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Land use Land Cover Change in East Jaintia Hills, Meghalaya in Relation to Limestone Mining

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Abstract Large scale extraction of limestone in Jaintia Hills began in 2004 near Lumshnong village after setting up of the cement plants in the area. With time, several numbers of cement plants have established and are also operational in the area resulting into extensive mining of limestone in the region. To assess the land use land cover (LULC) change in relation to limestone mining in East Jaintia Hills District of Meghalaya two time-series Landsat satellite images were compared using Remote Sensing (RS) and Geographical Information System (GIS). The satellite images were classified into seven LULC classes namely; dense forest, open forest, shrub/grass land, crop land, barren land, water body and built-up. The analysis of the post-classified satellite imageries of the year 1999 and 2013 revealed a marginal increase in dense forest and decrease in open forest in the area. The LULC data revealed that dense forest in the study area has increased by 592.29 hectare whereas open forest declined by 1918.44 hectare. Other non-forest classes namely shrub/grass land, crop land, barren land, built-up area and water body were also found to have increased during the study period by 571.23, 0.36, 704.07, 50.04 and 0.45 hectares, respectively. The increase in dense forest in the study area is attributed due to transformation of open forest on account of afforestation activities undertaken in some pockets of the area. Simultaneously, open forest was also found to have decreased considerably due to the deforestation and forest fragmentation attributed mainly to limestone mining, construction of cement plants and their expansion. Increase in built-up area, shrub/grass land, barren land happened due loss of open forest.

Keywords Forest cover change, LULC, Limestone mining, Cement plants, East Jaintia Hills.

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Introduction

The state of Meghalaya is blessed with rich limestone resources accounted for about 9% of the country's total limestone reserves. It is also the most abundantly found and extracted mineral in Meghalaya, after coal. Various grades and extent of limestone rocks are found in the southern fringe of the state extending for about 200 km from Jaintia Hills in the East to Garo Hills in the West. According to Tripathi et al. (1996), the maximum limestone reserve in Meghalaya is reported in Jaintia Hills (55%), followed by Khasi Hills (38%) and Garo Hills (7%). The area in and around

Litang River valley in Jaintia Hills District have the largest deposit of limestone in the state.

Initially mining of limestone in the southern fringe of Jaintia Hills was insignificant. However, extensive mining began in the year 2004 on establishment of cement manufacturing plants in the area. At present, 11 cement plants are operating in the area. Thus, extraction of limestone has increased significantly in the last 15 years in order to fulfil the raw material requirements of the cement plants. The extensive extraction of limestone has lead to removal or disturbances of productive land and depletion of forest cover in the area. In addition, establishments of cement plants, their expansion and spread of the built-up area likely have accelerated the deforestation in the area. Thus, limestone mining activities and establishment of cement manufacturing industries in Jaintia Hills are liable to affect various environmental components of the area including the change in Land Use Land Cover (LULC).

Studies done in other parts of the world have reported the loss of vast tracts of forest lands and their conversion into non-forest land (Delang 2002, Aryee et al. 2003, Duram et al. 2004), development of mine land or artificially created mountains of mine overburden (Chitade and Katyar 2010), reduction of agricultural land (Singh et al. 2010), deforestation (Sherbinin et al. 2007, Sakthivel et al. 2010), habitat fragmentation (Armenteras et al. 2003, Ahmad and Abbasi 2011), biodiversity loss (Prakash and Gupta 1998) and change in overall LULC (Porwal and Pant 1989, Roy et al. 1991, Panigrahy et al. 2010, Borana et al. 2014).

In Jaintia Hills, studies have been done to assess the impact of limestone mining on water and soil resources (Lamare and Singh 2014, 2015, 2016a, 2016b, 2017). However, very little information is available on the quantum and dynamics of land use land cover change in Jaintia Hills due to limestone mining. Therefore, monitoring the change LULC cover over the years is vital. Hence, to assess and understand the LULC change as a consequence of limestone mining in Jaintia Hills, a change detection analysis using Remote Sensing (RS) and Geographical Information System (GIS) was carried out. The results of the study are presented in the present research paper.

Area of study

The selected study area is situated in the southern fringe of Jaintia Hills District and is demarcated in green color in Fig. 1. Due consideration was given to the area selected for the study, so that it encompassed predominantly the limestone mining area in Jaintia Hills. The selected study area lies between 25°10´ N and 25°18´ N latitudes and 92°18´ E and 92°26´

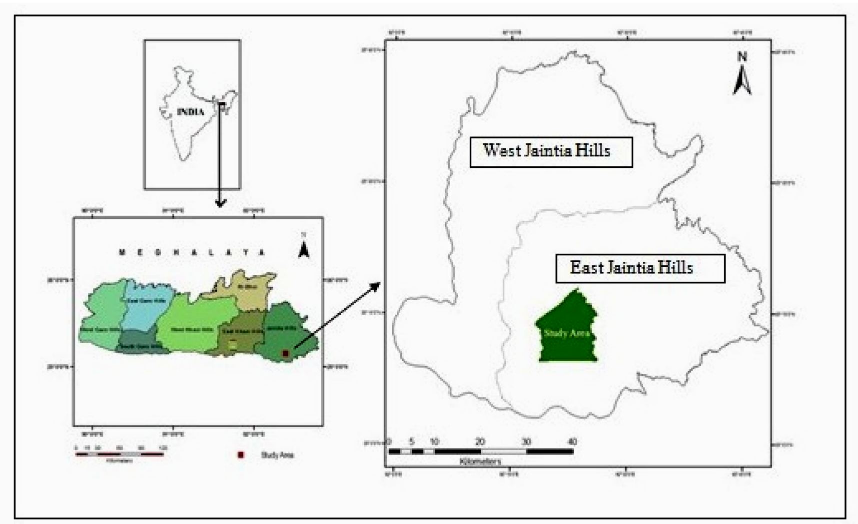

Fig. 1. Map showing the area of study in East Jaintia Hills, Meghalaya.

E longitudes on the map. It covers about 14,697.27 hectares of the geographical area. Elevation of the area varied from 52 meters above mean sea level in the south (Sonapur) to 792 meters above mean sea level in the north (Umtyra).

The different villages encompassed within the study area include Umtyra (northern part), Nongsning, Mynkree, Chiehruphi, Umlong, Wahiajer-Narpuh, Lumshnong, Brichyrnot and Sonapur (southern part). Water body incorporated in the map includes a part of the Lunar and Lukha Rivers towards the eastern side and a stream that drains from Myndihati and Khliehriat from the western side. In addition to this, study area also includes a part of the Narpuh Reserve Forest situated towards the south-eastern part of the map.

The Central portion of the study area is the focal point for limestone mining in Jaintia Hills. Thus, different activities such as mining, processing and manufacturing of cement is distributed in and around this area. This thereby led to inevitable clearing or removal of large portion of the forest/native vegetation cover during the recent years which ultimately lead to the drastic change in LULC of the area over a period of time.

Materials and Methods

The LULC change in the study area was evaluated using two time-series satellite images i.e. Landsat Enhance Thematic Mapper Plus (ETM+) acquired on 20 th December, 1999 and Landsat Operational Land Mapper (OLI) and Thermal Infrared Sensor (TIRS) acquired on 7th December, 2013. The time duration of change detection study is 14 years. These two different years were chosen since extensive mining of limestone in Jaintia Hills began in the year 2004 on establishment of cement manufacturing plants in the region. The images were geometrically rectified to the common local UTM coordinate system and the area of interest was clip out for the respective images.

In this study, the Anderson level-1 LULC classification scheme was adopted and seven LULC classes were identified. The seven broad LULC classes include dense forest, open forest, shrub land/grass land, crop land, barren land, built-up and water body.

Two hybrid supervised-unsupervised training approaches technically known as guided clustering (Bauer et al. 1994) and cluster busting (Jensen 2005) have been combined in order to generate training sets for the time series LULC image classification. The training sets for each LULC class were generated by using a stratified randon sampling from the field survey. For the ETM + data, training set were prepared and collected from image interpretation, historical published thematic maps and field knowledge. In addition, 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. 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 was carried out particularly for shadows and confusion areas to improve the accuracy of the LULC maps. The LULC maps were also clumped and filtered before producing the final output LULC maps by using the 3 by 3 majority filter in order to reduce the salt and pepper effect (Liilesand and Kiefer 1999). Subsequently, the classification accuracy of each classified LULC dataset was then evaluated using standard error matrix (Congalton 1991), a stratified random samples of 520 reference points covering the entire study area. The overall accuracy for 1999 (ETM+) and 2013 (OLI) were 91.03% and 88.97%, respectively with kappa coefficient value 0.89 and 0.87, respectively.

The LULC change detected in the study area was determined by employing the raster LULC maps of 1999 and 2013. Change detection was computed by comparing the LULC maps of 1999 and 2013 and areas were presented in hectare (ha) for all the classes. The LULC rate of change for different classes was computed using the formula given by Kashaigili and Majaliwa (2010).

$$\text{Change \%} = \frac{\text{Area}_{i\ \text{year}\ x} - \text{Area}_{i\ \text{year}\ x+1}}{\sum_{i=1}^{n} \text{Area}_{i\ \text{year}\ x}} \times 100$$

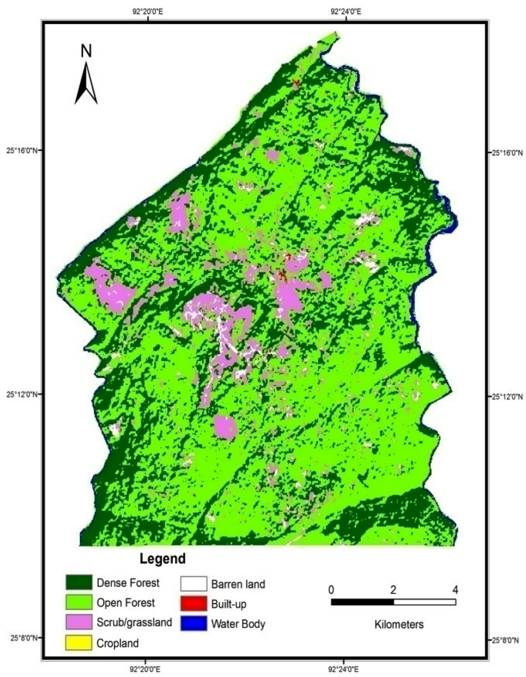

Fig. 2. Land Use Land Cover (LULC) map of the study area in 1999.

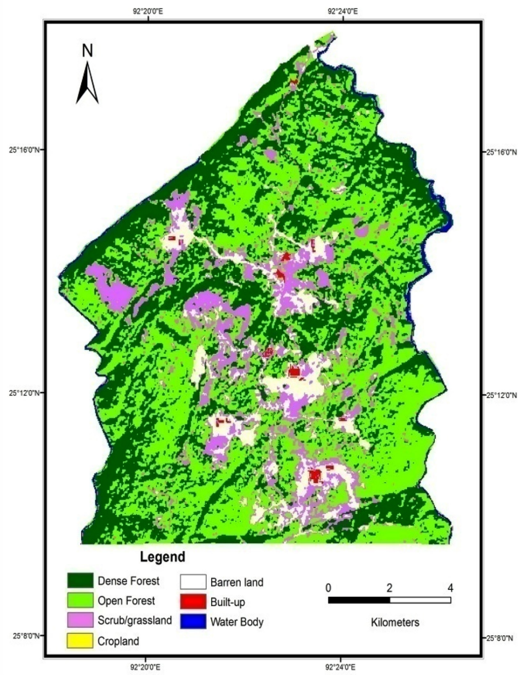

Fig. 3. Land Use Land Cover (LULC) map of the study area in 2013.

$$\text{Annual rate of change} = \frac{\text{Area}_{i\ year\ x} - \text{Area}_{i\ year\ x+1}}{t_{years}}$$

$$\%\ \text{Annual rate of change} = \frac{\text{Area}_{i\ year\ x} - \text{Area}_{i\ year\ x+1}}{\sum_{i=1}^{n} \text{Area}_{i year\ x} \times t_{years}} \times 100$$

Where,

$\text{Area}_{i\ year\ x}$ =Area of land cover at the first date,

$\text{Area}_{i\ year\ x+1}$ =Area of land cover at the second date,

$\sum_{i=1}^{n} \text{Area}_{i\ year\ x}$ =Total area of land cover at the first date,

t_{years} =Number of years between first and second date.

Results and Discussion

Land use land cover change

The LULC maps of the study area showing various LULC classes for the year 1999 and 2013 are presented in Figs. 2 and 3, respectively. Table 1 show the area occupied by different LULC classes in the study area during 1999 and 2013. In addition, net change in terms of hectares, percentage of change, annual rate of change (ha per year) and percentage annual rate of change (% per year) were also computed and incorporated in this table. The results showing extent of change in terms of area and overall gain or loss of different LULC classes expressed in hectare during 1999 and 2013 are graphically presented in Figs. 4 and 5, respectively.

Analysis of the LULC change during 1999

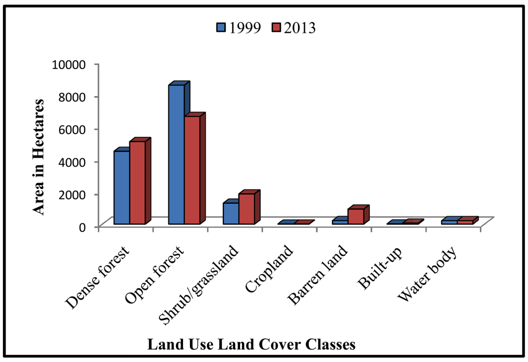

Fig. 4. Graph showing area of different LULC classes in the study area during 1999 and 2013.

Table 1. Data on area of different Land Use Land Cover classes in the study area in 1999 and 2013. + (plus) =Gain, - (minus) = Lost.

LULC category	1999 Area in hectare (ha)	%	2013 Area in hectare (ha)	%	Net change Area in hectare (ha)	%	Annual rate of change ha per year	% per year
Dense forest	4467.51	30.40	5059.80	34.43	+592.29	+4.03	42.31	0.288
Open forest	8522.19	57.98	6603.75	44.93	-1918.44	-13.05	-137.03	-0.932
Shrub/grass land	1281.06	8.72	1852.29	12.60	+571.23	+3.89	40.80	0.278
Crop land	0.00	0.00	0.36	0.002	+0.36	+0.0024	0.026	0.00017
Barren land	211.59	1.44	915.66	6.23	+704.07	+4.79	50.29	0.342
Built-up	7.83	0.05	57.87	0.39	+50.04	+0.34	3.57	0.024
Water body	207.09	1.409	207.54	1.412	+0.45	+0.0031	0.032	0.00022
Total area	14697.27	100.00	14697.27	100.00	-	-	-	-

and 2013 revealed that the area under dense forest in the study has increased whereas open forest has decreased. Other non-forest classes namely shrub/grass land, crop land, barren land, built-up area and water body were also found to have increased in its area during 1999 to 2013. The details of the change detected in different LULC classes in the study area are discussed in the following sections.

Dense forest

The study revealed that dense forest covers an area of 4,467.51 ha, which is 30.40% of the total study area in 1999 and 5,059.80 ha, which is 34.43% in 2013. The results clearly show that there was an increase of about +592.29 ha (+4.03%) in area under dense forest between 1999 and 2013. The analysis also shows that the dense forest was expanding at the rate of 42.31 ha per year or 0.288% per year. Comparison of 1999 and 2013 LULC maps also showed that increase in

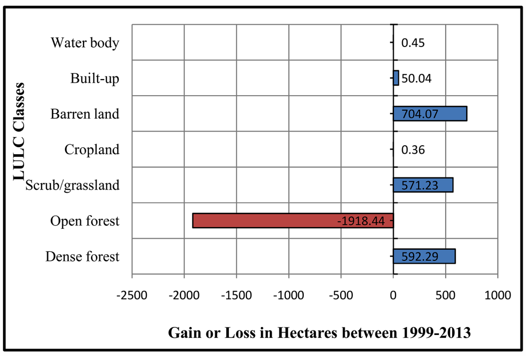

Fig. 5. Graphical representation of the overall gain or loss of different LULC classes expressed in hectares (ha) between 1999 and 2013.

dense forest area was observed mostly at the fringe of the study area. The increase in dense forest in the study area could be attributed largely due to transformation of open forest to dense forest or increase in density of open forest around the periphery of the study area due to the reason that human intervention is infeasible because of the hilly terrains and steep slope coupled with location being away from human habitation areas. However, the increase of dense forest around the central parts of the map is attributed chiefly due to progressive growth of open forest or greenery for green belt maintenance in and around the mine lease or cement plants in order to promote environmental condition of an area. In addition, influence of plantation programs, land use management and environmental policy could be the other factors that contribute to this increase of dense forest. In the same context, it can be mentioned that an increase of dense forest in entire Jaintia Hills from 899 km^2 in 1999 to 1661 km^2 in 2013 was also recorded during 1999 to 2013 by Forest Survey of India (FSI Report 1999, 2013) and report cited reason for increase in dense forest as the improvement of open forest.

Open forest

Out of the total study area, open forest occupies about 8,522.19 ha (57.98%) in 1999 and 6,603.75 ha (44.93%) in 2013. The results indicate that open forest has drastically reduced by about 13.05% between 1999 and 2013. The analysis also shows that open forests are being cleared at the rate of about 137.03 ha per year or 0.932% per year. This signifies that open forest is declining drastically in the study area.

The huge percentage decrease of open forest in the study area between 1999 and 2013 is chiefly due to clearing or removal of forest or vegetation cover, which is the first step for any activity such as mining, construction of cement plants and their expansion, built up, development of infrastructure. During the given study period, major changes were seen taking place at the central part of the study area due to conversion of open forest to other non-forest classes such as quarry, mines, roads, shrub/grass land, barren land and built-up. FSI Reports (1999, 2013) also recorded an overall decrease of open forest in the entire. Jaintia Hills from 1106 km^2 in 1999 to 885 km^2 in 2013 due to its conversion to other land uses such as dense forest and non-forest classes. Conversion of forest into other non-forest classes in limestone mining area of Jaintia Hills is also attributed by industrial expansion in the area (Chakraborty and Sudhakar 2014).

Shrub/grass land

Shrub/grass land has significantly increased from 1,281.06 ha (8.72%) of the total study area in 1999 to 1,852.29 ha (12.60%) in 2013 with a net increase of about +571.23 ha (+3.89%). The shrub/grass land was found expanding at about 40.80 ha per year or 0.278% per year. This is due to conversion of shrub/grass land to other LULC classes and most likely due to the expansion of mining and other related infrastructural development activities taking place in and around the study area.

Crop land

The area under crop land category is the least covered in terms of area and percentage occupied in the study area. No crop land was present in 1999 in the study area predominantly being a forest area. However, in 2013, due to increase in population and expansion of agriculture, the analysis revealed only a slight increase in crop land area which is about 0.36 ha (0.0024%). It was found that annual rate of increase of crop land is about 0.026 ha per year meaning a gain or rise of crop land of only about 0.00017% per year, which is very insignificant. This slight increase of crop land between 1999 and 2013 could be attributed mainly due to the Broom grass cultivation practice in the study area. However, the slow expansion of crop land in the study area is attributed chiefly due to landscape not suitable for agriculture and inclination of people towards more income generating activities like mining and business (Somendro and Singh 2015).

Barren land

In the year 1999, the barren land constituted about 211.59 ha i.e. about 1.44% of the total study area. During 2013, barren land increased to about 915.66 ha, which is about 6.23%. This shows that barren land tremendously increased by +704.07 ha during the study period. In terms of percentage, barren land was found to increase by about +4.79% during 1999 and 2013. The analysis also showed that the annual rate of change of this class during 1999 and 2013 is 50.29 ha per year or 0.342% per year indicating expansion of barren land in the study area. This change observed in the area can be due to limestone mining (both mining done by locals and the cement plant owners), expansion and modification of cement plants, creation of barren land within the periphery of the cement plants for creating facilities like storage of coal, limestone, clay soil and other ingredients/materials used for cement manufacturing, unpaved roads from mining sites to the cement plants for transportations of raw material,conveyor belts from mining sites to the plants and also area for lining up of motor vehicles for loading and unloading of raw materials and products.

Built-up

The built-up area comprises of intensive use with much of the land covered by buildings or other manmade structures. In this case areas include villages, cement plants, residential colony, mines, quarries. This class is portrayed by red color in the map. The built -up area constitutes about 7.83 ha i.e. about 0.05% of the total study area in 1999. This increased to about 57.87 ha i.e. about 0.39% in 2013. The net increase in built-up area is +50.04 ha or +0.34% between 1999 and 2013. The analysis also showed that the annual rate of change for this category was 3.57 ha per year i.e. an increase at the rate of 0.024% per year. This is undoubtedly attributed by the infrastructural development taking place in the area during the study period like setting up of cement plants and their expansions, development of residential colonies within the plants periphery, roads network and expansion of villages due to population rise. Chakraborty and Sudhakar (2014) also found that large area of forest has been converted to non-forest area due to industrial expansion such as expansion of manufacturing units and establishment of mining area in Jaintia Hills.

Water body

The area covered with surface water either in the form of river, streams, ponds, lakes, reservoirs, dams falls under this category (Strahler et al. 1999, Atayi et al. 2016). However, in this case water body predominantly occupies rivers. This class is presented by blue color in the map. Water body occupied about 207.09 ha in 1999 and 207.54 ha in 2013, which percentage wise covers about 1.409% and 1.412%, respectively of the total study area. The net increase was very small, which is +0.45 ha (+0.0031%) during the study period. The results also showed annual in water body to about 0.032 ha per year or 0.00022% per year. This indicates that water bodies increased during the 14 years period very slightly. The increase could be attributed to the spreading of the river water due to siltation from the upstream or construction of small check dams near the river channels.

Conclusion

Based on the study, the forest cover in Jaintia Hills has been found to gradually and progressively decreasing due to large scale mining of limestone and its processing for the manufacturing of cement. The results of land use land cover (LULC) change study during 1999 and 2013 showed that dense forest in the study area has increased by 592.29 hectare whereas open forest has decline by a 1918.44 hectare. However, other non-forest classes namely shrub/grass land, crop land, barren land, built-up area and water body were found to increase in the study area by 571.23, 0.36, 704.07, 50.04 and 0.45 hectares, respectively. Study concludes that limestone mining and establishment of cement plants in Jaintia Hills has rsulted into the drastic decline of open forest class and increase in other non-forest classes. The change was contributed predominantly by anthropogenic activities such as mining of limestone, construction of cement plants and their expansion, increase in built-up area, development of infrastructure.

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References

Ahmad SS, Abbasi Q (2011) Assessment of forest cover decline in Pakistan : A GIS perspective. Int J Environ Sci 2 (1) : 220—227.

Armenteras D, Gast F, Villareal H (2003) Andean forest fragmentation and the representativeness of protected natural areas in the eastern Andes, Colombia. Biol Conserv 113 (2) : 245—256.

Aryee NAB, Ntibery BK, Atorkui E (2003) Trends in the small-scale mining of precious minerals in Ghana : A perspective on its environmental impact. J Cleaner Prot 11 : 131—140.

Atayi J, Kabo-Bah AT, Akpoti K (2016) The effects of large -scale mining on land use and land cover changes using remotely sensed data. Int J Sci Nature 7 (4) : 724—733.

Bauer ME, Burke TE, Ek AR, Coppin PR, Lime SD, Waksh TA, Walters DK, Befort W, Heinzen DF (1994) Satellite inventory of Minnesota forest resources. Photogram Engg Rem Sens 60 (3) : 287—298.

Borana SL, Yadav SK, Parihar SK, Palria VS (2014) Impact analysis of sandstone mines on environment and LULC features using remote sensing and GIS technique : A case study of the Jodhpur city, Rajasthan, India. J Environ Res Dev 8 (3A) : 796—804.

Chakraborty K, Sudhakar S (2014) The expansion and impact of cement manufacturing units and mining areas in Lumshnong, Jaintia Hills, Meghalaya. Curr Sci 106 (7) : 997—1000.

Chitade AZ, Katyar SK (2010) Impact analysis of open cast coal mines on land use land cover using remote sensing and GIS technique : A case study. Int J Engg Sci Technol 2 (12) : 7171—7176.

Congalton RG (1991) A review of assessing the accuracy of classifications of remotely sensed data. Rem Sens Environ 37 : 35—46.

Delang CO (2002) Deforestation in northern Thailand : The result of Hmong farming practices of Thai development strategies. Soc Nat Res 15 : 483—501

Duram LA, Jon B, Christina R (2004) A local example of land use change : Southern Illois-1807, 1938 and 1993. The Professional Geographer 56 (1) : 127—140.

FSI (1999) State of Forest Report Ministry of Environment and Forest Dehradun, pp 72—76.
FSI (2013) State of Forest Report Ministry of Environment and Forest Dehradun, pp 167—168.
Jensen JR (2005) Introductory Digital Image Processing : A Remote Sensing Perspective. Prentice Hall Inc New Jersey, pp 383—389.
Kashaigili JJ, Majaliwa AM (2010) Integrated assessment of land use and cover changes in the Malagarasi river catchment in Tanzania. Physics and Chem the Earth 35 : 730—741.
Lamare RE, Singh OP (2014) Degradation of water quality due to limestone mining in East Jaintia Hills, Meghalaya, India . Int Res J Environ Sci 3 (5) : 13—20.
Lamare RE, Singh OP (2015) Localised effect of artisanal and small scale mining of limestone mining on water quality in Meghalaya, India Poll Res 32 (2) : 321—329.
Lamare RE, Singh OP (2016a) Application of CCME water quality index in evaluating the water quality status in limestone mining area of Meghalaya, India. The Ecoscan 10 (1 & 2) : 149—154.
Lamare RE, Singh OP (2016b) Limestone mining and its environmental implications in Meghalaya, India. ENVIS Bull Himalayan Ecol 24 : 87—100.
Lamare RE, Singh OP (2017) Changes in soil quality in limestone mining area of Meghalaya, India. Nature Environ Poll Technol 16 (2) : 545—550.
Lillesand TM, Kiefer RW (1999) Remote Sensing and Image Interpretation. New York : John Wiley and Sons.
Panigrahy RK, Kale MP, Dutta U, Mishra A, Banerjee B, Singh S (2010) Forest cover change detection of Western Ghats of Maharashtra using satellite remote sensing based visual interpretation technique. Curr Sci 98 : 657—664.
Porwal MC, Pant DN (1989) Forest cover type and land use mapping using LANDSAT Thematic Mapper-A case study for Chakrata in Western Himalayas, Uttar Pradesh. J Ind Soc Rem Sens 17 : 33—40.
Prakash A, Gupta RP (1998) Land use mapping and change detection in a coal mining area : A case study in the Jharia coal field. Int J Rem Sens 19 (3) : 391—410.
Roy PS, Das KK, Naidu KSM (1991) Forest cover and land use mapping in Karbi Analog and north Cachar Hills Districts of Assam using LANDSAT MSS data. J Ind Soc Rem Sens 19 : 113—123.
Sakthivel R, Manive L, Jawaharraj M, Pugalanthi N, Ravichandran V, Vijay N, Anand D (2010) Remote Sensing and GIS based forest cover change detection study in Kalrayan Hills, Tamil Nadu. J Environ Biol 31 (5) : 737—747.
Sherbinin A, Carr D, Cassels S, Jiang L (2007) Population and environment. Ann Rev Environ and Res 32 : 5.1—5.29.
Singh PK, Singh R, Singh G (2010) Impact of coal mining and industrial activities on land use pattern in Angul-Talcher region of Orissa, India. Int J Engg Sci Technol 2 (12) : 7771—7784.
Somendro T, Singh OP (2015) Analysis o land use land covers dynamics using remote sensing and GIS techniques : A case of Jaintia Hills, Meghalaya. Int J Curr Res 7 (1) : 11873—11879.
Strahler A, Muchoney D, Borak J, Friedl F, Gopal S, Lambin L, Moody A (1999) MODIS Land Cover Product Algorithm Theoretical Basis Document, pp 72.
Tripathi RS, Pandey HN, Tiwari BK (1996) State of Environment of Meghalaya. North-eastern Hill University, Shillong 793022.