Forest Cover Change Estimation using Remote Sensing and GIS–A Study of the Subarnarekha River Basin, Eastern India

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Abstract—*The Earth's forest cover is continuously effected by several climatological and anthropogenic factors, and its change impacts the entire natural hydrological system, global carbon cycle and biodiversity at local, regional and global scale. In this study, we mapped the land use land cover (LULC) including forest cover over the Subarnarekha river basin, located at the eastern part of India and estimated forest change over a 21-year period (1987-2008) using Landsat satellite imageries and GIS approaches. Supervised classification followed by the unsupervised image classification was applied to the imageries to produce eight LULC classes, viz. dense forest, open forest, mixed forest, agricultural land, settlement area, waterbodies, current fallow and barren land. The change matrix was prepared for 1987-2008 period in ERDAS Imagine 2014. Error matrix and kappa statistics method were introduced to assess the accuracy of the produced LULC maps. Overall accuracies resulting from supervised classification of 1987 and 2008 imageries were 88.89% (Kappa 0.85) and 90.91% (Kappa 0.86), respectively. The results of the change detection in this research reveals that natural forest cover is being converted to agricultural land and settlements with increasing anthropogenic pressure. The area of the dense forest and open forest has drastically deceased by 52.05% and 43.44% respectively, while the area of the agricultural land and settlements has increased by 20.71% and 161% respectively during 1987-2008 period. It also found that there is a higher probability of the natural forest cover getting converted to agricultural land and settlement areas. Thus deforestation is an important factor that leads to LULC change. Increasing human population and their activities have made the classes more vulnerable to unwanted changes which may affect the ecological processes. This research concludes that for better understanding of change dynamics, study about the LULC change, their magnitude and impact are important. Thus for proper management of natural forest resources, this type of research can be a useful tool.*

Keywords*: LULC, Forest Cover, Change Matrix, Change Rate, Markov Transition Probability.*

1. INTRODUCTION

In recent year, conservation of biodiversity and management of tropical forest have become a major issue in developing countries. According to data provided by the U.N. Food and Agricultural Organization, approximately 4,168 million hectares of the earth's terrestrial surface was covered by woodlands and forest cover in the 1990s. Over the last three decades, the Earth's forest cover is continuously effected by several climatological and anthropogenic factors: tropical deforestation, rangeland modification, agricultural intensification, high urbanization and population growth (Lambin et al., 2001), and decreased to 4,033 million hectares during 2010. In the first decade of this century, the rate of removal of tropical forest was comparatively lower, but still on an average 13 million hectares were destroyed annually.

Remote sensing and Geographical information systems (GIS) are well established, efficient, cost effective and accurate alternative to study the landscape pattern and its change over a time period (Kachhwaha, 1985; Miller et. al., 1998). Satellite data plays a major role to identify the forest change due to its spatial and temporal coverage at short time interval (Mas, 1999). Recent improvements in the quality and availability of the satellite imageries make it possible to perform image interpretation and analysis at much larger scale rather than in the past.

Digital change detection, a process to understand dynamics of landscape to identify and monitor differences in LULC pattern over time, regardless of the casual factors. According to the IHDP/IGBP report, digital change detection studies make an effort to assess the information about the processes of forest cover change, their pattern and human interactions to forest cover change. Lambin and Strahler (1994) highlighted five types of sources which influenced the forest cover change. Forest cover changes are often influenced by various natural factors: climate variability and climate change; and anthropogenic factors: population growth and their activities such as high urbanization, timber production and pasture development (Boakye et. al., 2008). Changes in forest cover impacts the catchment processes by effecting various hydrological variables: streamflow, sediment yield, runoff coefficient and evapotranspiration; and biochemical cycles, biodiversity at local, regional and global scale and increase the probability of occurrence of flood and other natural calamities. Inventory and monitoring the forest cover and other LULC change are therefore of major concern in current environmental change research for the natural resources management.

Accurate information about the current and past LULC including natural forest cover along with accurate means of monitoring the changes are very necessary for any person, related to the production of new land use policies and natural resources management. In the environment, the importance of forest cover is underscored by its role as a major carbon sink. Therefore, this study is attempt to analyze the status of LULC of the Subarnarekha river basin, located at the eastern part of India over a 21-year period of study (1987-2008) with a view in assessing the rate of forest cover that has been lost due to high urbanization, population growth and agricultural expansion.

2. MATERIALS AND METHOD

2.1 Description of Study Area

Subarnarekha, one of the most important interstate river is located in the eastern part of India, which is about 400 km in length (Bhuyan et al., 2014) and flows into the Bay of Bengal. The entire basin (shown in Fig. 1) has an elevation ranging from 98 m to 610 m, covers an area of 19,121 km^2 with a longitudinal range of around 85º11´00´´E to 87º23´31´´E and a latitudinal of 21º33´18´´N to 23º18´00´´N. The catchment is dominated by forested, mostly terrace land with a slope in between one to twelve percent towards the eastern direction. The soil of the entire basin is characterized as red soil mostly of residual and alluvial origin which is derived from old bedrock. The average annual rainfall in the basin is around 1498.2 mm. May is the hottest months of the year over the entire basin with the temperature rising to about 45 °C. The minimum temperature is observed in the months of January with temperature dipping to around 10°C. May is the hottest months of the year over the entire basin with the temperature rising to about 45 °C.

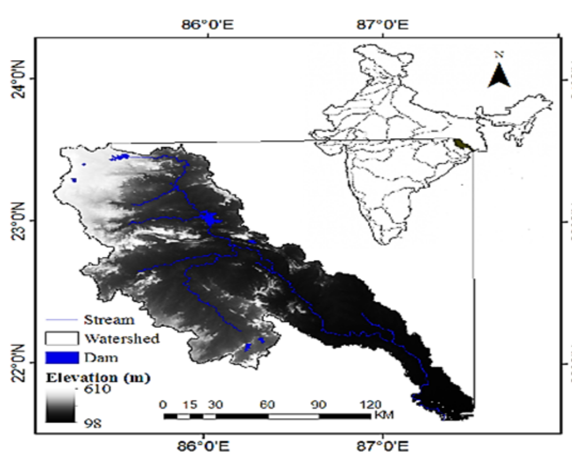

Fig. 1. Location of the Subarnarekha river basin.

The minimum temperature is observed in the months of January with temperature dipping to around 10°C. The industries like Heavy Engineering Corporation, MELCON and SAIL in Ranchi; Indian Aluminum Industries at Muri; TELCO, Tata Steel, Indian Tube Company, and Tata Pigments in Jamshedpur; Uranium Corporation of India and Hindustan Copper Limited in Ghatsila are existing in the entire river basin.

3. DATA ACQUISITION AND PROCESSING

Landsat TM data were employed in this study with the purpose to maintain a consistency in data set for the 21-year period. Eight Landsat TM scenes were used to cover the entire basin (four adjacent scenes for each of two years; table 1). Based on data availability, data quality and minimum percentage cloud cover scenes were selected for 1987 and 2008, from data available during December, the growing season in India.

Each of eight Landsat TM scene consist of a seven spectral bands with a spatial resolution of 30 meter for band 1 to 5 and 7 and 120 meter for band 6. All seven bands were stacked in order to form a multilayer image with higher spatial details. Later mosaic was performed to blend the four scene to form one large radiometrically balanced image through the colour balancing technique and weighted seamline generation. The entire basin was then extracted by shape file from the mosaicked image.

Table 1. Characteristics of the satellite data used for LULC change mapping in the Subarnarekha river basin.

Date acquired	***Path***	***Row***	***Scene center time***
1987-12-06	140	44	04:11:46.4440440Z
1987-12-06	140	45	04:12:10.3630310Z
1987-12-15	139	44	04:05:43.4560810Z
1987-12-15	139	45	04:06:07.5190880Z
2008-12-15	140	44	04:27:35.1860190Z
2008-12-15	140	45	04:27:59.1590130Z
2008-12-08	139	44	04:21:11.5820630Z
2008-12-08	139	45	04:21:35.6980250Z

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Scene ID	***Type of imageries***	***Landsat No.***	***Normal spectral resolution (m)***
LT51400441987340BKT00	TM	5	30
LT51400451987340BKT00	TM	5	30
LT51390441987349BKT00	TM	5	30
LT51390451987349BKT00	TM	5	30
LT51400442008350BJC00	TM	5	30
LT51400452008350BJC00	TM	5	30
LT51390442008343BJC00	TM	5	30
LT51390452008343BJC00	TM	5	30

Data source: Earth Explorer (http://www.earthexplorer.usgs.gov)

4. LULC CLASSIFICATION SCHEME

A supervised classification approach followed by the unsupervised classification was applied to satellite imageries to produce LULC classes. At first, the imageries were classified into sixty spectral clusters using unsupervised classification technique through the ISODATA (Iterative Self-Organizing Data Analysis Technique) algorithm in Erdas Imagine. The images were stacked into different band combination format and classified into 60 spectral clusters using unsupervised classification through the ISODATA (Iterative Self-Organizing Data Analysis Technique) algorithm with the help of 25 iterations in ERDAS Imagine. Visual interpretation was employed to assign a thematic class name to each spectral cluster. For interpretation, an interpretation key was developed (shown in table 2) and used. Sixty clusters were then recoded into eight thematic classes viz. dense forest, open forest, mixed forest, waterbody, settlements, agriculture, current fallow and barren land/sand. Recode tool is used to group similar thematic values into the same class. After recode, all pixels from the original class are changed to the new class value. The signatures of the spectral classes were used to obtain the final signature file, which was later used in maximum likelihood classifier in order to generate LULC map for the period of 1987 and 2008. The results are shown in Figures 2.

Table 2: Interpretation keys used for LULC change mapping.

LULCs	Tone/ Colour	Description
Dense forest	Dark red	Area with more than 40% canopy density
Open forest	Light red	Area with 10–40% canopy density
Mixed forest	Bright red / Brown	Area with less than 10% canopy density
Settlements	Cyan blue	Urbanized area
Waterbody	Deep / Light blue	River, reservoir, pond, tank
Agriculture	Bright green	Area under crop cultivation
Current fallow	Whitish / Grayish	Area with sparse or no vegetation
Barren land	White	River bed areas

5. POST-CLASSIFICATION COMPARISON

Of numerous methods (i.e., Band rationing, change vector analysis, image overlay, principal component analysis) that are available for LULC change detection especially on forest cover (Devi and Baboo, 2012), post classification comparison was employed in this study. In this method, at first imageries of different periods are primarily classified and labelled separately. Later the classified imageries were compared through both unsupervised and supervised classification technique and changed areas extracted (Singh, 1986; Teng et al., 2008). This method has been used to detect the area that changed from one LULC class to another classes (e.g. forest to settlement area or agricultural land, changes in forest or wetland).

6. DETERMINATION OF TRANSITION MATRIX

Markov chain theory was used in this study to compute the probability of each LULC change over a time period. Markovian chain process is worked based on the transition matrix. The Markov chain process can be expressed for the matrix notation, given by Baker (1989):

$$\pi(t+v) = \pi(t) \cdot P^{v}$$

Where $\pi(t)$ is a vector with Mx1 dimension (M is the number of land use land cover classes) at time t, $\pi(t+1)$ is a vector with M×1 dimension of the number land use cover states at time t+1 and M×M matrix of transition probability P^{v} which executes the probability of transition between each pair of land use land covers k and l.

The above equation can be expressed as:

$$\begin{bmatrix} 1 \\ 2 \\ 3 \\ : \\ l \end{bmatrix}_{t+v} = \begin{bmatrix} P_{11} & P_{21} & P_{31} & ..... & P_{k1} \\ P_{12} & P_{22} & P_{32} & ..... & P_{k2} \\ P_{13} & P_{23} & P_{33} & ..... & P_{k3} \\ : & : & : & ..... & : \\ P_{1l} & P_{2l} & P_{3l} & ..... & P_{kl} \end{bmatrix}^{v} \cdot \begin{bmatrix} 1 \\ 2 \\ 3 \\ : \\ k \end{bmatrix}_{t}$$

Where k, l = 1, 2 … M and v is the time steps.

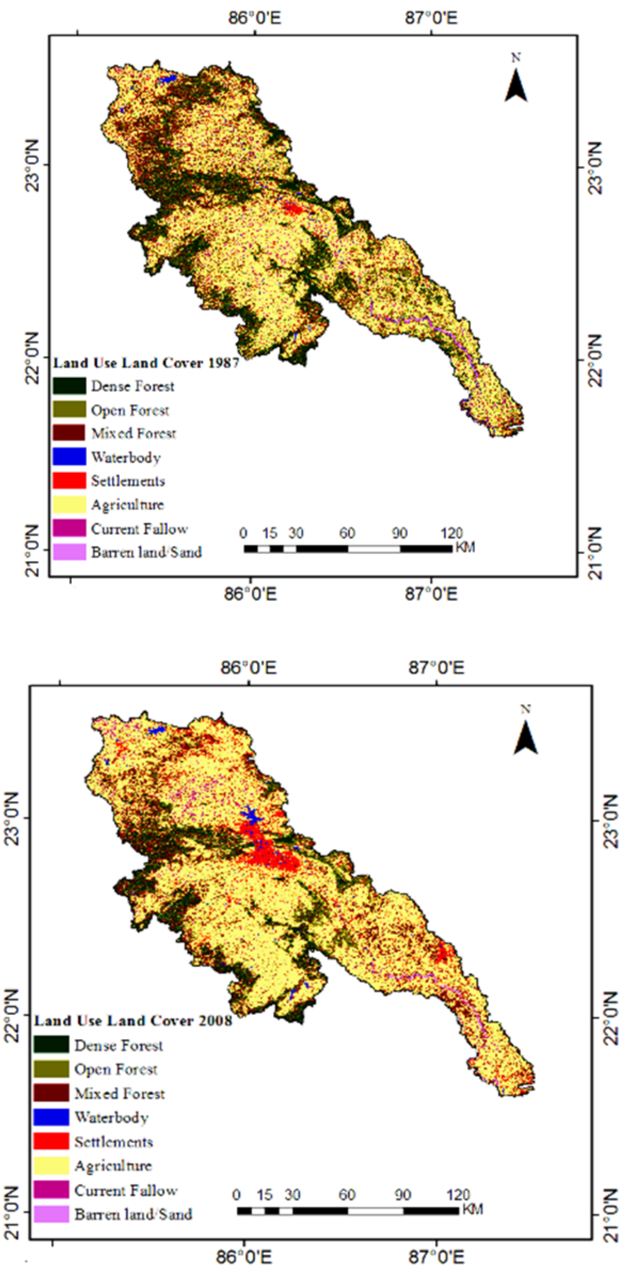

Fig. 2: LULC maps of the Subarnarekha river basin during 1987 and 2008.

7. RESULTS AND DISCUSSION

Accuracy Assessment LULC Classification

Classification process is incomplete until its accuracy is evaluated. Accuracy assessment of a classified image can be achieved by comparing the classified image with the reference data (Jensen, 1996). In the study, the accuracy of LULC classification was assessed by an error matrix. This is a representation of square array of numbers in rows and columns, which define the number of pixels assigned to a particular category relative to the actual category as verified by the reference data (Congalton, 1996). Various measurements have been developed to improve the interpretation of the error matrix, among which overall accuracy and the Kappa statistic are one of the most popular measures (Foody, 1992). The Kappa statistic is basically a discrete multivariate technique used to assess the accuracy of a classified image (Congalton, 1996). An overall accuracy of 88.89% and 90.91% were achieved for the year of 1987 and 2008. The Kappa statistic of the classified LULC maps are achieved as 0.85 and 0.86 respectively, for year of 1987 and 2008.

LULC Change Trend from 1987 to 2008

The supervised classification followed by the unsupervised classification of the Landsat TM imageries yielded two LULC maps of the Subarnarekha river basin (as shown in Figure 2) for the period of 1987 and 2008. The classes were calculated in percentages as well as in km^2 based on the number of pixels. The trend analysis of the Subarnarekha river basin reveals a change in area of each LULC over the 21-year period of the study (shown in Table 3). The changes occurred in the basin are mainly deforestation, agricultural expansion and high urbanization (shown in Figure 3). During 1987, a land area of 2460.58 km^2 (12.87%) and 2667.93 km^2 (13.95%) were covered by high dense forest and open forest respectively, which are generally found in the Northeastern part of the river basin with a high concentration around the Subarnarekha river. Due to high urbanization, agricultural development and mismanagement of forest resources the area of dense forest and open forest are decreased to 1179.11km^2 (6.17%) and 1508.25km^2 (7.89%) in 2008. The land area under mixed forest was nearly same in both time periods. Around 18.63% (3562.08 km^2) area was occupied by mixed forest during 1987 and around 18.20% (3480.51 km^2) area was occupied by mixed forest during 2008. Settlements experienced a most positive change during the 21-year study period. Due to ongoing population growth, their socioeconomic activities and, development of several national and multinational companies, the area under settlements increased from 2.63% (about 502.73 km^2) to 6.89% (about 1317.14 km^2) during the period of study. A positive trend is also found in case of agricultural land use. People utilize the land for crop cultivation and production. Agricultural land has increased from 47.80% (9140.37 km^2) to 57.70% (11033.55 km^2) during the study period. From 1987 to 2008, area under water experienced a positive change, while that of barren land/sand and current fallow experienced a negative change.

Table 3: Area under different land use land cover categories during 1987 - 2008

LU LC	Year				% Change
	1987		2008		
	Area (km^2)	Area %	Area (km^2)	Area %	
Df	2460.58	12.87	1179.11	6.17	-52.08
Of	2667.93	13.95	1508.25	7.89	-43.47
Mf	3562.08	18.63	3480.51	18.20	-2.29
Wt	141.27	0.74	174.14	0.91	+23.27
Set	502.73	2.63	1317.14	6.89	+162.00
Ag	9140.37	47.80	11033.55	57.70	+20.71
Cf	566.30	2.96	352.76	1.84	-37.71
Br	80.50	0.42	76.30	0.40	-5.22

Df- dense forest, Of- open forest, Mf- mixed forest, Wt- waterbodies, Set- settlements, Ag- agriculture, Cf- current fallow, Br- barren land / sand.

LULC Conversion Analysis

Change matrix is used in this study to summarize the major LULC conversion which has been occurred within the Subarnarekha river basin during the study period. The change matrix for the period of 1987 and 2008 was created in Erdas Imagine. The diagonal of the change matrix indicates the LULC proportions that has remained under same class in both time periods. The other elements except diagonal represent the LULC proportions that has changed during the study period.

Due to low resolution of satellite imageries and errors in mapping some unexpected changes are found in these matrix, e.g. conversion of settlements to agricultural land. The major finding in the result (shown in Table 4) is that mixed forest made the highest conversion to agricultural land by 53.68% of the entire area. Similarly, 43.63% area under open forest has converted to mixed forest, 18.47% area under dense forest has converted to mixed forest and 24.09% area under dense forest has converted to open forest during 21-year period of study. The conversion of dense forest to other LULC classes viz. agricultural land, settlements, waterbodies, current fallow and barren land are 10.09%, 4.53%, 1.27%, 0.07% and 0.02% respectively. Other LULC conversions are agricultural land to settlements by 6%, barren land to settlements by 12.18%, current fallow to agricultural land by 78.14%.

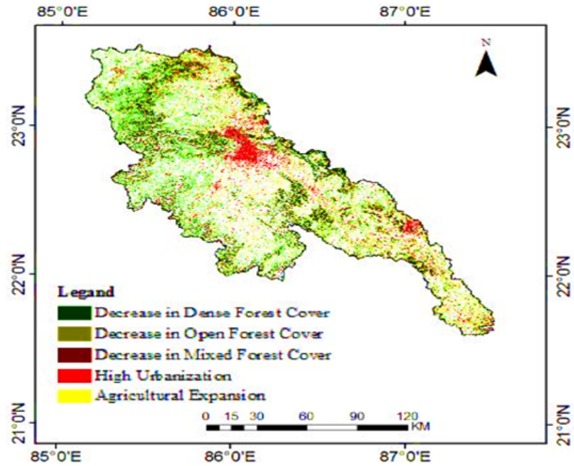

Fig. 3. Main changes in the entire basin during 21-year study period.

Probability of LULC Change

For the development of new management strategy to manage the natural resources, beside the LULC conditions, information about the probability of each LULC change is very important. Transition matrix is used in this study to assess the probability of change from one LULC class to another LULC class in future. The diagonal elements of the transition matrix (shown in Table 5) left blank because there is no probability of changing under same LULC class over the study period and the probability of LULC change is calculated up to three decibels.

Transition matrices revels that mixed forest and open forest are most vulnerable to the future LULC change. Current fallow land has the highest probability (0.782) of getting converted into agricultural land, whereas mixed forest has a probability of 0.537 to convert into agricultural land. Similarly, open forest has a probability of 0.463 to convert into mixed forest. Dense forest has a probability of 0.241 and 0.185 getting convert into open forest and mixed forest respectively.

Table 4: Change matrix for 1987 and 2008 (area in percentage)

2008 data		
Ag	Cf	Br
10.09	0.07	0.02
20.13	0.05	0.03
53.68	0.52	0.04
12.93	1.86	6.60
44.42	0.36	0.59
83.52	2.76	0.08
78.14	11.24	2.58
21.87	13.15	49.01

1987 data	Df	Of	Mf	Wt	Set
Df	41.47	24.09	18.47	1.27	4.53
Of	4.93	25.65	43.63	0.21	5.37
Mf	0.64	5.81	32.50	0.30	6.51
Wt	0.39	0.58	1.82	51.10	24.73
Set	0.23	0.81	9.25	2.08	42.26
Ag	0.03	0.20	7.01	0.40	6.00
Cf	0.10	0.15	2.70	0.85	4.24
Br	0.22	0.17	0.62	2.77	12.18

Df- dense forest, Of- open forest, Mf- mixed forest, Wt- waterbodies, Set- settlements, Ag- agriculture, Cf- current fallow, Br- barren land / sand.

8. CONCLUSION

The relationship between the natural forest covers and related LULC classes were studied and two thematic maps were prepared. The main LULC classes identified over the Subarnarekha river basin are dense forest, open forest, mixed forest, waterbody, settlements, agriculture, current fallow and barren land/sand. A remarkable change in natural forest covers have been observed during the 21-year period of study. The area under dense forest and open forest has deceased, while the area under settlements and agricultural land has increased over the period. There is a higher probability of mixed forest getting converted to agricultural land.

Table 5: Transition matrix of 1987-2008

1987 data \ 2008 data	Df	Of	Mf	Wt	Set	Ag	Cf	Br
Df		0.241	0.185	0.013	0.045	0.101	0.001	0.000
Of	0.049		0.436	0.002	0.054	0.201	0.000	0.000
Mf	0.006	0.058		0.003	0.065	0.537	0.005	0.000
Wt	0.004	0.006	0.018		0.247	0.130	0.019	0.066
Set	0.002	0.008	0.092	0.021		0.445	0.004	0.006
Ag	0.000	0.002	0.070	0.004	0.060		0.028	0.001
Cf	0.001	0.002	0.027	0.008	0.042	0.782		0.026
Br	0.002	0.002	0.006	0.028	0.122	0.219	0.131	

Df- dense forest, Of- open forest, Mf- mixed forest, Wt- waterbodies, Set- settlements, Ag- agriculture, Cf- current fallow, Br- barren land / sand.

Thus deforestation is an important factor that leads to LULC change. Increasing human population and their activities have made the classes more vulnerable to unwanted changes which may affect the ecological processes. This research concludes that for better understanding of change dynamics, study about the LULC change, their magnitude and impact are important. Thus for proper management of natural forest resources, this type of research can be a useful tool.

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