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RESEARCH ARTICLE

ANALYSIS OF LAND USE/LAND COVER DYNAMICS USING REMOTE SENSING AND GIS TECHNIQUES: A CASE OF JAINTIA HILLS, MEGHALAYA

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ABSTRACT

The study aims at identifying and analyzing the changes in land use/land cover (LULC) in Jaintia Hills, Meghalaya, using Landsat series satellite data for 1987, 1999 and 2013. The study is based on comparison of LULC data of two time interval periods of 1987-1999 and 1999-2013. Using an integrated supervised-unsupervised hybrid training approaches of image classification, the LULC maps were prepared and used to analyze the changes in LULC of the study area. The findings of this study revealed that the area under dense and open forest had experienced significant reduction while all the others remaining LULC classes constantly increased during the study period. The area under dense forest and open forest had decreased approximately by 12.17 % and 10.97% during the entire study period. However, a declining trend in the rate of change for both the forest classes have been observed in the study period. Though there is a decline in the rate of forest cover loss, the quality of forest cover tends to degrade as there has been an increasing conversion to shrub/grassland specifically during 1999-2013. The study suggests that continuous human interference in the natural landscape has led to the depletion of the quantity and quality of forest cover, resulting in deforestation and degradation in the study area. This study provides the baseline data and an updated information for LULC changes phenomena in the Jaintia Hills, Meghalaya and thus results can be used for better planning and conservation of forest in the area.

INTRODUCTION

Land cover denotes the physical and biotic attributes, condition and characteristics of the earth surface, while land use describes how human use the land for various activities (Lambin *et al*., 2006). Land use/ land cover (LULC) change is becoming one of the major global environmental problem in the present day world due to its diverse impact on environment and natural landscape. Hence, LULC studies has emerged over the past few decades as one of the key topic for addressing and resolving the global environmental change and sustainability issues (Meyer and Turner, 1992; Rindfuss *et al*., 2004). LULC studies has relied heavily upon remotely sensed data. The information derived from a variety of satellite remote sensing data has been particularly useful in better understanding the phenomena of LULC change and its impacts (Meyer and Turner, 1992; Narumalani *et al*., 2004). The recent development of remote sensing and Geographic Information System (GIS) technology has made a variety of analytical tools which are capable of quantifying and analyzing the dynamic nature of LULC changes and its implications (Singh, 1986; Southworth *et al*., 2004).

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Several studies have been conducted to explore the LULC changes and its related consequences on environment throughout the world (Singh, 1986; Boutin and Hebert, 2002). Nowadays, it is widely accepted that LULC changes are required to be monitored at a global, regional and local scale, as the changes is often required to comprehend from different scale for better understanding of the complex nature of LULC dynamics phenomena (Lambin *et al*., 2006). However, the LULC studies at local level in Meghalaya are still limited, and specifically in Jaintia Hills where the natural landscape has been constantly subjected to several human interferences such as mining, agricultural expansion, built-up expansion and industrial expansion. Till date very few attempts have been to explore the LULC changes in Jaintia Hills.

This paper focuses on identifying and analyzing the LULC dynamics in Jaintia Hills of Meghalaya, India. Additionally, this paper will also explore the rate of changes in the forest cover dynamics. Thus, this study will strengthen the existing information of LULC dynamic phenomena in the study area. Such information is of immense importance for the research community as well for the local planners while formulating the conservation and management strategies for natural resources and environment. It is believed that this study will provide an updated information and the baseline information for understanding the LULC changes phenomena of the Jaintia Hills, Meghalaya.

Study area

The present study is conducted in Jaintia Hills, Meghalaya, India. It constitutes a major portion of Jaintia Hills covering a total areal extent of about 2191 km^2, and also covers the major mining areas in Jaintia Hills (Fig.1). The natural vegetation in the study area is predominately covered by mixed evergreen forest, pine forest (*Pinus kesiya*), and extensive grassland. Climatically, the study area experiences a sub-tropical climate with monsoon covering the period from middle June to October. The study area selected is exposed to several commercial and development activities including mining activities (coal and limestone), industrial expansion, urbanization, etc., and also to other human activities such as cultivation, plantation etc. Jaintia Hills is also the major coal producing district in Meghalaya.

coordinate system. For the purpose of this study, seven land use/land cover classes were identified: dense forest, open forest, scrubland, barren land, built-up, cropland and water body. Two hybrid supervised-unsupervised training approaches technically known as “guided clustering” (Bauer *et al*., 1994) and “cluster busting” (Jensen, 2005) were combined in order to generate training sets for the time series LULC image classification. The training sets for each LULC classes were generated covering each LULC classes by using a stratified random sampling from the field survey. For the earlier data, training set were prepared and collected from image interpretation, historical published thematic maps and field knowledge. The CARTOSAT and Google Earth images were also used as to assist the interpretation of the earlier data. The training samples for each LULC classes were spectrally evaluated using the future space scatter plot and transformation divergence statistics.

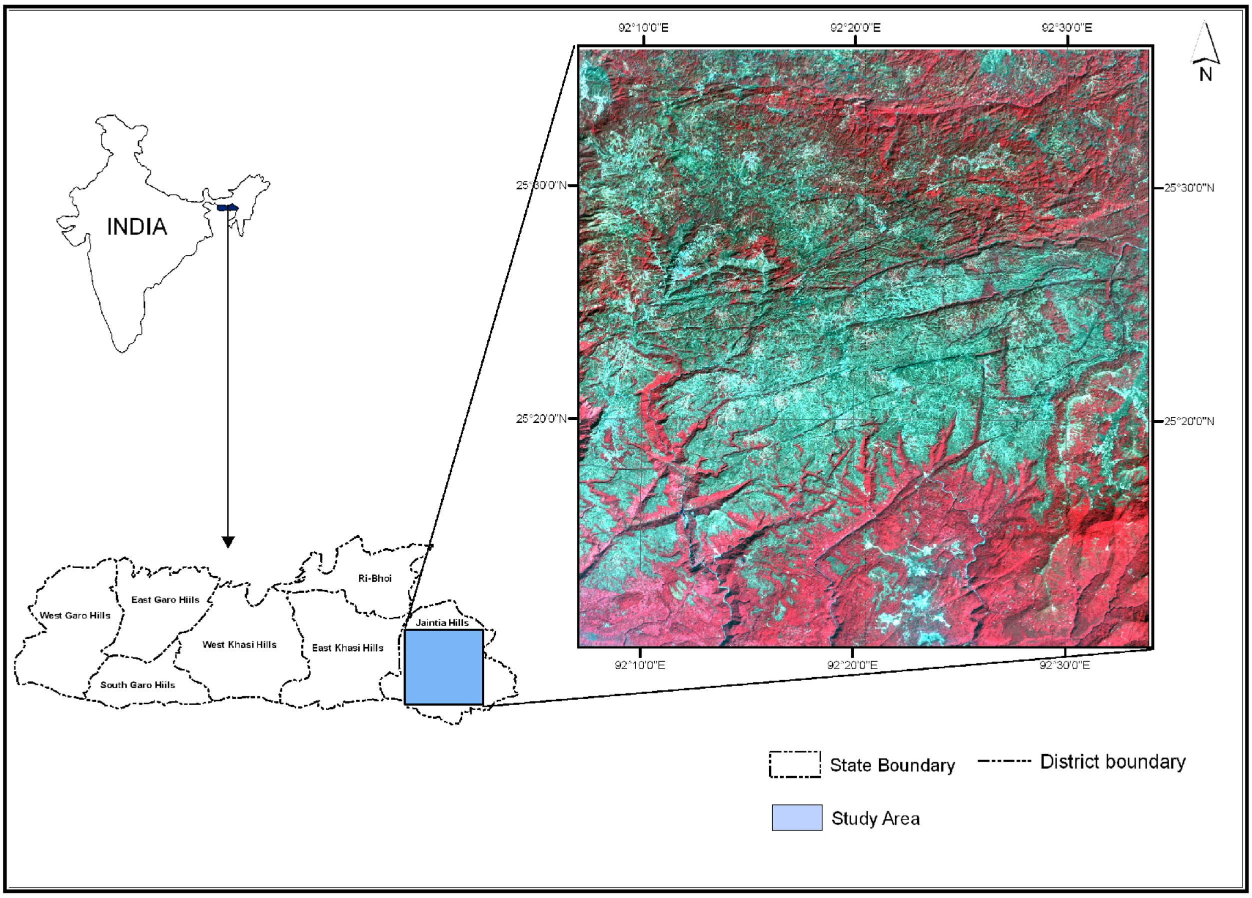

Fig 1. Location of the study area

MATERIALS AND METHODS

In this study, Landsat series images constituting TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus) and OLI (Operational Land Imager) in order of 1987, 1999 and 2013 having very near anniversary date provided by Global Land Cover Facility (GLCF) (http://glcf.umd.edu/data/landsat/) were used to prepare the LULC maps of the study area. The images were geometrically rectified to the common local UTM

The overlap signatures were either remove/modified or cluster busted until the optimum separability was attained, and then a final set of signature generated for each respective LULC classes for each time series images. Using this final training set of signature for each time series data, the LULC classification was performed by using the maximum-likelihood classifier.

After the classification, minor post-classification editing has been carried out particularly for shadows and confusion areas to improve the accuracy. Then, the rectified LULC maps were clumped and filtered before producing the final output LULC maps to reduce the 'salt and pepper' effect (Lillesand and Kiefer, 1999). The classification accuracy of each classified LULC dataset was then evaluated using standard error matrix (Congalton, 1991), and the producer's , user's accuracy and overall accuracy along with Kappa coefficient were determined using a stratified random samples of 520 reference points covering the entire study area. The overall accuracy for the 1987 (TM), 1999 (ETM+) and 2013(OLI) were 89.66%, 91.03% and 88.97%, respectively with kappa coefficient value 0.87, 0.89, and 0.87, respectively.

A pixel by pixel base comparison of two set of LULC map (i.e.1987-1999 and 1999-2013) representing two time interval were compared to produce the LULC transition matrix by using matrix analysis embedded in ERDAS IMAGINE software. We further applied post-classification comparison technique to identify the LULC change during 1987-1999 and 1999-2013 using IDRISI taiga in order to depict the changes in the form of table. In addition, the forest cover change has been analyzed using the Land change Modeler (LCM) embedded in IDRISI Taiga, and the deforestation rate has been calculated using the formula provided by Puyravaud (2003). Puyravaud (2003) suggested that the annual rate of change of forest class should be calculated as:

$$r = (1/t2-t1)) \times \ln (A2/A1) \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where A1 and A2 are the area obtained at time t1 and t2. We used the above formula for calculation of the percentage of annual rate for dense and open forest class.

1999 and 1999-2013 representing the two time interval of LULC change analysis in the study area (Table 1 and Fig 3).The results of the LULC analysis revealed that the area under dense and open forest had experienced significant reduction while all the others remaining LULC classes constantly increased during the study period. Fig 2 depicts the amount of gains and losses of each LULC classes for the two time interval of 1987-1999 and 1999-2013 and thus shows the overall exchange. From this figure it can be clearly made out that the amount of forest loss is higher than the amount of forest regrowth for both dense and open forest during the two time interval of investigation. Thus, this clearly reflects the occurrence of deforestation and forest degradation in the study area.

The shrub/grass land increased by a total area of 8355 ha (13.11%) during the entire study period. This is in contrast with the dense and open forest that have lost area. Similarly, the cropland has increased by 1244 ha (32.33%) during the entire study period. The cropland has experienced an abrupt increase during the first time interval by 806 ha (20.95), however, it has experienced a moderate increased by 438 ha (9.41 %) during the second time interval of 1999-2013. This decline in the cropland may be attributed to the unavailability of land for cropland expansion and also people's inclination towards others more income generated activities such as mining and business. In addition, agricultural activities is comparatively not a profitable activities in some area due to degradation of soil, water quality etc. caused by coal mining (Swer and Singh, 2005). The contribution to cropland expansion are mainly from shrub/grass land in Jaintia Hills.

Table 1. LULC matrix during the two time interval of 1987-1999 and 1999-2013

	LULC Transition Matrix 1987-1999							
LULC Class	Dense forest	Open forest	Shrub/grassland	Barren land	Cropland	Built-up	Water body	Total in 1987 (in Ha)
Dense forest	45597.51	13049.82	2794.95	260.28	149.22	13.41	0	61865.19
Open forest	10458.81	50894.37	11695.41	119.79	931.23	153.99	0	74253.6
Shrub/grassland	1723.23	5562.36	50902.02	718.65	6926.4	189.18	0	66021.84
Barren land	9	44.1	239.22	3548.97	7.02	0.54	0	3848.85
Cropland	60.66	453.51	4666.59	6.57	5967.63	55.17	0	11210.13
Built-up	0	0	0	0	0	612.72	0	612.72
Water body	0	0	0	0	0	0	1303.65	1303.65
Total 1999(in Ha)	57849.21	70004.16	70298.19	4654.26	13981.5	1025.01	1303.65	
	LULC Transition Matrix 1999-2013							
LULC Class	Dense forest	Open forest	Shrub/grassland	Barren land	Cropland	Built-up	Water body	Total in 1999 (in Ha)
Dense forest	41953.5	10373.58	5102.28	62.91	303.48	39.78	13.68	57849.21
Open forest	10738.62	47825.19	10149.84	80.55	1014.84	186.75	8.37	70004.16
Shrub/grassland	1548.9	7360.65	53542.62	420.03	7049.61	373.14	3.24	70298.19
Barren land	18	14.85	96.39	4523.4	0.99	0.63	0	4654.26
Cropland	76.77	535.59	5785.74	5.58	7412.22	164.43	1.17	13981.5
Built-up	0	0	0	0	0	1025.01	0	1025.01
Water body	0	0	0	0	0	0	1303.65	1303.65
Total 2013(in Ha)	54335.79	66109.86	74676.87	5092.47	15781.14	1789.74	1330.11	

RESULTS AND DISCUSSION

LULC dynamics

Figure 2 shows the three time series LULC maps for 1987, 1999 and 2013. Changes in LULC were computed and analyzed by comparing the two set of LULC map i.e. 1987-

Similar trend has also been reported from other part of Meghalaya has found similar manner (Lele and Joshi, 2009; Areendran *et al*., 2013). Further, the LULC change analysis shows a notable increase in the areas under "barren land" and "built-up" class. Table 1 shows that the area under built-up a sharp increase in its area by a total of 1177 ha (192.32 %). The majority of the increase in built-up comes from shrub/grassland

and open forest class. Similarly, the barren land also increased by 4571 ha (47.8 %) and it comes from shrub/grass land and forest classes.

In case of “water body” class, it remains approximately unchanged. The noticed small increase of 27 ha (2.07%) during the second time interval of 1999-2013 is possibly due to the construction dam in the study area.

Forest cover change

It is clear from the above LULC change analysis that the forest class (i.e. dense and open forest) has experienced a constant decline during the two time interval of 1987-1999 and 1999-2013. This study further assessed the annual rate the changes in the forest cover class i.e. dense and open forest (Table 2), and the contributors to the net changes in the forest classes has been explored by using the LCM module available in IDRISI Taiga (Figure 4 and 5).

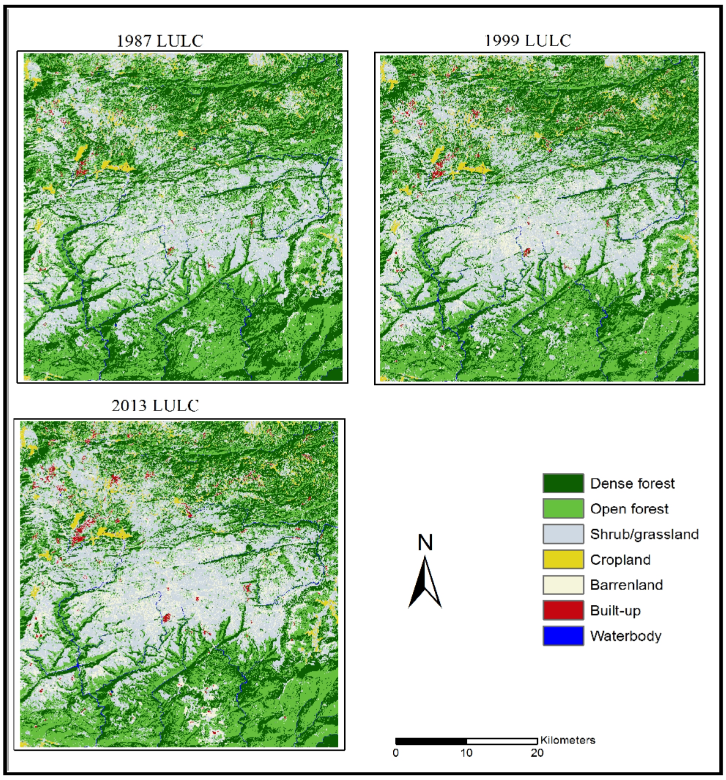

Fig. 2. LULC maps of 1987, 1999 and 2013

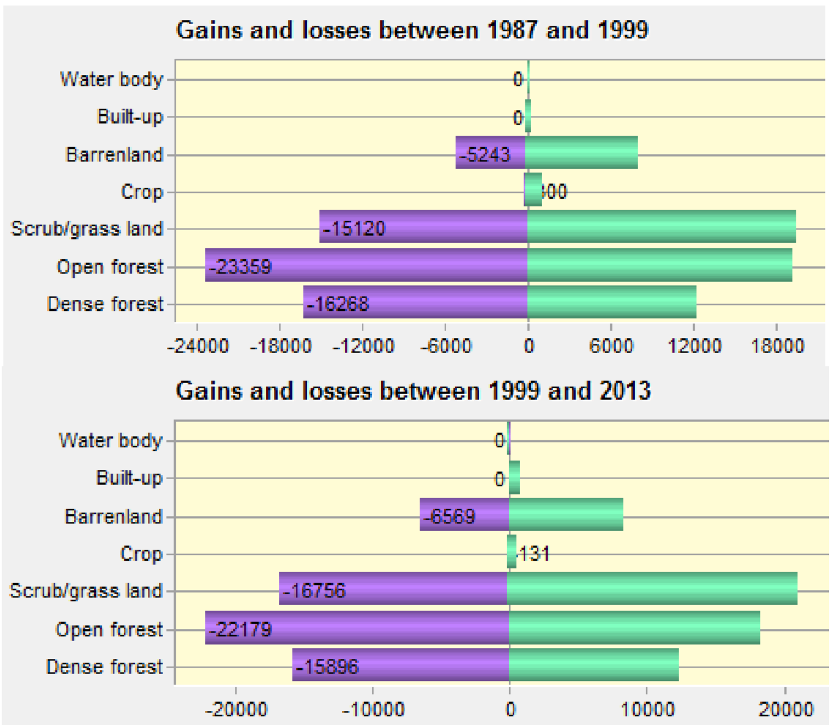

Fig. 3. Gains and losses for each LULC class during 1987-1999 and 1999-2013 (in ha)

This was done in order to gain the better understanding of the phenomena of forest covers dynamics in the study area.

The results of the annual rate of change shows that the loss in dense forest and open forest were 0.24% and 0.21%, respectively during the first time interval i.e. 1987-1999 and 0.19% and 0.17%, respectively during the second time interval i.e. 1999-2013. Thus, it reveals a declining trend in the deforestation rate in the study area.

Table 2 shows that the loss in dense forest was comparatively higher than the open forest. Further, Figure 4 shows that the leading contributors to the net change in dense forest differs between the two time interval of 1987-1999 and 1987-2013. During 1987-1999, the main contributor to the net decline in dense forest was open forest. However, during 1999-2013 the main contributor to the net decline in dense forest was scrub/grassland. In case of open forest, the main contributors to its net loss in area were scrubs/grassland and barren land (Figure 5).

Table 2. Annual deforestation rate of dense forest and open forest class during 1987-1999 and 1999-2013

Forest Class	Year			1987-1999			1999-2013		
	1987	1999	2013	Change (in ha)	Total %	Rate of change %	Change (in ha)	Total %	Rate of change %
Dense forest	63922	67006	70351	-3345.03	-4.75	-0.24	-3083.85	-4.60	-0.19
Open forest	46120	51300	57735	-6435.45	-11.15	-0.21	-5179.95	-10.10	-0.17

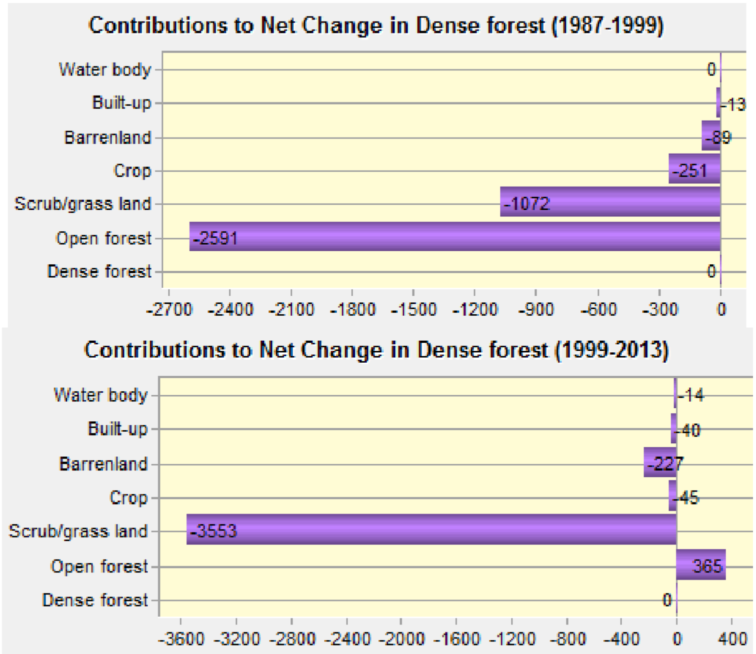

Fig. 4. Contribution to net change in dense forest during 1987-1999 and 1999-2013 (in ha)

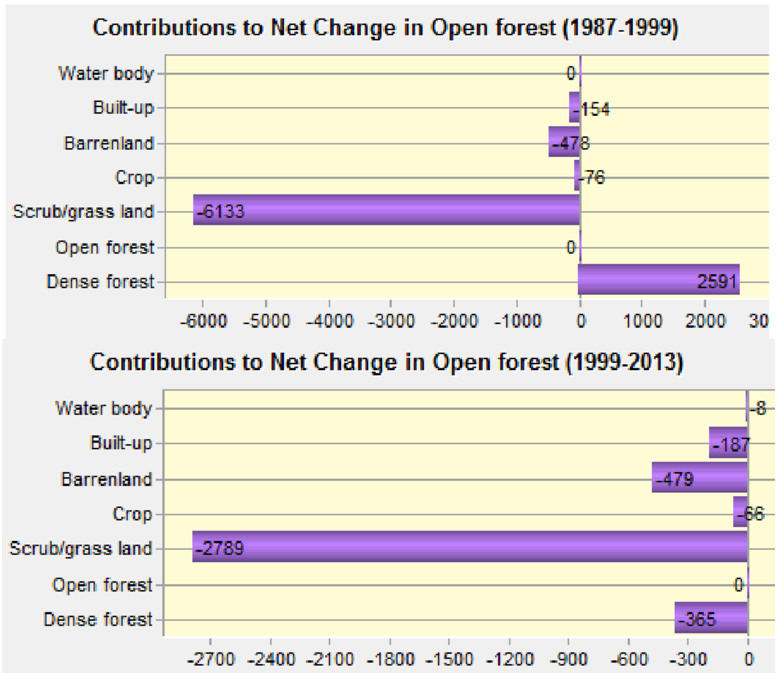

Fig. 5. Contribution to net change in open forest during 1987-1999 and 1999-2013 (in ha)

But, a declining intensity of net loss of area under open forest during the second time periods of 1999-2013 was observed. In addition, it is also been observed that there is a strong exchange between the dense forest and open forest, but the overall conversion from open to dense forest exceeded during the second time period of 1999-2013.

The increasing trend of conversion of dense forest to shrub/grassland shows the decline in the forest quality. This is further ascertained by the increasing trend of deforestation of dense forest class. This can be largely attributed to deforestation and degradation initially but depletion in the latter period as a result scrub/grassland continued to increase.
Earlier studies in the central part of the study area pertaining the vegetation loss in association to the coal mining activities had been identified (Sarma and Kushwaha, 2009). While in another recent studies, the changes in the southern part of the study area have also reported that the expansion of the industrial units during the recent period had resulted in the vast loss of vegetation in the areas (Chakroborty and Sudhakar, 2014). It can be observed that the forest cover change in the study area is spatially affected by diverse human intervention. Thus, the occurance of forest loss can be observed in several part of the study area (Figure 2). Althoug, the changes in the forest cover in the central part is mainly associated with the coal mining activities, while the changes in the noth-western part is mostly driven by the recent developmental activities (Figure 2).

Conclusion

This study presents an attempt to identify and analyse the LULC dynamics by using the remote sensing and GIS techniques in Jaintia Hills during the past 26 years represented by two time interval of 1987-1999 and 1999-2013. For this purpose, three time series of Landsat satellite imagery comprising TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus) and OLI (Operational Land Imager) in order of 1987, 1999 and 2013 were used. We used an integrated supervised and unsupervised hybrid image classification approach in order to prepared the LULC maps of the study area. The changes in the LULC were examined by using a pixel by pixel comparison to produces a tabular LULC trastion matrix and gaphical representation in Erdas and Idrisi taiga software environments.

In our study, a constant decrease in dense forest and open forest has been identified during the two time interval of 1987-1999 and 1999-2013 of the Jaintia Hills, Meghalaya. In contrast there has been a significant increase in the remaining others LULC classes i.e. schub/grassland, cropland, barren land, built-up and water body. During the examined period of the two time intervals, a notable decrease in the dense forest and open forest with varing deforestaion trends have also been observed. Thus, the findings of the present study ascertained that the forest has become more depleted in terms of its quantity and quailty indicated by its constant areal loss and increasing conversion to shrub/grassland.

The changes in forest classes (i.e. dense and open forest) due to deforestation and degradation can be considered mostly to the increased in human interferences such as agricultural expansion, built-up expansion, mining activities, industrial expansion and others infrastructural deveopment in the study area. This study provides the baseline and an updated information for the understanding of the LULC dynamics phenomena in the study area.

However, it can also be perceived that this significant LULC changes in the study area and its significant tendency of deforestation and degradation of the forest covers might lead to several ecological implications. Therefor, future study from an ecological prespective is sugested for indepth understanding of the ecological and environmental consequences of the LULC changes. Besides, a detailed analysis regarding all the possible factors affecting the LULC changes in the study area is also recommended in order to enhanced further understanding of the phenomena of LULC dynamics in the study area.

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