International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Temporal Analysis of Forest Cover Change: East Khasi Hills Meghalaya, India: Using Remote Sensing and GIS

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Abstract: ***The state Meghalaya is known for its diverse, extensive and luxuriant forests. The diverse topography and varied climatic condition the natural vegetation of the sate ranges from Sub-tropic to Tropical. Due to both urbanization and its ethnic culture the forest cover of the state undergoes vegetal degradation processes, which, is decreasing forest cover area and changing the original quality of the forest cover. Applying remote sensing and GIS techniques the present study tries to assess the present status of forest of the selected study area and examine it in relation to possible socio economic factors. The primary aim of the paper is to find out the changes in forest cover due to rapid rate of urbanization and other anthropogenic factors and calculate the deforestation rate. The present study also tries to assess the temporal changes in land cover with help of change matrix. The results show that between the years 2003 to 2011, area about 110. 05 square kilometres under goes vegetal degradation and converted to non-forest contributed by scrubs 28.12 square kilometres, open forest 77 square kilometres, unclassified forest 4.93 square kilometres.***

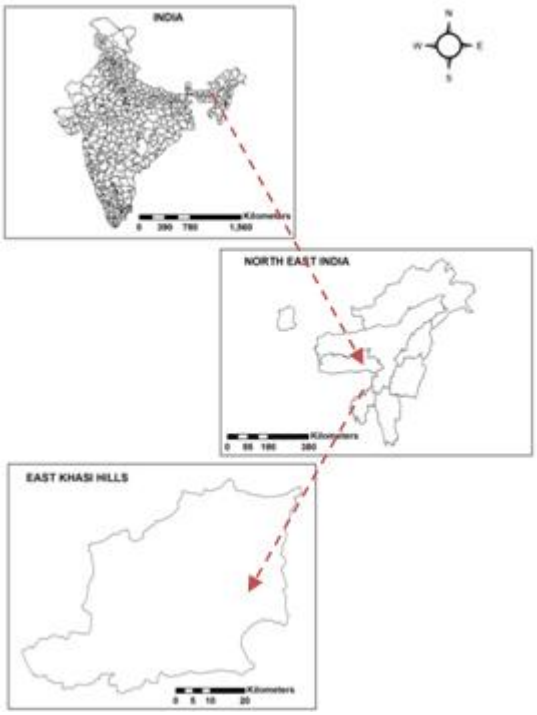
Keywords: Forest cover & type, change detection, forest cover estimation, deforestation rate, change matrix

1. Introduction

The temporal change of forest cover is the conversion of forest to permanent non-forested land use such as agriculture, grazing or urban development over the time. Likewise it also includes changes in the type of forest cover. As a one of the prim outcome of forest cover change "Deforestation is primarily a concern for the developing countries of the tropics (Myers, 1994) as it is shrinking areas of the tropical forests (Barraclough and Ghimire, 2000)" "causing loss of biodiversity and enhancing the greenhouse effect (Angelsen et al., 1999)".

The study area East Khasi Hills (25°07" to 25°41" north latitudes and 91°21" to 92°09" east longitudes) has combination of both urban and rural societies. The state capital city Shilong (Hill station) acts as a core of the district According to 2011 census total population of East Kahsi hills is about 825922. Population density of district is 301/kilometre square. On the other hand Shillong Metropolitan shares 354759 numbers of populations. The urban area has experienced increasing population (Planning department, Meghalaya) due to natural growth and in-migration from neighbouring states. This has reflected in increasing and expanding urban settlement resulting in urban sprawling in vicinity of the urban agglomeration.

According to 2011 state tourism department report total 672,307 numbers of tourist both domestic and foreign visited the hill station. Which is another important factor regarding urban agglomeration. Apart from the city site, rest of the district still holds its ethnic coulters. According to 2011 census district has 27.5 % tribal population. As a result, areas that mainly dominated by the local tribes the cultural landscape also mostly based on local ethnic couture. The tribal dominance over the region reflects in traditional land relationship of the people. Practising *„Jhum agriculture'* displaying slash and burn techniques, where tress, scrubs are cut off letting them dried in the sun. After which the dried leaves are burned thereby, generating natural manure for the soil. By using remote sensing and GIS technique the present study attempts to estimate the present status of forest cover and assess the temporal changes in land cover of East Khasi hill district in relation to state forest report.



Source of Primary Data:

1) The primary data is based on ground truth verification and collecting GPS points at certain areas of the vegetal

degradation and collecting information from digital photography.
2) The study has been done between two yeas 2003 and 2011 (Path 110 & Row 54). There are two satellite imageries of LISS-III image, with 23.5 meters spatial resolution for the year of 2003 and 2011, (Bhuvan ISRO).

Source of Secondary Data:
1) The secondary data are mostly based on remote sensing technique. Aster DEM with 30 meters spatial resolution (Aster GDEN) and Google earth images.
2) Meghalaya state forest reports
3) District census hand books
4) Meghalaya Environment reports

2. Methodology

The digital image analysis of satellite data for forest cover mapping considers the reflectance behaviour of different tree covers. Radiometric and contrast corrections were applied for removing radiometric defects and for improving visual impact of the False Colour Composites (FCC). Geometric rectification of the data was carried out with the help of SOI topographical maps [as 78 O/6, 78 O/7, 78 O/8, 78 O/10, 78 O/10, 78 O/11, 78 O/12, 78 O/14, 78O/15, 78 O/16, 83C/2. 83 C/3 and 83 C/4.]

Normalized Difference Vegetation Index (NDVI) transformation was also used for density classification of forest cover. The Normalized Difference Vegetation Index (NDVI) introduced by Rouse *et al.* (1974), is a very commonly used index to monitor vegetation presence and properties. The NDVI varies between -1.00 and 1.00 and is computed as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

To correlate NDVI values with the forest cover type, recent classification of (Julien *et al.,* 2011) is followed using Database Query-Re class; a) non-forest type: NDVI < 0.2, b) moderate forest type: 0.2 < NDVI < 0.5, and c) Dense forest type: NDVI > 0.5 (Das and Joshi, 2013). These steps are applied for the images of 2003 and 2011 and areas of each land cover are calculated.

Further Supervised classification has done for preparation of land use/land cover maps. As LISS –III is used for forest cover mapping, a scale of 1:50,000 considered as minimum mapping unite (MMU) of one hectare. Areas of less than one hectare, whether classified as forest within non-forest areas or blanks within forested areas, were excluded by clustering pixels and merged with the surrounding class.

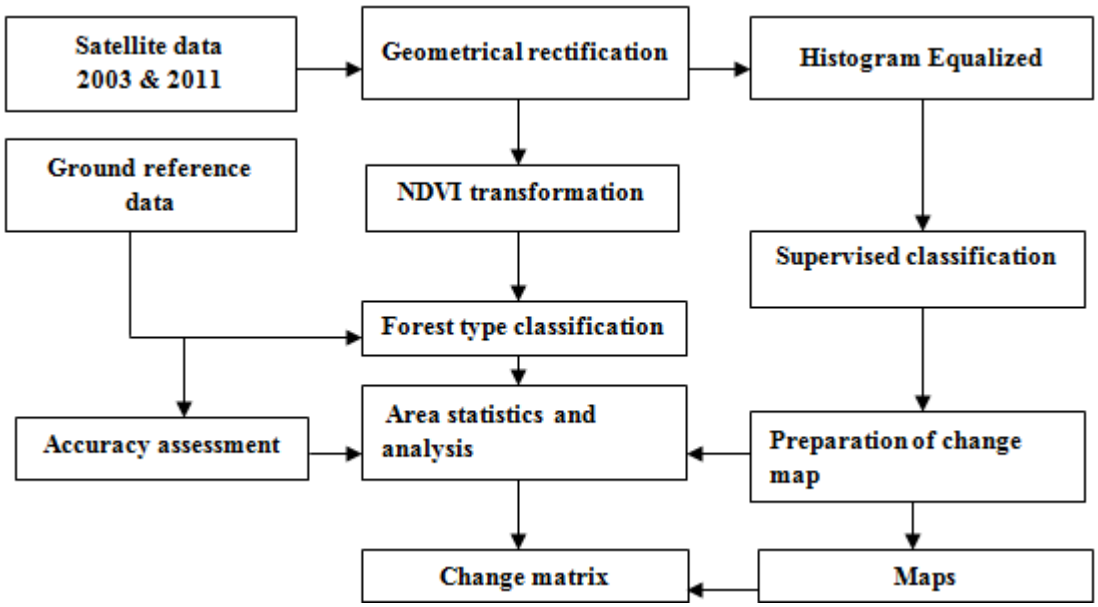
Area calculation in Raster: *Ground Area* = (Count) * (x*y) in square metres

Where, Count represents the numbers of pixels in one feature class, (x*y) area of one pixel in relation to real ground in square meters.

The present study followed the forest cover classification scheme of FSI (forest survey of India).
Classification scheme for the purpose of assessment in this paper is described as follows (FSI):

Class	*Description*
Very dense forest	All lands with tree canopy density of 70% and above.
Moderate dense forest	All lands with tree canopy density of 40% and more but less than 70%
Open forest	All lands with tree canopy density of 10% and but less than 40%
Scrub	Degraded forest lands with canopy density less than 10%
Non forest	Lands not included in any of the above classes.

The flow chart for methodology



3. Results & Discussions

The total geographical area of the district about 2748 square kilometre of which 1877 square kilometre comes under forest cover in 2003(state forest report 2003) and 1836 square kilometres in 2005 (state forest report 2005). In 2011 the forest cover become 1800 square kilometres. The following table shows the forest cover according to the types of the district.

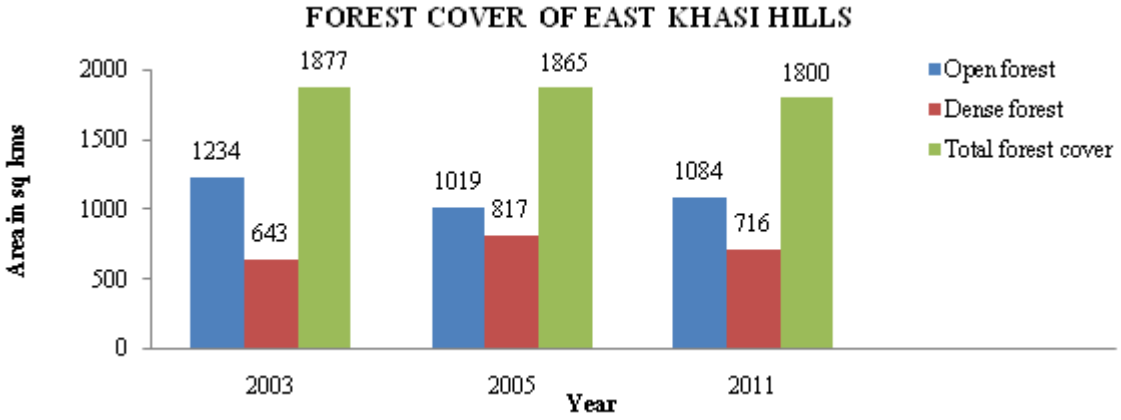
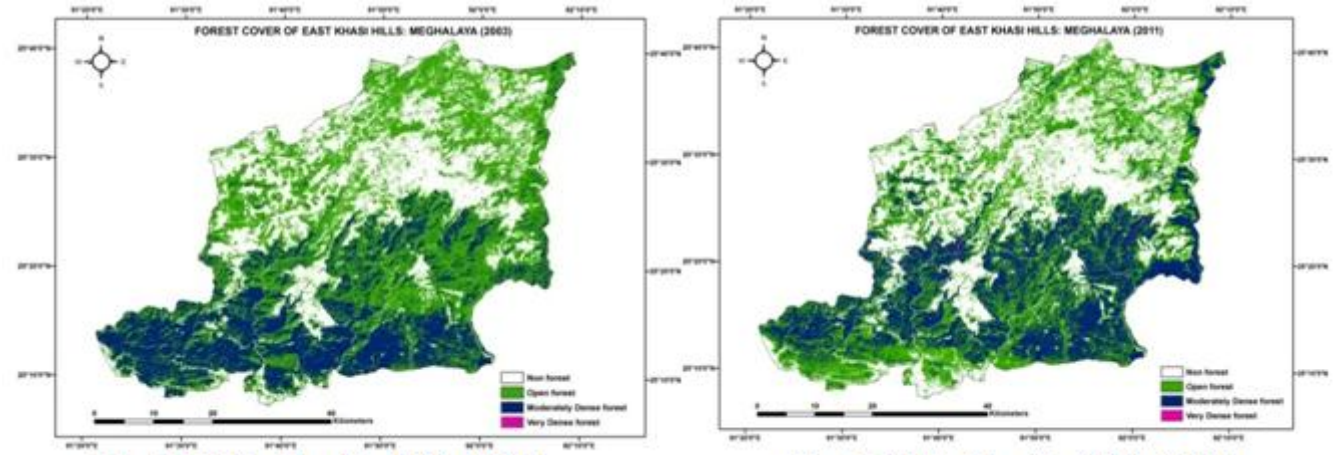


Figure 1: Forest cover of East Khasi Hills, Meghalaya
Source: ENVIS centre on Himalayan ecology (Sate forest report)

Results of NDVI

The NDVI results show that most of the open forest degraded. In 2003 the total area under open forest is about 1234 square kilometres where as in 2011 the total area under open forest is about 1084 square kilometres. On the other hand in 2003 the area comes under moderately dense forest cover is about 643 square kilometres, in 2011 it increase up to 716 square kilometres. Between these eight years the total forest cover of the district decreases 77 square kilometres. Most of the open forest degraded from high altitude zone that is above 1500 meters whereas, the dense forest is mostly increasing at low and middle altitudes, in between 500 to 1500 meters.

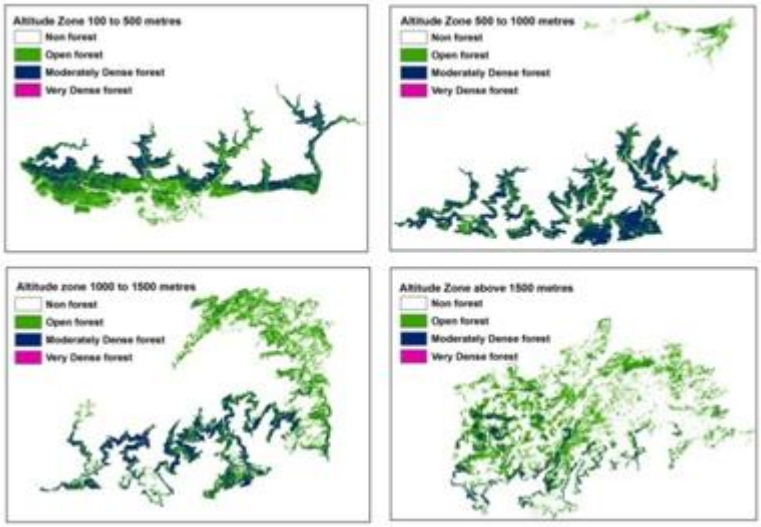


Map 1: NDVI of East Khasi Hills (2003)

Map 2: NDVI of East Khasi Hills (2011)

Non forest
Open forest
Moderately Dense forest
Very Dense forest

About 25.18 % of total forest cover comes under 100 to 500 metres altitude, 27.02 % comes under between 500 to 1000 metres altitude. The highest percentage of forest cover i.e. 28.76 is seen in 1000-1500 metres altitude of the district while, 19.04 % of forest cover seen above the altitude 1500 metres. The altitude wise forest cover of the district is given bellow:



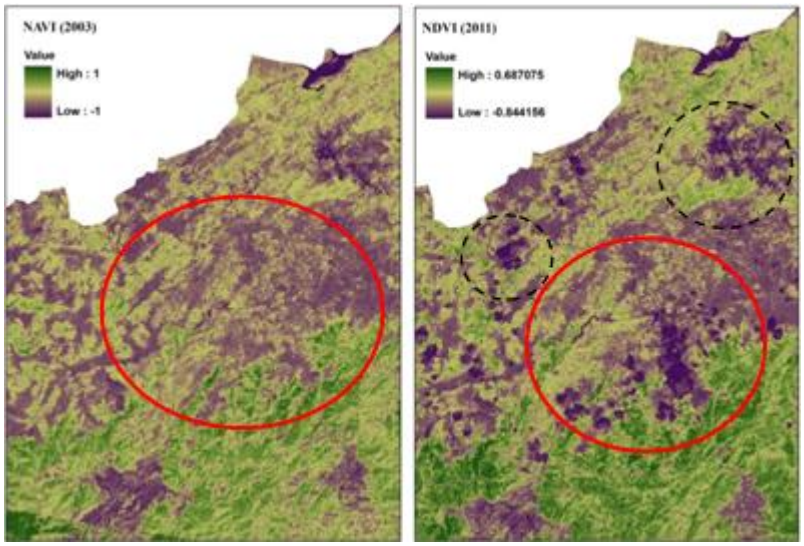
Map 3: Altitude wise forest cover, East Khasi Hills, Meghalaya (2011)

Table 1: Altitude wise forest cover, East Khasi Hills, Meghalaya (2011) in square kilometres

Altitude	OF	MDF	NF	Total Forest (area in km2)
100 - 500	271.67	182.41	103.5	454.09
500 -1000	198.05	288.49	69.49	487.25
1000 - 1500	331.28	185.33	293.19	518.53
➢ 1500	283	59.77	481.82	342.37

Note: Here OF represents open forest, MDF represents moderately dense forest, VDF represents very dense forest and NF represents non forested areas (Non forest includes degraded scrub lands and bare soil, water body, urban settlement etc).

Comparing NDVI values for 2003 and 2011, it has found that in the year 2003 the value ranges between 1 to -1, where as in the year 2011 the values ranges between + 0.68 to -0.84. The fluctuation in the high and low value indicates decreasing quality and quantity of vegetation. The -0.84 value indicates complete removal of vegetation cover. The estimation shows that About 98.16 square kilometres of area converted to bare land.

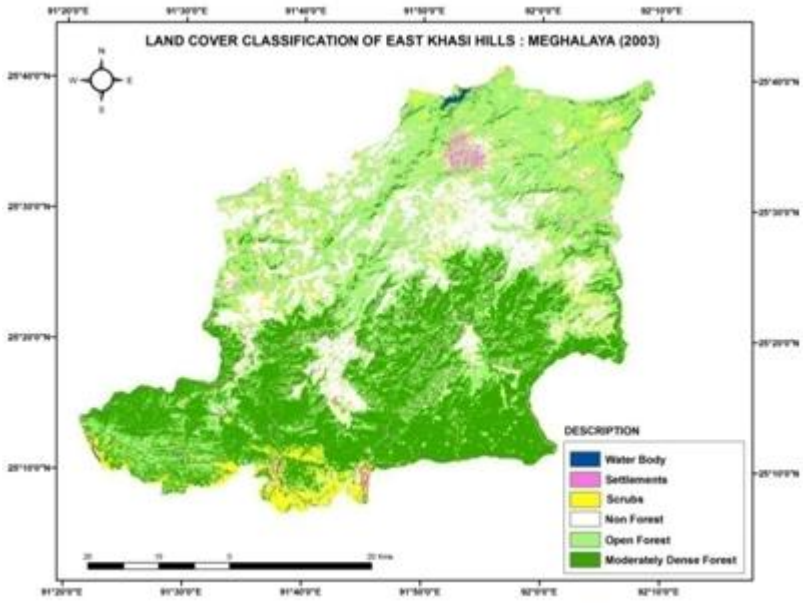


Map 4: Area showing vegetal degraded areas

4. Results of Supervised

Classification: The Supervised classification of 2003 and 2011 images shows that about 495.48 square kilometres of area comes under Non forest area or vegetal degradation. In 2011 it rises up to 605.53 square kilometres.

On the other hand in terms of other classes, the settlement in 2003 occupied an area of about 76.03 square kilometres and in 2011 it increased up to 77.73 square kilometres. The scrubland in 2003 was 100.04 square kilometres, which decreased to 70.02 square kilometres in 2011. Analysed the statistics generated by supervised classification it found that the scrub lands are mostly affected by vegetal degradation.



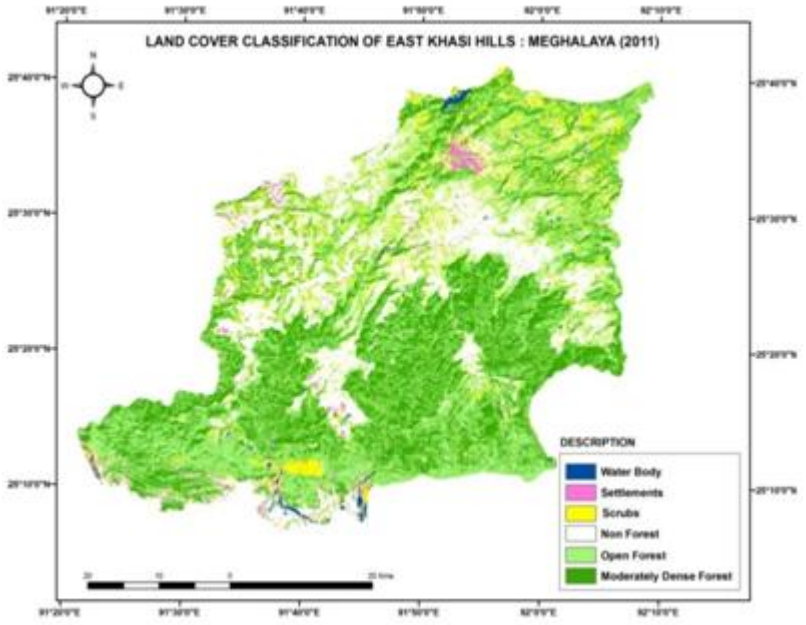
Map 5: supervised classification (2003)

Table 2: Land cover classes, East Khasi Hills, Meghalaya (2003 & 2011)

Description	Area inKm^2 (2003)	Area inKm^2 (2011)	Net Change inKm^2
Water Body	19.38	19.58	0.2
Settlement	76.03	77.73	1.7
Scrubs	100.04	70.02	-30.02
Moderately Dense forest	643	716	73
Open forest	1234	1084	-150
Unclassified Forest	180.07	175.14	-4.93
Non Forest	495.48	605.53	110.05

Here, unclassified forests are those forests that are not yet brought under the classification. These areas are supposedly owned by the state and in reality these are mostly, controlled by local communities (De, 2003).

While considering classes of forest cover of the district, result reveals by supervised classifications of 2003 and 2011 shown 77 square kilometres of open forest significantly comes under vegetal degradation or vegetal change between the years 2003 to 2011.



Map 6: supervised classification (2011)

This vegetal change mostly seen between 1000 to 1500 metres of altitude. To re-examined the forest boundary of the district, the Forest boundary of Meghalaya (Forest survey of India), finally overlay upon the generated maps.

Table 3: Land cover assessment (change matrix), East Khasi Hills, Meghalaya (2003 & 2011)

	2011 Assessment							
2011 Assessment	**Water Body**	**Settlement**	**Scrubs**	**MDF**	**OF**	**U F**	**N F**	**Total 2003**
Water Body	**19.38**	**0**	**0**	**0**	**0**	**0**	**0**	**19.38**
Settlement	**0**	**76.03**	**0**	**0**	**0**	**0**	**0**	**76.03**
Scrubs	**0.2**	**1.7**	**70.02**	**0**	**0**	**0**	**28.12**	**100.04**
MDF	**0**	**0**	**0**	**643**	**0**	**0**	**0**	**643**
O F	**0**	**0**	**0**	**73**	**1084**	**0**	**77**	**1234**
U F	**0**	**0**	**0**	**0**	**0**	**175.14**	**4.93**	**180.07**
NF	**0**	**0**	**0**	**0**	**0**	**0**	**495.48**	**495.48**
Total 2011	**19.58**	**77.73**	**70.02**	**716**	**1084**	**175.14**	**605.53**	**2748**
Net Change	**0.2**	**1.7**	**-30.02**	**73**	**-150**	**-4.93**	**110.05**	

The above matrix shows positive and negative changes concerning different land cover classes. In relation to forest cover of the study area changes are observed mostly in moderately dense forest and open forest. 73 square kilometres of open forest has been converted to moderately dense forest which indicates changes in forest type. On the other hand 28.12 square kilometres of scrub land goes under non forest, and 4.93 square kilometres of unclassified forest also goes under non forest. These temporal changes of land as well as forest cover basically observed at middle to high altitudes.

Deforestation Rate

Depending on the government and estimated records, the deforestation rate for a given period was evaluated using the following formula given by Armenteras *et al.,* (Nath and Mwchahary, 2012)

$$\text{Deforestation rate} = \frac{(\log Ft1 - \log Ft2) * 100}{t2 - t1}$$

Where t 1 and t 2 indicates time-1 and time-2 and Ft1 and Ft2 are the corresponding forest cover.
Calculating the deforestation rate of East khasi hills it shows that 0.23 % per year, that is annually 6.49 square kilometres of land area goes under deforestation.

Accuracy Assessment:
To verify the quality and reliability of the classification exercise, accuracy assessment was done. Topographic maps and a Global Positioning System (GPS) were used to obtain ground control point for accuracy test. A total of 25 points were obtained randomly, (Mostly in the mining areas) focusing on the distribution along the forest.

Limitations of Remote Sensing Data: Data recorded by remote sensing instruments are valuable for providing information on forest cover conversion and modification but are not always a consistent indicator of discrete change events (Loveland et al., 2002) The delectability and accurate characterization of forest disturbance using remotely sensed data are influenced by the type of disturbance, the magnitude and duration of the modified signal, and natural variability (species/landscape). These factors can often result in high errors of omission and commission in forest change maps.

Some of these limitations faced in this present study are mentioned below.

1) Since the resolution of the LISS III sensor data 23.5 m the land cover having dimension less than the above are not captured.
2) Young plantations and tree species with less chlorophyll or poor foliage are many times not discernable on satellite images due to poor leaf area index and transmittance.
3) Considerable ground details may sometimes be obscured due to clouds and shadows. Such areas are difficult to classify without help of collateral data ground truth verification.
4) Gregarious occurrence of weeds like lantana in forest areas and agricultural crops like sugarcane, cotton etc. Occurring in the vicinity of forest area causes mining of the spectral signatures and often makes forest cover delineation difficult.
5) Where heterogeneity in crop composition is high, generalized classification may affect the accuracy level.
6) Non availability of appropriate season data sometimes leads to misinterpretation of the features

5. Conclusions

Destroying forest cover in East Khasi Hills is a big loss of future markets for ecotourism. Annually 6.49 sq kilometres of land area of the district goes under deforestation. Considering *Jhum* cultivation, annually 6.2 sq. kilometres of area of the district use for *Jhum*, providing 3605 persons their livelihood (soil and water conservation department government of Meghalaya, 2003). It shows that the impact of *Jhum* cultivation is minimum in terms of deforestation. The study reveals that rapid urbanization and population growth is the primary factors of removing forest cover of the district. As the city area is expanding, it has its negative impact on forest cover. Mostly at high altitudes, that is above 1500 metres. On the other hand the NDVI results also show that area above in high altitudes mostly comes under non forest. The changes in forest cover types also one of the significant find out of the present study. Comparing NDVI results of 2003 and 2011, it finds out that at the middle altitudes between 1000 to 1500 metres the open forest changed into moderately dense forest. However it is one of the result of plantation by the local people as well as regeneration of plants. From the generated statistics of supervised classification it has found that between the years 2003 to 2011, about 605.53 square kilometres (22.03%) Land cover went under vegetal degradation in East Khasi hills.

According to state forest report 2011 East khasi Hills has 35.34 % of forest cover of the total geographical area. Regarding the possible causes of vegetal degradation ; the forest covers of the state as well as the East Khasi Hill district provides both timber and non timber forest products

(NTFPs), which are the sources of income and livelihood of the locals. More than 380 different types of NTFPs are collected by the people of the state for various uses (Tiwari, 2002). Of these, 51 percent are used for medicinal purposes and 36 percent as food and the rest for other purposes. In terms of extraction of timber in 2004-2005 the total timber extraction for the state was 1072.24 cubic metres, where 1056.63 cubic metres were illegal logging (Source: State Forest Department and the Autonomous District Councils). On the other hand between the years 2004 - 2005 total bamboo extraction of the state was 5708.84 metric tonnes (Source: State Forest Department and KHADC, Shillong; JHADC, Jowai; GHADC, Tura.) The fire wood consumption by the state between the years 2002-2004 in the urban areas was 607942.2 metric tonnes in urban, where as in rural it was 10952.14 metric tonnes. Regarding East Khasi hills it was about 155745.5 metric tonnes in urban, in rural it was 1301.01 metric tonnes (Source: Forest Resource Survey, Meghalaya 2002-2004). Considering minerals East Khasi Hills mostly known for its coal and limestone reserves. The state Meghalaya has estimated coal reserves of 559 million tonnes and East Khasi hills contributes 31 million tonnes (State of the Environment Report 2005: Meghalaya).

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