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Analysis of Land Use/Land Cover Changes and its Future Implications in Garo Hill Region of Meghalaya: A Geo-Spatial Approach

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ABSTRACT

The satellite imagery of 1991, 1999, 2009 and 2013 has been used to understand the land use / land cover change in Garo hill region of Meghalaya. The result shows that there is substantial change of land use / land cover in the region. The dense forest in the region has declined from 26.73% in the year 1991 to 13.96% in 2013. Similarly the percentage of open forest has decreased from 55.40% in the year 1991 to 48.98% in 2013. On the other hand the agricultural land in the region has increased from 10.65% in the year 1991 to 17.77% in 2013. Built up area has also showed a rising trend from 0.57% in the year 1991 to 3.29% in 2013. The current research has also identified that the traditional agricultural practices in the region has been gradually replaced by the plantation crops. It is also evident from the current research that remote sensing and GIS tools are quite applicable for monitoring and assessment land use / land cover change at landscape level.

Keywords: Land Use / Land Cover, Deforestation, Remote Sensing, GIS,

1. INTRODUCTION

The land use / land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space[1] Knowledge of land use and land cover is important for many planning and management activities and is considered an essential element for modelling and understanding the earth as a system[2]. Information on land use / land cover in the form of map and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban-industrial activities, environmental studies, economic production etc.[3]. Though the land use and land cover are oftenassumed to be identical, they are rather quite different; land cover is the biophysical earth cover, while land use is often shaped by human beings and their socio-economic and political influences on the land[4][5] Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled with economic growth. Often improper land use is causing various forms of environmental degradation[6] Currently with the growing human population pressure, changing human-population land ratio and increasing land degradation, the need for optimum utilization of land assumes much greater relevance. Anthropogenic changes in the land use and land cover are being increasingly recognized as critical factor for global changes.[7]

During the last four decades, development of remote sensing and GIS techniques has made significant contribution in the management of natural resource and environmental monitoring. Remote sensing (RS), integrated with Geographic Information System (GIS), provides an effective tool for analysis of land-use and land-cover changes at a regional level [8]. This technique have been used extensively in tropics for generating valuable information on forest cover, vegetation types and land use changes[9] . Temporal changes of land use and land cover have become possible in less time, at low cost and with better accuracy through remote sensing and GIS techniques [10].

Land use / Land Cover change in mountainous ecosystem are extremely complex due to human interactions that are determined by a whole range of factors. Highly diverse human societies living in these natural resource rich areas of the region are facing an accelerated rate of societal changes leading to finer patterns with respect to the processes contributing to the land use / land cover changes[11]. Here in this present study an attempt has been made to understand the land use / land cover change and its future implications in Garo Hill region of Meghalaya, India through multi-temporal remotely sensed data and with limited ground verification. The current study has also a great significance, because most of the Garo Hill region is

remains inaccessible due to the prolonged insurgency in the region from the last one decade.

Study Area:

The Garo Hill Districts of Meghalaya is under biogeography zone 9B (north-east India) and it is located between latitude 25°9´ to 26°1´ N and longitude 89°49´ to 91°2´E (Fig.-1). The Garo Hill Districts of Meghalaya situated in the peninsular plateau areas in the South and Brahmaputra plains in the north. It is consist of three districts viz. East Garo Hill, West Garo Hill and South Garo Hill District with an area of 8,167 sq. km [12][13]. The highest point of Garo hills is the Nokrek peak with an altitude of 1412m above msl [14].

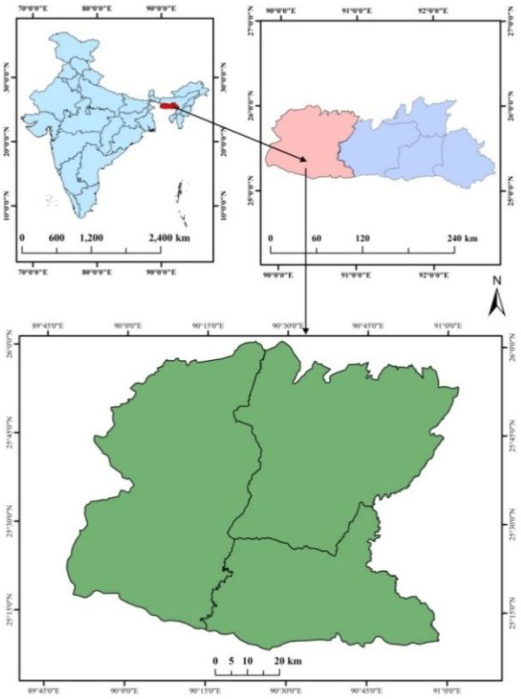


Fig.-1: Location of Study Area

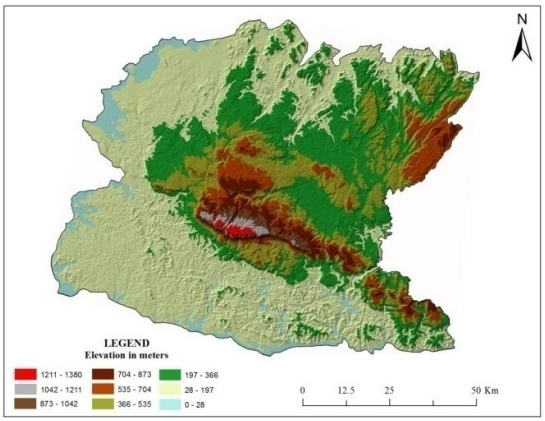
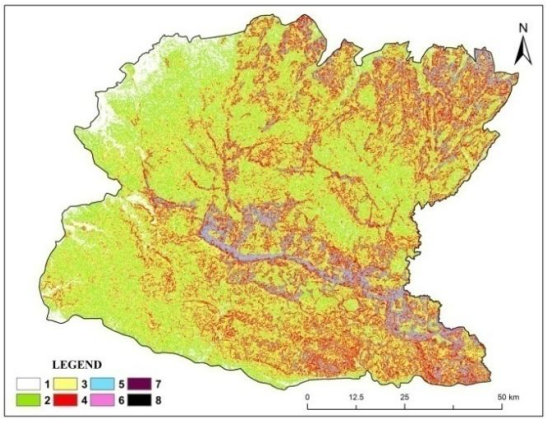


Fig-2: Elevation Zones of Garo Hill Districts of Meghalaya

Deep gorges and abrupt slopes are found in the southern Garo hills along narrow plains of Bangladesh border. Maximum rivers flow towards Bangladesh plains in the south and the Brahmaputra valley in the north and the west. The important rivers of the north flowing are the Kalu, Ringgi and the Didak and south flowing are the Bhogai, Darengetc[15].



Abbreviations: Slope in percent; **1**. Very Gentle (0- 4), **2**. Gentle (4-10), **3**. Moderate (10-20), **4**. Moderately Steep (20-35), **5**. Steep (35-60), **6**. Very Steep (60-100), **7**. Most Steep (100-175), **8**. Extremely Steep (> 175)

Fig.-3: Slope Variations in Garo Hill Districts of Meghalaya

Garo Hill's peoples are largely dependent on the forest resources for their livelihood[16]. The mining activity has a good effect on economic growth but it affected the surrounding environment, which leads to its degradation[17] Government forest area is only 15% in the Garo Hills and remaining belongs to community reserve forest[18].

2. DATASET AND METHODOLOGY USED

To assess the land use / land cover change and its future implication in Garo hill region, satellite imagery of Landsat TM of 1991, IRS 1D LISS III of 1999 and IRS P6 LISS III of 2009 and 2013 were used. Besides these the Survey of India (SOI) topographical sheets at

1:50000 scale were used to delineate the study area boundary and also to gather base line information of the study area. Ancillary data which are available with different government and non-government organizations were also used here in this current study. The table 1 shows the dataset used in the current study.

Table 1: Dataset used

Data Types	Path/Row	Date of Acquisition
Landsat TM	137/42 & 137/43	26.11.1991
	138/42& 138/43	14.11.1991
IRS 1D LISS III	109/53 & 109/54	19.12.1999
	110/53 & 110/54	16.12.1999
IRS P6 LISS III	109/53 & 109/54	09.03.2009, 13.02.2009 & 28.02.2013
	110/53 & 110/54	05.03.2013
Topographical sheets	1:50000 scale	1978-88
Ancillary Data	Ancillary maps	N/A

3. METHODOLOGY

Satellite imagery of Landsat TM of 1991, IRS 1D LISS III of 1999 and IRS P6 LISS III of 2009 and 2013 were used to assess the land use / land cover change and its future implication analysis in Garo hill region of Meghalaya. The satellite imagery of landsat TM of 1991 was downloaded from the open source web link provided by NASA's Global Land Cover Facilitator's (GLCF) website (www.glcf/edu.org). The IRS 1D LISS III and IRS P6 LISS III satellite imageries of 1999, 2009 and 2013 were procured from National Remote Sensing Centre (NRSC), Hyderabad. All the imageries were projected using UTM-WGS 84 projection system taking the reference from Landsat TM imagery of 1991. Sub-pixel image to image registration accuracy was achieved through repeated attempt. The radiometric correction of the images was done through dark pixel subtraction technique[19]**.** Re-sampling of the IRS 1D LISS III and IRS P6 LISS III images were carried out at 30 m pixel size as the Landsat TM imagery of 1991 was at 30 m pixel resolution. Mosaic operation of the images was done as the study area was not covered in a single image. The SOI topographical sheets at 1:50000 scale were also geo-coded using the UTM-WGS 84 projection system and the boundary of the study area was digitized using on-screen digitization technique. Subset operation of the satellite imageries of 1991, 1999, 2009 and 2013 was carried out creating an area of interest (AOI) layer of the vector layer of the study area, which was digitized from the SOI topographical sheets. After subset all the images, an on-screen digitization approach was adopted to delineate the different land use / land cover pattern of the study area. Initially the land use / land cover pattern of the study area of 1991 was identified using the satellite imagery of Landsat TM for the year 1991 and after that same has been overlapped over the other images of 1999, 2009 and 2013 respectively and changes of the land use / land cover was identified for each of the years and saved as a separate land use / land cover layers for the region. After that post classification comparison method was adopted using cross matrix analysis for assessment of land use / land cover changes in the region. The cross operation allows the analyst to know the extent and nature of changes observed, in other words, the transition between different land cover classes and the corresponding areas of changes. After that a quantitative analyses of the land use / land cover changes was done using the formula

$$K_T = (U_b - U_a / U_a) * 100\%$$
$$K = (U_b - U_a / U_a) * (1/T) * 100\%$$

Where K_T is the period change rate of a certain category, $\mathbf{U_b}$ and $\mathbf{U_a}$ are the areas of this land use/land cover type at the beginning and at the end of the research period. K is the annual average rate of change of a certain type (dynamic trend of single land use/land cover category). T is the time period. The result of this model presents the annual change rate of this land use/land cover type in this region when the unit is set as years[20]. This analysis of land use / land cover change was done to understand and assess the range and speed of changes in different periods. The range appears as an area change of various land use/land cover categories. The speed change means the dynamic trends of land use/land cover changes in different periods. It plays an important role in the comparison of spatio-temporal changes of different land use/land cover categories. The areas and percentages of various land use/land cover categories are calculated on classification results of land use/land cover in Garo Hill districts of Meghalaya in different periods.

Through the classification process nine land use / land cover classes were identified in the region. These classes including agricultural land, built up area, shifting cultivation, waste land, rivers, wet land, dense forest, open forest and degraded forest area. Ground verification was done from January, 2014 to October, 2014. A total 21 transacts were either walked or covered using vehicles for the entire Garo hill region. Ground verification was carried out using GPS device. A total 1235 GPS point were collected from different land use / land cover types as visualized from the field. All the satellite image processing and GIS analysis for assessment of land use / land cover change was done using Super Map 7C and Erdas Imagine 9.1 software.

4. RESULTS AND DISCUSSION

Land use/land cover reflects the areal changes of its natural and man-made features of that area. The Garo hill districts of Meghalaya are categorized into following land use/land cover classes

Agriculture Land: It is the second largest category in terms of covering area of 1450 sq. km in 2013 (17.73%) whereas it was calculated 865.80 sq. km

(10.59%) in 1991. The annual average growth rate was calculated 1.83% for the period of 1991-2013. The maximum and minimum average growth rate was calculated 4.05% and 0.99% during 2009-2013 and 1999-2009 respectively.

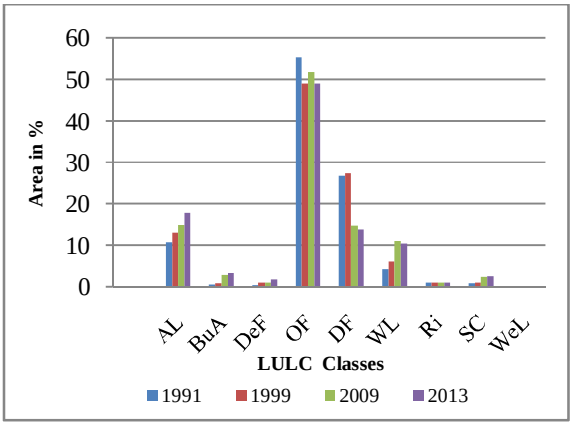
With the increasing demand of agriculture for livelihood, it was increased by 20.92% during 1991-1999, 9.92% during 1999-2009 and 16.18% during 2009-2013. It was increased by 40.29% during 1991-2013 because of high demand. Traditional agricultural practices operative in the Garo hill districts of Meghalaya with changing pattern from traditional to plantation crops like Pine apples, cashew nut, strawberry, palm etc.

Built up Area: According to Census of India, the total population of Garo hills districts were was 668,930, 869,952 and 110, 3115 in 1991, 2001 and 2011 respectively. It was more than 37% of Meghalaya's total population which is distributed mainly in plains along with some pocket of hilly areas. The built up area has increased from 0.57% in 1991 to 3.29% in 2013 in this region. The growth of built up areas are mainly found in the urban areas like Tura and William Nagar.

Shifting Cultivation: Shifting or Jhum is a traditional agriculture practices operated by the tribal people of hilly areas of north-east India. Shifting cultivation is an important factor of livelihood pattern of peoples of Garo hill region. It is calculated 0.79% of total area in 1991and increased to 2.52% in 2013. The changing pattern of agriculture from traditional to plantation crops helps to reduce the trends of shifting cultivation. It is observed that the Garo Hill districts of Meghalaya dominated by the open forest cover mainly betel nut, strawberry, pine apples, chestnut, cashew nut, strawberry, palm, tea estate and rubber plantation which are practices in the gentle and moderately steep slopes.

Wastelands: Wastelands is an important land use/land cover category which is not used in any purpose. It is calculated 4.27% in 1991 and increased 6.28% in 1991, 11.20% in 2009 and decreases to 10.46% in 2013. The fallow land of shifting cultivated area, recent clearance of forest cover, mining area etc. are falls under this category.

Wetlands: In Garo hill districts of Meghalaya, only natural wetlands are found mostly in the plain areas which is covered a small proportion of its total area. These wetlands characterized by rich flora and fauna



Abbreviations: ***AL****=Agricultural Land,* ***BuA****=Built up Area,* ***SC****=Shifting Cultivation,* ***WL****=Waste Land,* ***Ri****=Rivers,* ***WeL****=Wetlands,* ***DF****=Dense Forest,* ***OP****=Open Forest and* ***DeF****=Degraded Forest*

Fig.-4: Land use / Land cover changing pattern in Garo Hill region.

Table- 2: Area of land use/Land Cover and dynamic change in Garo HillDistricts of Meghalaya during 1991-2013

LULC Classes	1991		1999		2009		2013	
	Area (Sq. Km)	Area (%)	Area (Sq. Km)	Area (%)	Area (Sq. Km)	Area (%)	Area (Sq. Km)	Area (%)
AL	869.99	10.65	1062.02	13.00	1214.09	14.87	1451.09	17.77
BuA	46.53	0.57	70.30	0.86	236.26	2.89	268.39	3.29
DeF	27.84	0.34	98.18	1.20	79.49	0.97	148.29	1.82
OF	4524.72	55.40	3996.25	48.93	4223.81	51.72	4000.41	48.98
DF	2183.28	26.73	2239.45	27.42	1206.76	14.78	1139.90	13.96
WL	348.62	4.27	512.71	6.28	914.73	11.20	854.61	10.46
Ri	93.42	1.14	92.91	1.14	88.80	1.09	88.70	1.09
SC	64.35	0.79	81.69	1.00	193.16	2.37	205.80	2.52
WeL	8.25	0.10	13.50	0.17	9.91	0.12	9.82	0.12
Total	**8167.00**	**100.00**	**8167.00**	**100.00**	**8167.00**	**100.00**	**8167.00**	**100.00**

Table 3: Transfer matrix of land use / land cover change from 1991 to 2013

Year	LULC	2013									Total Area
		AL	BuA	DeF	OF	DF	WL	Ri	SC	WeL	
1991	AL	561.40	33.80	6.19	181.18	8.97	63.39	4.65	5.63	7.67	872.88
	BuA	1.20	43.11	0.04	3.87	0.07	1.07	0.00	0.01	0.00	49.38
	Def	5.48	0.03	4.02	13.37	2.68	2.38	0.01	2.75	0.00	30.73
	OF	753.89	158.47	109.03	3542.82	208.28	595.47	4.66	156.75	0.58	5529.95
	DF	75.47	24.37	21.34	480.54	460.96	93.25	0.95	26.87	0.00	1183.75
	WL	41.04	10.01	8.01	194.75	4.74	80.35	1.12	11.41	0.02	351.45
	Ri	4.93	0.34	0.19	3.92	1.00	5.22	80.08	0.08	0.59	96.35
	SC	7.42	1.14	2.45	30.02	7.36	13.70	0.00	5.16	0.00	67.26
	WeL	3.02	0.00	0.00	1.77	0.00	2.44	0.06	0.00	3.81	11.11
	Total Area	1453.86	271.28	151.27	4452.26	694.06	857.27	91.55	208.65	12.68	8192.87

Water Bodies: The water bodies include the streams, rivers, rills etc. The main rivers Kalu, Ringgi, Didak Bhogai and Dareng in Garo hills districts of Meghalaya. But there are so many small streams, and rills are found in the area. The total water bodies are almost remains unchanged whole study period. In 2009 onwards, the total area was decreased but decreasing rate is very negligible.

Dense Forest: The dense forest in Garo hills districts are mainly found in the protected forest areas of the region. Protected forest means the area under vegetation with the maintenance of government authority. It includes national parks and reserve forest. The main reserve forest and national parks in Garo hill districts of Meghalaya are Diburuhill reserve forest, Tura Peak Reserve forest, Angoratoli reserve forest, Baghmora national park, Rewak reserve forest, Siju reserve forest, Imangiri reserve forest, Rongrengiri reserve forest, Songsak reserve forest, Darugiri reserve forest, Dambu reserve forest, Chima Bangsi reserve forest, Dhima reserve forest, Dilma reserve forest, Raja Simla reserve forest etc. The protected forest cover was increased 26.73% in 1991 to 27.42% in 1999, while it was decreased 14.78% and 13.96% in 2009 and 2013 respectively due to encroachment of forest cover by the local people.

Open Forest: The open forests are mainly the community forests which are found mainly outside the protected areas. This research found a decreasing trend open forest area in the region. The total area under this category was calculated 55.40% in 1991 and it decreased to 48.93% in 1999 and 49.98% in 2013. Open forest cover area replaced by agricultural activity, mining activities and built up area with the increasing demand of food supply and habitation with the increasing rate of population.

Degraded Forest: The degraded forest area is increases with the increasing rate of destruction of dense and open forest cover in the Garo hill districts of Meghalaya. Shifting cultivation, mining activities, illegal encroachment of forest land, illegal forest resource business etc. are the main causes of increase the degraded forest cover in this area.

The figure 5 shows the trend of land use / land cover change in Garo hills district of Meghalaya.

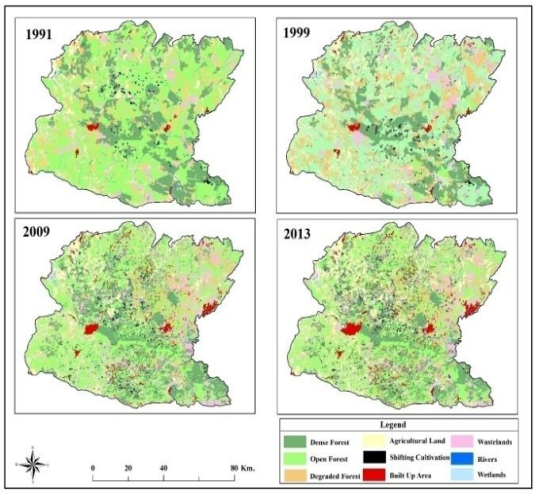


Fig.-5: Land use/land cover changes in different period

The quantitative analysis of land use/land cover changes shows that open forest cover reduced 0.60% annually from 1991 to 2013. On the other hand, the highest reducing rate of open forest cover was observed during 1991-1999 (13.22%) with the decreasing rate of 1.65% annually. The dense forest cover was decreased maximum during 1999-2009 (8.56% annually). Overall decrease of dense forest was recorded at the rate of 4.16% annually during 1991-2013 due to illegal encroachment, shifting cultivation, mining and developmental activities. The reducing rate in degraded forest covers also high in during the study period. The area under river was decreased in Garo hill districts of Meghalaya during the study period with negligible decreasing rate. Increasing rate of population and high demand of food, agricultural land and built up area was

increased during the study period. Whereas, area under shifting cultivation was also increased with decreasing trend due to awareness of its negative effect among the mass, change of traditional to plantation crops etc.

Table-4: Change Rate Index of Area Changes of Various Land Use/Land Cover Types in Garo Hill Districts of Meghalaya

LULC	1991-1999			1999-2009			2009-2013			1991-2013		
	Variation (Km²)	Period Rate of Change %	Annual Average Rate of Change %	Variation (Km²)	Period Rate of Change %	Annual Average Rate of Change %	Variation (Km²)	Period Rate of Change %	Annual Average Rate of Change %	Variation (Km²)	Period Rate of Change %	Annual Average Rate of Change %
AL	192.03	18.08	2.26	152.07	12.53	1.25	237.00	16.33	4.08	581.10	40.05	1.82
BuA	23.78	33.82	4.23	165.95	70.24	7.02	32.13	11.97	2.99	221.86	82.66	3.76
DeF	70.34	71.65	8.96	-18.69	-23.52	-2.35	68.81	46.40	11.60	120.46	81.23	3.69
OF	-528.48	-13.22	-1.65	227.57	5.39	0.54	-223.40	-5.58	-1.40	-524.31	-13.11	-0.60
DF	56.17	2.51	0.31	-1032.68	-85.57	-8.56	-66.87	-5.87	-1.47	-1043.38	-91.53	-4.16
WL	164.09	32.00	4.00	402.02	43.95	4.39	-60.12	-7.03	-1.76	505.99	59.21	2.69
Ri	-0.51	-0.55	-0.07	-4.11	-4.63	-0.46	-0.09	-0.11	-0.03	-4.72	-5.32	-0.24
SC	17.34	21.23	2.65	111.47	57.71	5.77	12.64	6.14	1.54	141.44	68.73	3.12
WeL	5.25	38.88	4.86	-3.59	-36.22	-3.62	-0.09	-0.92	-0.23	1.57	15.97	0.73

5. CONCLUSION

Land use/land cover change detection is an important part of assessing the developmental activities of a region. It is indicates the overall changes of each categories of land use/land cover categories. It is important to note that the changes are found rapid in land categories like forest cover, agricultural land and built up area and the main cause of these changes is due to anthropogenic activates. There are some specific findings inferred from the present analysis

(a) The forest cover changes rapidly both dense and open category. The open forest area of the region has decreased from 55.40 % in the year 1991 to 48.98% in the year 2013. Similarly the dense forest in the region has decreased from 26.73% in the year 1991 to 13.96% in the year 2013. The main causes of changes are shifting cultivation, expansion of settlement area due to increasing rate of population, illegal felling of forest resources.

(b) Agricultural land area has increased in the study area from 1991 to 2013. This increase is mainly due to the shifting from traditional agricultural practices to plantation crops. Traditional practices of agriculture were operated mainly in plain areas for cultivation of paddy and vegetables. But plantation crops like tea, coffee and betel nut cultivation has started growing in gentle to steep slope and even in the steep slopes of hill in the region.

(c) The built up area of the region has increased from 0.57% in the year 1991 to 3.19% in the year 2013. The growth of built up areas are mainly found in the forest areas.

(d) The percentage of degraded forest has also increased from 0.34 % in the year 1991 to 1.82% in the year 2013.

The current study shows that there are changes in land use and land cover pattern in Garo hill region and these changes have their impact on the forest cover of the region and its wildlife habitat. This study also suggests to conserve the forest resources of the region specially the wildlife habitat and their corridors to minimize the man – animal conflicts in the region. The current study also prove that the use of remote sensing and GIS tools are quite useful for land use / land cover change assessment and monitoring.

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