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연구논문

Forest Cover Change Detection Analysis in the Eastern Ghats of Tamil Nadu, India - a Remote Sensing and GIS Approach

원격탐사와 GIS를 이용한 인도 Tamil Nadu의 Eastern Ghats(EG) 지역에 대한 산림의 변화 탐지

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Abstract

Information on forest type and cover density status of the present and past on large scale (1:50,000) is very much needed for conservation of any forest region. Such large-scale maps are not available for the Eastern Ghats (EG) of Tamil Nadu. This study deals with the preparation of forest type and cover density map of EG of Tamil Nadu during 2003 and the changes it has undergone between 1990 and 2003 using appropriate satellite data. About 10 forest types have been identified and mapped. Major changes have been observed in the forest types such as evergreen, and deciduous.

Keywords : Change detection, Eastern ghats, India, Forest, Remote sensing, GIS

要 旨

대축척(1:50,000)지도의 산림 정보는 산림지역 보호에 중요한 자료로 이용된다. 그러나 대상지역인 인도 Tamil Nadu의 Eastern Ghats(EG) 지역에는 대축척 지도를 사용할 수 없기 때문에 위성 데이터를 이용한 산림의 변화 탐지를 적용하여 분석하였다. 대상지역의 1990년과 2003년의 산림의 변화에 대한 연구 결과 약 10가지의 산림 종류가 관측되었으며 가장 변화가 큰 지역은 상록수와 낙엽수지역에서 관측되었다.

핵심용어 : 변화탐지, Eastern Ghats, India, 산림, 원격탐사, GIS

1. Introduction

NATURAL forests are one of the most magnificent terrestrial ecosystems of the world and also the living treasure on earth, have assumed much importance as they satisfy the needs of the living beings and also because of their significant role in the environmental harmony. In developing countries like India, peoples' dependence on forests for their basic needs is inevitable. Consequently demand and dependence on forestland and materials have increased tremendously resulting in depletion and degradation of dense and open forest covers.

Deforestation has many ecological, social and economic consequences, one of which is the loss of biological diversity and has affected a number of species world wide (Ciesla 1989). According to the recent report of Forest Survey of India (FSI 2002) the forest cover of our country is estimated to be 637,293 sq. km., which is 19.39% of the geographical area of the country. Information on forests such as type and cover density is very much needed for resource management and sustainable utilization (Martin *et al*. 1998).

Elaborate field survey in various parts of India have been done by Champion and Seth (Champion and Seth

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1968) and prepared the report of forest types of India. Conventional mapping procedures are time consuming and accuracy of information is also questionable in many cases (Tiwari *et al*. 1996). The application of newer technology such as satellite data for forest cover inventory and monitoring is more than 25 years old. Mapping of vegetation through satellite images can be done using visual interpretation of images (Beaubren 1986) or through computer aided digital classification such as supervised, unsupervised (Jensen 1986) and hybrid classification (Behra *et al*. 2000, Hoffer 1986) or by onscreen visual interpretation (Jayakumar *et al*. 2002, Kushwaha *et al*. 2000). Forest cover mapping using visual and digital classification has also been followed in many studies (Jha *et al*. 2000, Martin *et al*. 1998, Nagendra and Gadgil 2003, Nelson *et al*. 1984, Shen *et al*. 1985, Lakshmi *et al*. 1998, Unni *et al*. 1985). Satellite remote sensing technique with reasonably high spatial and temporal resolution could be used as a potential tool to monitor the changes in different surface and sub-surface features in spatial and temporal scale (Lillesand and Kiefer 1978, Jayakumar *et al*. 2000). Application of remotely sensed data to illustrate changes in forest over time has been reported by many investigators (Green and Sussman 1990, Hall *et al*. 1998, Hall *et al*. 1991, Iverson *et al*. 1989, Sader and Joyce 1988).

Hill area is a unique place for the luxuriant growth of the forest. Hilly terrains are the areas with high and rugged relief and occupy unique physiographic location and form the most fragile ecosystem vulnerable to all kind of anthropogenic influences (Gupta *et al*. 1993). They are frequently affected by extensive soil erosion, landslides, deforestation, overgrazing and drought caused due to wanton destruction of hill slopes for development (Dobhal 1987, NRSA 1998, Congalton *et al*. 1983).

Forest Survey of India (FSI), Dehra Dun was created in 1981 under the Ministry of Environment and Forests, which is assessing the country's forest cover at definite intervals of time (two years). Beginning in 1983, FSI has made seven such assessments on 1 : 250,000 and 1 : 50,000 scale using Indian Remote Sensing Satellite (IRS) data. However, large-scale forest cover map (1: 50,000) for Tamil Nadu is not available. As far as forest resources are concerned, type and density are the two important elements in both resource management and sustainable utilization (Martin *et al*. 1998). But so far FSI has prepared forest cover density map only. Therefore this study was envisaged with the following objectives

a. Mapping the present status of forest type and cover density of the Eastern ghats (EG) of Tamil Nadu on 1:50,000 scale and
b. Estimation of the changes in the forest type and cover density between 1990 and 2003

2. Study area

Eastern ghats of Tamil Nadu is a rugged hilly terrain, which starts from the Jawadi hill and extends up to the Alagar hill. Jawadi, Shevaroy, Chitteri, Kalrayan, Kolli and Pachaimalai, are major hills, which totally cover an area of about 5,126 sq. km (Figure 1). Among which, the total reserved forest area occupies 3536 sq km and the non-reserved forest area occupies 1590 sq. km. Geographically it is situated between 11° 00' 00" to 13° 00' 00" N and 78° 00' 00" to 79° 10' 00" E. The minimum and maximum altitude of this region is ranging from 180 m above MSL to 1700 m above MSL at the foothill and Sholaikaradu of Shevaroy hill respectively. The mean minimum and maximum temperature is ranging from 17°

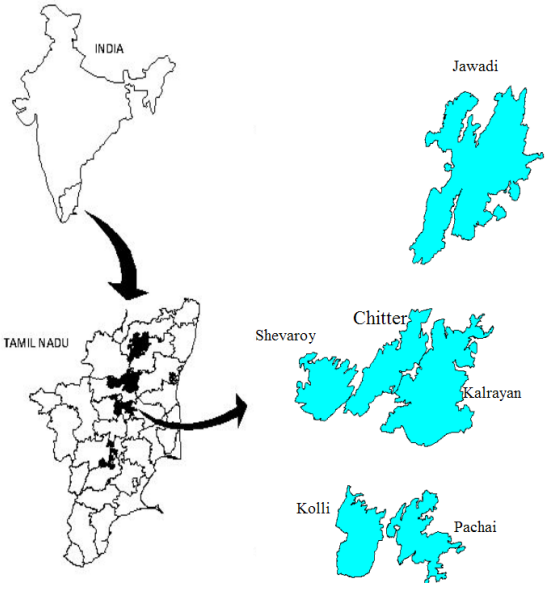

Figure 1. Location map

to 33℃ respectively. The mean minimum and maximum rainfall is ranging from 800 to 1600 mm respectively.

3. Materials and methods

Landsat Thematic Mapper digital data of 23 April 1990 of path 143 and row 51, 52 and 53, IRS 1C LISS III digital data of 26 April 2003 of path 101 and row 64, 65 and 66, twenty three Survey of India (SOI) topo sheets No. 57 L/ 8, 9, 10, 11, 12, 13, 14, 16, 57 P/ 1, 2, 3, 58 I/ 1, 2, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, global positioning system (GPS), *ERDAS IMAGINE – 9.0* - Image processing software, *ArcGIS 9.1* - GIS software, *HP PLOTTER (42")*, *HP WORKSTATION*, secondary data such as Forest working plan for Thiruppattur, Vellore, Thiruvannamalai, Harur, Salem, Attur and Tiruchy divisions were used in the present study.

4. Forest cover mapping and change detection

The methodology followed to prepare the change detection map of EG of Tamil nadu is explained in the Figure 2. The digital data of Landsat Thematic Mapper (TM) (3 scenes) with 30 m ground resolution were corrected geometrically taking sufficient ground control points (GCPs) from SOI maps. All the satellite data were geometrically corrected using first order polynomial geometric model with root mean square error (RMSE) less 0.5 pixel using ERDAS IMAGINE software. The geometrically corrected data were subsequently mosaiced. IRS 1D digital data (3 scenes) with 23.5 m resolution were also corrected geometrically using the corrected Landsat TM data through image-to-image registration technique. Utmost care was taken to minimize the RMSE (0.5) and these three scenes of IRS 1D LISS III data were subsequently mosaiced.

Reserved forest (RF) boundary was traced for each hill from the SOI maps and digitized. After creating the topology in ARCGIS software, it was overlaid on the digital data. The RF areas of each hill were subset from the digital data of 1990 and 2003 and the RFs subset alone were processed in order to avoid misclassification. False color composites were generated from the Landsat TM using bands 4,3,2 in red, green and blue (RGB) color guns and from IRS LISS III using bands 3,2,1 in RGB and printed on 1:50,000 scale. Normalized difference vegetation index (NDVI) was generated from TM and LISS III satellite data. Interactive method of display is used to assign threshold values for each density class viz., dense (>40% crown cover), open (10 – 40%) and degraded (<10%) on the basis of the ground knowledge (Rawat *et al*. 2003) and density map of forests were prepared. The forest type map was prepared following expert classification technique (Ramachandran *et al*. 2007) (Figure 2). The classified forest cover and density maps of different hills were printed on 1:50,000 scale using HP plotter. Intensive field verification was carried out in the field with SOI maps, FCC hard copy, classified maps, compass and GPS. For 1990, field check was performed only at the

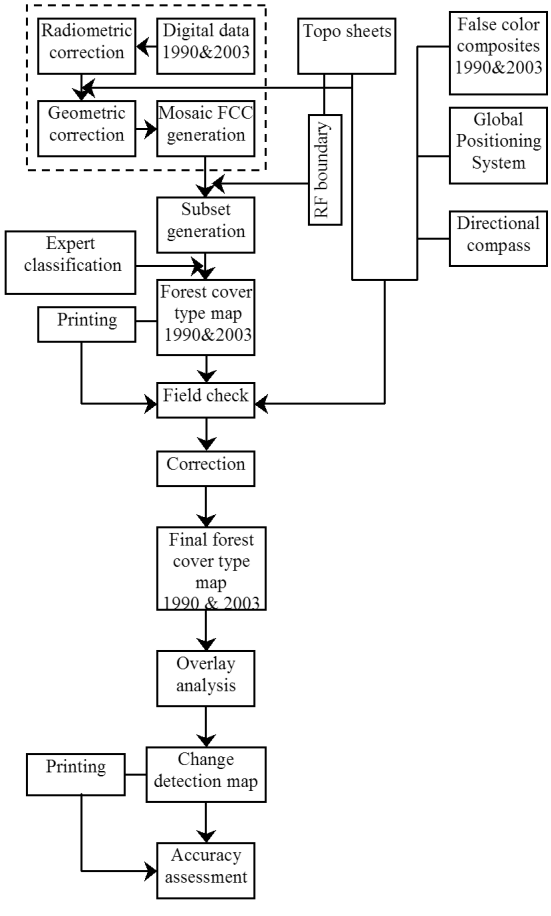

Figure 2. Methodology flow chart for Forest type and cover density map preparation and change detection analysis

unchanged area. Corrections were made in the interpreted maps wherever found necessary, spatial information such as RF boundary, roads and villages were overlaid and final forest type and density map for 1990 and 2003 were finalized.

Intensive field verification was carried out in the field with SOI toposheets, FCC hard copy, classified maps, compass and GPS (*GARMIN* −12 channel). For 1990, field check was performed only at the unchanged area. Corrections were made in the interpreted maps wherever found necessary, spatial information such as RF boundary, roads and villages were overlaid and final forest type and density map of each hill for 1990 and 2003 was finalized.

Changes in the forests were analyzed using *ERDAS IMAGINE* software. Change detection maps of various hills were prepared and the area in each class was estimated. After finalization, maps were printed on 1: 50,000 scale using HP plotter and accuracy check was carried out in 849 points using GPS to estimate the accuracy of classification (Congalton *et al*. 1983). The accuracy sample points were distributed randomly in the classified map proportionate to the area of each class. The latitude and longitude values of the accuracy check pointes were noted and in the field the location of each point was identified with the help of GPS. As the GPS accuracy was less then 5 meter in all the places, the location of each point was identified accurately. Once all points were checked, the producer and user accuracy of individual class and overall accuracy of the classification were calculated (Table 1).

5. Results and Discussion

Forest cover type mapping on 1: 50,000 scale and change detection analysis in the EG of Tamil Nadu of the present study is a pioneer study. Ten forest types such as Tropical dry evergreen (7/C1), Evergreen (2/E4), Southern dry mixed deciduous (5A/C3), Dry deciduous

Table 1. Accuracy assessment

	A	B	C	D	E	F	G	H	I	J	K	L	Row Total
A	98	-	-	-	-	-	2	-	-	-	-	-	100
B	7	180	-	-	13	-	-	-	-	-	-	-	200
C		11	32	2	7	5	-	-	-	-	-	-	57
D	-	2	2	23	8	6	-	-	-	-	-	-	41
E	-	15	-	1	179	17	-	-	-	-	-	-	212
F	-	4	-	-	18	108	-	-	-	-	-	-	130
G	-	-	-	-	-	-	29	-	-	-	-	-	29
H	-	-	-	-	-	-	-	5	-	-	-	-	5
I	-	-	-	-	-	-	-	-	23	-	-	-	23
J	-	-	-	-	-	-	-	-	-	35	-	-	35
K	-	-	-	-	-	-	-	-	-	-	8	-	8
L	-	-	-	-	-	-	-	-	-	-	-	9	9
Column Total	105	212	34	26	225	136	31	5	23	35	8	9	849

A − Evergreen, B − Deciduous, C − Secondary Deciduous, D − Deciduous scrub, E − Southern thorn, F − Southern thorn scrub, G − Tropical riparian, H − Grassland, I − Bamboo, J − Barren rocky, K − Plantation, L - Others

Overall mapping accuracy = 701/849 = 82.5%

User's accuracy for the different classes: Evergreen 98%; Deciduous 90%; Secondary Deciduous 56%; Deciduous scrub 56%; Southern thorn 84%; Southern thorn scrub 83%; Riparian 100%; Grassland 100%; Bamboo 100%; Savannah 100%; Barren rocky 100%; Plantation 100% & Others 100%

Producer's accuracy for the different classes: Evergreen 93%; Deciduous 81%; Secondary Deciduous 87%; Deciduous scrub 81%; Southern thorn 75%; Southern thorn scrub 76%; Riparian 93%; Grassland 100%; Bamboo 100%; Savannah 100%; Barren rocky 100%; Plantation 100% & Others 100%

scrub 5/DS1), Tropical riverain (5/1S1), Secondary deciduous (5/2S1), Southern thorn (6A/C1), Southern thorn scrub (6A/DS1), Dry savannah (5/DS2) and Dry grassland (5/DS4) were identified with various cover density classes. The total RF area in the EG is 4202.96 sq. km. A small portion of the study area with change detection map is given in figure 3.

During 2003 the total dense forest cover was 57247.09 ha, in which, the dense forest cover of Jawadi hill contributed 28101.5 ha, which accounts for about 49% of the dense forest area. Chittery hill contributed 11768.75 ha, which accounts for about 20.5% of the dense forest area. Kalrayan hill and Kolli hill contributed 6731.63 and 6326.82 ha, which account for 11.7 and 10.9% of the dense forest cover respectively. Shevaroy and Pachaimalai, hills contributed less than 5% each (Table 3). During 1990 the total dense forest cover was 65737.78 ha. Among them the Jawadi hill contributed 32617.5 ha, which comprises 49.6% of the area. The change in the dense forest cover in Jawadi hill between 1990 and 2003 was about 4513 ha (Table 4). Maximum change was also observed in Chittery and Elagiri hill where the change between 1990 and 2003 in the dense forest cover was about 2127.8 and 1323.4 ha respectively (Table 3 & 4). During 2003 the dense deciduous forest contributed 52902.77 ha, which accounts for 92% of the dense forest cover. Dense evergreen forest contributed 4344.32 ha, which comprises 7% of the total dense forest cover (Table 2). During 1990 the dense deciduous forest contributed 61212.97 ha, which constitutes 93% of the total dense forest cover. The difference observed in the dense deciduous forest cover between 1990 and 2003 was about 8310.2 ha. (Table 2).

The open forest cover during 2003 was about 38779.52 ha. Among them Jawadi hill contributed maximum area of about 17966.81 ha, which accounts for 46% of the total open forest cover. About 8330.38 ha area was contributed by Chittery hill, which accounts for 21% of the total open forest cover. Kalrayan and Kolli contributed 2545.38 and 3093.57 ha, which account for 7 and 8% respectively (Table 3). During 1990 the total open forest cover was about 39703.91 ha. Among them Jawadi hill contributed 17007.5 ha, Chittery hill contributed 8546.5 ha and Shevaroy hill contributed 6756.82 ha, which comprise 43, 22 and 17% respectively (Table 4). Kalrayan hill, Kolli hill and Pachaimalai contributed 3212.97,

Table 2. Forest cover type change detection in the Eastern Ghats of Tamil Nadu between 1990 and 2003

Sl. No.	Forest cover type	Area in hectare		Change
		1990	2003	
1.	Dense Evergreen	4524.81	4344.32	-180.49
2.	Open Evergreen	2513.82	2287.32	-226.5
3.	Degraded Evergreen	1394.85	1800.82	405.97
4.	Dense Deciduous	61212.97	52902.77	-8310.2
5.	Open Deciduous	37190.09	36492.2	-697.89
6.	Degraded Deciduous	24263.41	32570.26	8306.85
7.	Secondary Deciduous	15241.6	15034.26	-207.34
8.	Deciduous scrub	13506.24	13849.5	343.26
9.	Southern thorn	92480.81	90852.7	-1628.11
10.	Southern thorn scrub	96804.05	98313.07	1509.02
11.	Riparian	351.94	416.81	64.87
12.	Grassland	78.64	73.19	-5.45
13.	Other Plantations	276.25	275.81	-0.44
14.	Bamboo plantation	1837.69	2131.57	293.88
15.	Barren rocky	1552.44	1744.31	191.87
16.	Others	464.99	605.69	140.7

Table 3. Forest type and cover density status of Eastern Ghats of Tamil Nadu during 2003 (Area in ha)

Forest types	Major hills						Total
	Jawadi	Shevaroy	Chittery	Kalrayan	Kolli	Pachaimalai	
Dense Evergreen	2408.06	42.75	0	0	1759.63	133.88	4344.32
Open Evergreen	884.75	118.56	0	177.94	384.94	721.13	2287.32
Degraded Evergreen	953.31	142.44	0	297.75	244.88	162.44	1800.82
Dense Deciduous	25693.44	1864.88	11768.75	6731.63	4518.88	2325.19	52902.77
Open Deciduous	17082.06	5604.63	8330.38	2367.44	2708.63	399.06	36492.2
Degraded Deciduous	20293.81	2847.13	5716.38	2600.44	1112.5	0	32570.26
Secondary Deciduous	0	0	9423.38	5610.88	0	0	15034.26
Deciduous scrub	0	0	5029.69	8819.81	0	0	13849.5
Southern thorn	33195.63	13684.25	8780	9333.5	9405.94	16453.38	90852.7
Southern thorn scrub	59139.69	4154.5	2964.31	9845.25	5371.44	16837.88	98313.07
Riparian	0	246.06	0	0	48.31	122.44	416.81
Grassland	0	0	0	0	0	73.19	73.19
Other Plantations	0	275.81	0	0	0	0	275.81
Bamboo plantation	0	531.5	451.25	802.69	346.13	0	2131.57
Barren rocky	22.56	312.19	90.5	129.75	1093.31	96	1744.31
Others	0	408.13	7.56	82	108	0	605.69
Total	159673.31	30232.83	52562.2	46799.08	27102.59	37324.59	353694.6

Table 4. Forest type and cover density status of Eastern Ghats of Tamil Nadu during 1990 (Area in ha)

Forest types	Major hills						Total
	Jawadi	Shevaroy	Chittery	Kalrayan	Kolli	Pachaimalai	
Dense Evergreen	2439.94	48.81	0	0	1850.56	185.5	4524.81
Open Evergreen	893.56	135.88	0	315.56	402.88	765.94	2513.82
Degraded Evergreen	912.63	118.52	0	160.13	136.44	67.13	1394.85
Dense Deciduous	30175.49	2171.75	13896.6	7159.75	5310.25	2499.13	61212.97
Open Deciduous	16113.94	6620.94	8546.5	2864.81	2810.09	233.81	37190.09
Degraded Deciduous	16779.94	1596.81	3471.72	2089.19	325.75	0	24263.41
Secondary Deciduous	0	0	9481.44	5760.16	0	0	15241.6
Deciduous scrub	0	0	4912.44	8593.8	0	0	13506.24
Southern thorn	33448.19	14439.75	9072.81	9169.19	10713.56	15637.31	92480.81
Southern thorn scrub	58887.06	3701.81	2686	9834.24	4032.25	17662.69	96804.05
Riparian	0	189.69	0	0	39.81	122.44	351.94
Grassland	0	0	0	0	0	78.64	78.64
Other Plantations	0	276.25	0	0	0	0	276.25
Bamboo plantation	0	489.31	415.19	676.94	256.25	0	1837.69
Barren rocky	22.56	178.94	71.94	93.31	1113.69	72	1552.44
Others	0	264.37	7.56	82	111.06	0	464.99
Total	159673.31	30232.83	52562.2	46799.08	27102.59	37324.59	353694.6

Table 5. Forest density status in different hills and their changes between 1990 and 2003

	Dense forest cover			Open forest cover			Degraded forest cover		
	1990	2003	changes	1990	2003	changes	1990	2003	changes
Jawadi	32615.43	28101.5	-4513.93	17007.5	17966.81	959.31	110027.82	113582.4	3554.62
Shevaroy	2220.56	1907.63	-312.93	6756.82	5723.19	-1033.63	19856.89	20828.32	971.43
Chittry	13896.6	11768.75	-2127.85	8546.5	8330.38	-216.12	29624.41	31913.76	2289.35
Kalrayan	7159.75	6731.63	-428.12	3180.37	2545.38	-634.99	35606.71	36507.63	900.92
Kolli	7160.81	6278.51	-882.3	3212.97	3093.57	-119.4	15208	16134.76	926.76
Pachaimalai	2684.63	2459.07	-225.56	999.75	1120.19	120.44	33367.13	33453.7	86.57

3212.97 and 999.75 ha respectively.

The total area under degraded forest cover in the EG during 2003 was 252420.61 ha. Among them Jawadi hill contributed 113582.44 ha which comprises 45% of the degraded forest cover. Chittery, Kalrayan and Pachaimalai contributed 31913.76 ha (13%), 36507.63 ha (14%) and 33453.7 ha (13%) respectively (Table 3). All the other hills contributed less than 10%. During 1990 the total area of degraded forest cover was 243690.96 ha. Among them Jawadi hill contributed 110027.82 ha, which accounts for 45% of the degraded forest cover. Kalrayan contributed 15% of the area (35606.71 ha) and the Pachaimalai contributed 14% of the area (33367.13 ha). Chittery hill contributed 29624.41 ha, which comprises 12% of the degraded forest cover (Table 4). The over all changes that occurred in the forests between 1990 and 2003 are given in the table 2. The total dense, open and degraded forest cover status and changes are given in the Table 5.

The riparian forest present in the Shevaroy, Kolli and Pachaimalai hills occupied an area of about 351.94 ha during 1990 and it was 416.81 ha during 2003. The increase was about 64.87 ha. Grassland category was present only in the Pachaimalai hill. It occupied only 78 ha during 1990 and not much changes could be noted during 2003. In the EG Bamboo is cultivated as plantations and apart from that Silver oak and Teak were also planted. The Bamboo plantation could be identified by its characteristics tone and texture. It occupied about 1837.69 ha during 1990 and 2131.57 ha during 2003. The other plantation area occupied 276 ha during 1990 and 275 during 2003 (Table 2)

6. Conclusion

In the present study the reserved forest area of EG was classified into 10 categories. The forest cover change detection in the EG of TN on 1:50,000 scale is a pioneer study. Though Forest Survey of India (FSI) is preparing forest cover map of entire India, the scale of mapping is small (1:250,000). Recently FSI has initiated mapping on 1:50,000 scale, but Tamil Nadu has not been taken up so far. Moreover, from the FSI report, it is possible to estimate the density of forested area but it is not possible to estimate area under different forest types, but information on forest such as type and density is very much needed for management and sustainable utilization (Martin *et al*. 1998).

In the present study decrease in the forest cover was noted in all the dense and open cover types. As a result, increase in the area was noted in the degraded cover type. The forest cover change detection showed that the change in the forest cover has occurred on the periphery of the settlements and agriculture lands. This indicates that the human interference by means of fuel wood collection, illegal felling and livestock grazing are high in these regions. This is because, EG is a broken chain of hills surrounded by human settlements on all sides. The human interference not only denudes the forest cover but also affects severely the regeneration status (Jayakumar *et al*. 2002). The best way to revegetate the degraded forest would be by arresting human interference, because natural forests have its own regeneration capacity.

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