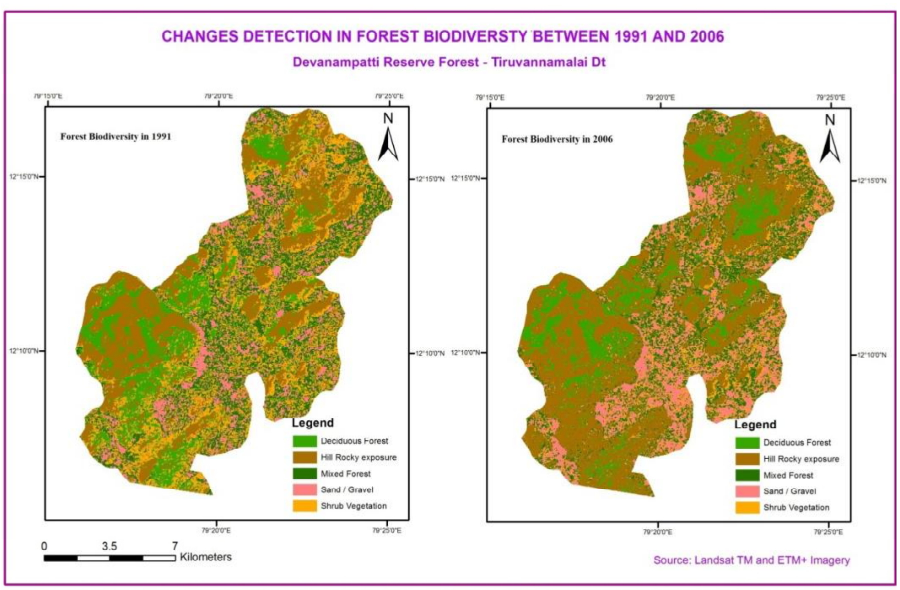

Fig. 6: Inventory of forest cover changes between 1991 and 2006.

Table 3: Estimation of changes in forest cover between 1977 and 1991 using change detection matrix.

1977 (area in sq.km)	Forest features changes in 1991 (area in sq.km)					
	Deciduous forest	Mixed forest	Shrub vegetation	Hill rocky exposure	Sand/gravels	Total forest area of changes
Deciduous forest	19.3280	7.2754	17.1156	12.3619	1.75197	57.8515
Mixed forest	4.9185	11.8100	13.6932	19.4871	3.2690	53.1778
Shrub vegetation	1.14084	11.8340	5.90241	0.55027	4.97082	24.39834
Hill rocky exposure	3.28595	3.68378	5.02854	30.8613	1.79591	44.65548
Sand/gravels	10.91481	7.09217	2.32517	0.41479	8.18019	18.92713
Total area of changes	29.56165	41.69535	44.06492	63.67536	19.96789	

Table 4: Estimation of changes in forest cover between 1991 and 2006 using change detection matrix.

1991 (area in sq.km)	Forest features changes in 2006 (area in sq.km)					
	Deciduous forest	Mixed forest	Shrub vegetation	Hill rocky exposure	Sand/gravels	Total forest area of changes
Deciduous forest	13.8272	1.69665	0.6874	12.6457	0.74812	29.60507
Mixed forest	0.79508	15.1193	8.31936	7.69902	9.82428	41.75704
Shrub vegetation	2.83239	10.9282	6.43465	19.3987	4.53149	44.12543
Hill rocky exposure	6.25386	1.57445	1.19916	36.4161	0.39127	45.83484
Sand/Gravels	0.1578	5.0606	3.9059	1.5907	9.2877	20.0027
Total area of changes	23.86633	34.3792	20.54647	77.75022	24.109552	

Table 5: Inventory of forest cover changes from 1977 to 2006.

1977 (area in sq.km)	Forest features changes in 1977 to 2006 (area in sq.km)					
	Deciduous forest	Mixed forest	Shrub vegetation	Hill rocky exposure	Sand/gravels	Total forest area of changes
Deciduous Forest	14.3615	6.85603	4.11443	28.6977	3.32172	57.35138
Mixed Forest	3.15311	9.81953	5.676672	11.1276	5.8312	35.6081
Shrub vegetation	0.48325	8.65674	4.79483	4.02445	6.4552	24.4144
Hill rocky exposure	31.1880	3.50180	2.66356	31.1880	2.3333	70.8746
Sandy/Gravels	0.37927	5.50904	3.25686	2.67860	7.11281	18.9365
Total area of changes	49.5650	34.3433	20.5063	77.544	25.0542	

were estimated and tabulated (Figs. 4 (a) and (b), Table 3).

Estimation of changes of forest features between 1991 and 2006: From the year of 1991 to 2006, tremendous changes have occurred among all types of forest features. There is no change in the location and distribution of 13.82 sq.km of the deciduous forest and the remaining area of this type is occupied by the other features like mixed forest, shrubs, etc. Most of the area of deciduous forest landform is converted with rocky exposure. The total area of deciduous forest is 29.60 sq.km in 1991 and this was decreased in to 13.82 sq.km in 2006. The distribution of mixed forest and shrub vegetation was decreased to 15. 11 sq.km and 6. 43 sq.km respectively. Rocky exposure, sandy deposits/gravel and eroded landforms were increased between 1991 and 2006 (Fig. 6 and Table 3).

Inventory of forest feature changes from 1977 up to 2006: The results of change detection matrix analysis reveal that

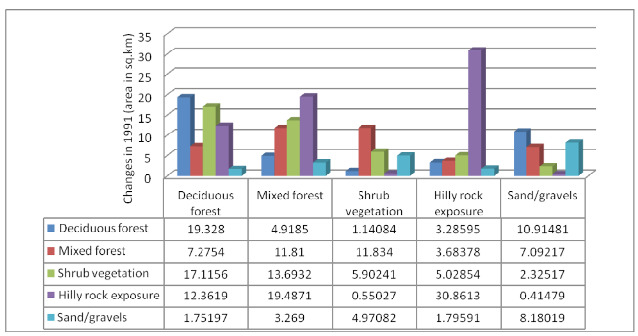

Fig.7: Spatial changes of forest cover between 1991 and 2006.

there is an incredible change occurred in each forest feature area and its spatial distribution from the year of 1977 to 2006. This also proved evidently, in which a particular feature changed into other landform from its original location and distribution within 29 years of interval. In 1977, the total area

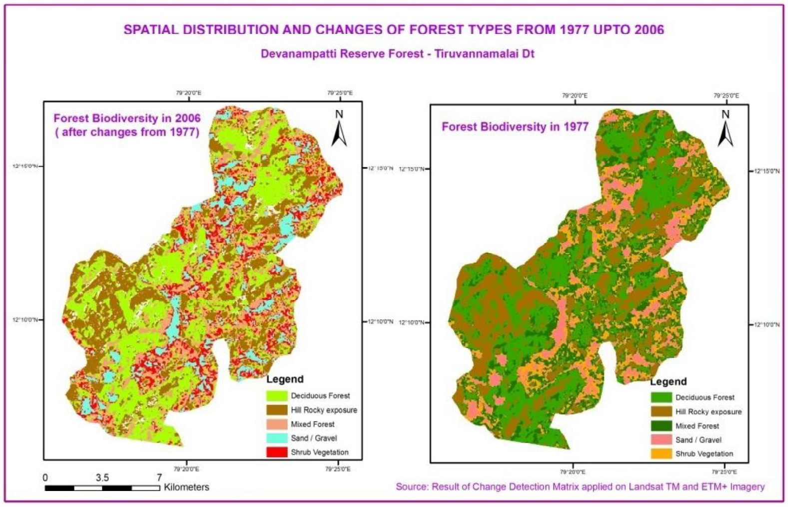

Fig. 8: Inventory of forest cover changes between 1977 and 2006.

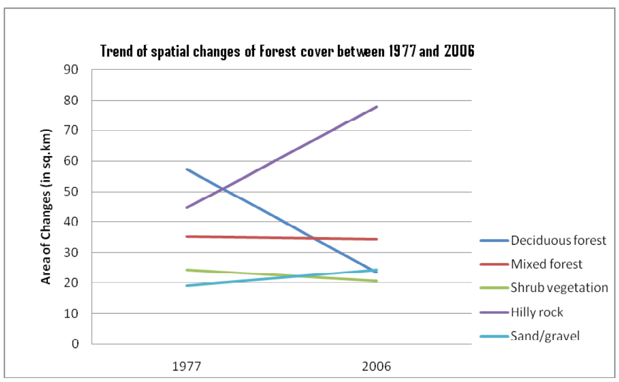

Fig. 9: Trend of spatial changes of forest cover between 1977 and 2006.

of deciduous, mixed forest and shrub vegetation, was estimated to be about 57.85 sq.km, 35.30 sq.km and 24.41 sq.km respectively. They have attained dynamic changes at huge amount into rocky exposure and eroded landforms.

This is confirmed by computing an area of extent of rocky landforms in 1977. In this period, the total covering area of rocky exposure was 44.67 sq.km, which enormously increased to 77.79 sq.km in 2006. Approximately, 31.18 sq.km area of deciduous forest lost its vegetation, and it is occupied with the sandy and gravel landforms, rocky wastes, and other types of vegetative cover in some places. About 5.50 sq.km area of mixed forest was replaced by degraded landforms like rocky waste and gravel landforms (Fig. 8 and Table 4).

CONCLUSIONS

It is proved from the study that the integrated remote sensing and GIS technologies produce valuable results on change detection analysis and to estimate the large-scale forest covers. From the study, the following main conclusions were brought out.

1. There is dynamic change occurred in each type of forest feature in its original location, area and distribution. Most areas of the forest types vanish their vegetative covers subsequently.
2. There is a significant decline in the percentage of deciduous forests, mixed forests and shrub vegetation areas, which tarnished into other types of landforms like sandy gravel and rocky exposure owing to continuous erosion and/or deforestation, lack of rainfall, etc.
3. In many locations, the rich forest biodiversity has undergone threatening stage by the tremendous changes into unwanted landforms.
4. This study can be a primary source to lay foundation for futuristic planning and decision making to conserve and protect the forest biodiversity.

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