



Spatio temporal analysis of urban expansion and its impact on land use land cover : a case study of Guwahati Metropolitan area.

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Abstract

This paper presents temporal and spatial dynamics of urban expansion and its impact on the land use land cover (LULC) in Guwahati Metropolitan Area, India by using Geographical Information Systems (GIS) and Remote Sensing. The LULC changes were detected through integration of remotely sensed Landsat imageries and GIS for the year 1991 and 2016. Normalized Difference Built-up Index (NDBI) was implemented for automated extraction of built up areas and Maximum Likelihood Supervised Classification and post classification techniques were carried out to examine the LULC changes over a period of 25 years. The growth trend of built up area and the LULC changes show that there are substantial exchanges of areas between vegetation and built up land along with dense forest loss occurring mainly in the hills and foothills in and around Guwahati mainly due to the need for coping up with substantial increase in population and economic activities. The limited land availability and the confinement of forest areas to the hills has forced the utilization of higher grounds resulting in huge land use transformation from vegetated land and forests to built up land.

Keywords: Urban Expansion, LULC, NDBI, GMA, Supervised Classification, Landsat TM.

1. Introduction

Urbanization as a phenomenon can be considered to be a boon to the human society if it occurs in a well-planned, controlled and coordinated manner. But, in case of the developing countries of the world the process of urbanization is rather considered a curse as it shoulders along with it problems of huge magnitude such as environmental deterioration, unplanned landscape development, increasing climatological and ecological disturbances, biodiversity loss, increasing pollution and many more. The year 2007 has been described as the tipping point in human history with half of the world's population living in urban areas for the first time. Urbanization in India has been closely following this global trend (Sridhar KS, 2010) (Yadav R, 2016). In the fast developing countries like India, there is a mass migration of people from rural to urban and also from smaller to bigger urban areas and then to metropolises like Delhi, Bangalore, Mumbai etc. The process of urbanization in India gained thrust with the start of industrial revolution in 1970s followed by

globalization in 1990s. Forests were cleared, grasslands ploughed or razed, wetlands drained and croplands encroached upon under the influence of expanding cities.

Guwahati, the city regarded as the gateway to north eastern India has also been witnessing a severe demographic hazard because of migration of people from other parts of Assam and the Northeast as a place of opportunity. The growing urban congestion and extension of human settlement, roads and other constructions to the marginal and delicate areas like the hill slopes, fringes of the beels, wetlands and rivulets have now made the city's once efficient ecosystem and drainage highly complicated and increasingly inefficient. These have caused some severe problems such as landslide, erosion, water logging and flash flood (Borah *et.al*, 2015).

2. Statement of the problem and significance of the study

Guwahati being one of the major urban centers of Assam comprises of 24% of the total urban

population of the state (Gogoi, 2012). The city faces acute influx of rural-urban migration owing to employment opportunities and provision of better quality of life. The unprecedented growth of population and settlement often results in encroachment on the hill slopes leading to deforestation and land use land cover change resulting in bio-diversity loss, habitat fragmentation of wild animals, human wildlife conflict and landslides particularly during the rainy season. The study therefore intends to focus on the impact of urban expansion on the changing land use and land cover of the city and also to find its causes and consequences both environmental and socio-economic.

Several studies have demonstrated applicability of remote sensing in the area of urban change analysis and the modeling of growth, LULC evaluation, and urban heat- island research (Mohan et.al, 2011). In particular, Remote Sensing based multi – temporal and spatial land use change data provide information that can be used for assessing the structural variation of LULC pattern. In addition, accurate and comprehensive land use change statistics are can be generated for developing sustainable urban and environmental planning strategies. It is therefore necessary to estimate the rate, pattern and type of LULC changes in order to predict future changes in urban development. This study will attempt to identify the spatio-temporal pattern of LULC changes which occurred in Guwahati using two satellite imageries of 1991 to 2016 in conjunction with the various master plans of GMDA and statistical data obtained from various reliable sources to understand the dynamical pattern of urbanization and its impact on the LULC change.

3. Objectives of the study

The prime objectives of the study undertaken are as follows:

1. Assess the dynamics of Land Use and Land Cover changes.
2. To examine the changing pattern of Urban Expansion between 1991 and 2016.
3. To analyze changes in fragile areas of the city over space and time dimension in relation to urban expansion.

4. Review of literature

Land use/land cover (LULC) changes play a major role in the study of global change. Land use/land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global

warming and increase of natural disaster-flooding (Dwivedi, R.S. *et.al*, 2005; Mas, J.F. *et.al.*, 2004; Zhao, G.X., 2004). These environmental problems are often related to LULC changes. Therefore, available data on LULC changes can provide critical input to decision-making of environmental management and planning the future (Fan, F. *et.al*, 2007; Prenzel, B., 2004).

(Mohan *et.al*, 2011) used multi-spectral data acquired from the LISS-III images of IRS (Indian Remote Sensing) satellite of the years 1997, 2000, 2003, 2004, 2005 and 2008 for the LULC change detection in Delhi. He emphasized that urban land cover classification scheme is also important to see the land use pattern of an area and the classification scheme should be based on local topography, land use etc.

Wu, Zhang, 2012, studied the Land use dynamics, built-up land expansion patterns, and driving forces analysis of the fast-growing Hangzhou metropolitan area of eastern China from 1978 to 2008. In this study, Hangzhou, the capital city of Zhejiang Province in eastern China was selected as a case study. Based on time series Landsat MSS/TM/ETM imagery and historical census data, analysis of the relationship between land use dynamics, built-up land expansion patterns, and underlying driving forces from 1978 to 2008 was performed, using an integrated approach of remote sensing (RS) and geographic information system (GIS) techniques and statistical methods. The analysis revealed that expansion patterns of built up land in the study area was highly co related with socio economic factors such as the GDP, population growth, urbanization and industrialization processes and these factors acted as the driving forces in expansion of built up land and urban growth patterns of Hangzhou Metropolitan Area.

LULC changes in Guwahati city were critically analyzed (Mondal *et.al*, 2015) for two time periods 1987–1997 and 1997–2007. The LULC changes were analyzed in terms of quantity of change and allocation of change. Relative changes; gross gains, gross losses and persistence; net change and swap changes of LULC of Guwahati were examined carefully. The study provided a better understanding of the LULCC pattern.

LULC classification of temporal satellite images (IRS-LISSIII) of Guwahati for the years 2006 and 2010 (Das, Choudhury, 2015) represented the overall change scenario of the several years and the approach of change matrix analysis determined the overall reduction and increment of LULC areas. The result

demonstrated that, the overall boundary area of Guwahati city has been decreased from 2006 to 2010. In that, Scrub land and Population increased rapidly, whereas, dense vegetation class has decreased due to rapid urbanization which leads to environmental degradation.

Zha, Gao and Ni in the year 2003 proposed a new method based on Normalized Difference Built-up Index (NDBI) to automate the process of mapping built-up areas. It takes advantage of the unique spectral response of built-up areas and other land covers. Built-up areas are effectively mapped through arithmetic manipulation of re-coded Normalized Difference Vegetation Index (NDVI) and NDBI images derived from TM imagery. The devised NDBI method was applied to map urban land in the city of Nanjing, eastern China. The mapped resulted in an accuracy of 92.6% indicating that it can be used to fulfill the mapping objective reliably. Compared with the maximum likelihood classification method, the proposed NDBI is able to serve as a worthwhile alternative for quickly and objectively mapping built-up areas.

5. Geographical background of the study area

Location and situation

The areal extension of Guwahati is between 26°5' to 26°13' North Latitude and 91°35' to 91°52' East Longitude and is situated on the banks of the river Brahmaputra. It is located towards the south-eastern side of Kamrup district surrounded by Nalbari district in the North, Darrang and Morigaon districts in the East, Meghalaya State in the south and Goalpara & Barpeta districts in the West. For the study, the Guwahati city Metropolitan Area (GMA) under the administrative control of the Guwahati Metropolitan Development Authority (GMDA) was considered. GMDA's administration encompasses a total area of approximately 262 sq. km and falls under the civil jurisdiction of Kamrup (Metro) district. It covers the entire area of Guwahati Municipal Corporation (GMC), North Guwahati Town Committee, Amingaon Census Town and 21 revenue villages (Abhoypur, Rudreswar, NamatiJalah, Gouripur, Silamohekhaiti, Tilingaon, Shila, Ghorajan, Mikirpara, Kahikuchi, Mirjapur, Jugipara, Borjhar, Garal Gaon, Ajara Gaon, Dharapur, Jansimalu and Jansimalu (NC), Kalitakuchi & Kalitakuchi (NC), Kharghuli, Bonda, Bondagaon and Bonda Grant (I&II), Birkuchi) (GMDA, 2025 & 2009).

Topography

The city is situated on an undulating plain with altitudes varying from 49.5 m to 55.5 m above mean

sea level (MSL). The southern and the eastern sides of the city are surrounded by hillocks. The central part of the city has small hillocks namely Sarania hill (193 m), Nabagraha hill (217 m), Nilachal hill (193 m) and Chunsali Hill (293 m). The Buragosain Parbat in the East and the hills of Rani and Garbhanga in the south form the major hill formations of the city. These hills make contiguous formations with the hills of Meghalaya. There are a total of 18 hills in the city. The total reported area covered by hills in GMDA area is 68.81 sq. km. The existence of forests in the city is largely confined to the hill areas. The city is also covered by swamps, marshes and water bodies like Dipar Bil, Dighali Pukhuri, and Silsakoo Bil.

Climate

The climate is subtropical and humid but the weather is not extreme. The minimum average temperature normally hangs around the 19°C mark while the maximum stays around 29°C. The high humidity is inherent and often rises past 80% except during the winter season when it is dry. Summer begins in March and ends by June. The hottest month of the year is June. The monsoon arrives in June and stays till September. The annual rainfall received by the city is a healthy 1613 mm. Guwahati also experiences an autumn season after the monsoons that begins in September and ends by November. Winter begins in November and stays till February. During winters the temperature can get as low as 10°C. The best time to visit Guwahati is from October to April when the climate is pleasant and enjoyable.

Forests

The hills are mostly covered, barring the rocky outcrops, with forests of various formations ranging from Sal forests, Mixed Moist Deciduous Forests, Evergreen Forest, Bamboo Brakes and Secondary Scrub Forests. The forests in and around the city fall under the jurisdiction of the Kamrup (East) Forest Division. The management of the forest tracts is carried out as per prescriptions of the Working Plans. As per the working plans, there are a total of 14 Reserved Forests (RF) within and on the immediate periphery of the city area. The total RF area comes to 33342.55 Ha comprising of Rani RF, Maliata RF, Agiathuri Hill RF, Garbhanga RF, Garbhanga 1st Addition, Fatasil RF, Amchang RF, SouthAmchang RF, Hengrabari RF, Gotanagar RF, Sarania RF, South Kalapahar RF, and Jalukbari RF. The forests on the southern periphery of the city have Sal formations mixed with patches of

Evergreen and bamboo formations. The forests in the city show Moist Mixed Deciduous forest formations.

Where soil is shallow and poor, stunted growth of bamboo and scrub occur.

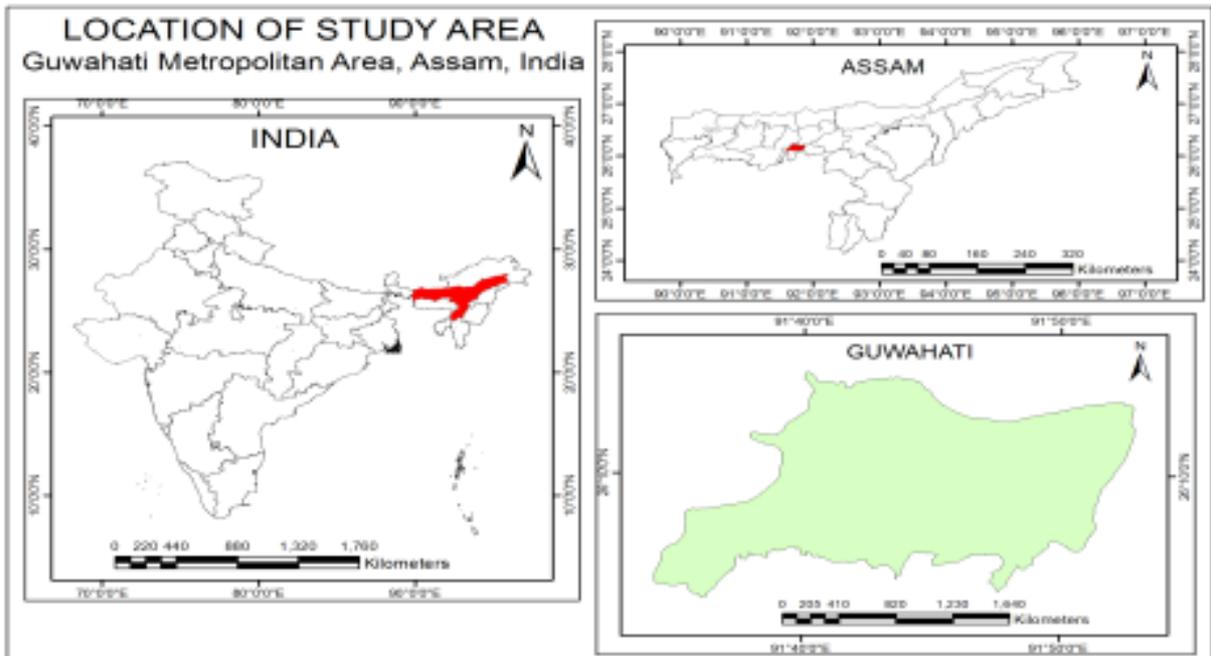


Fig. 2.1 (a): Location of study area

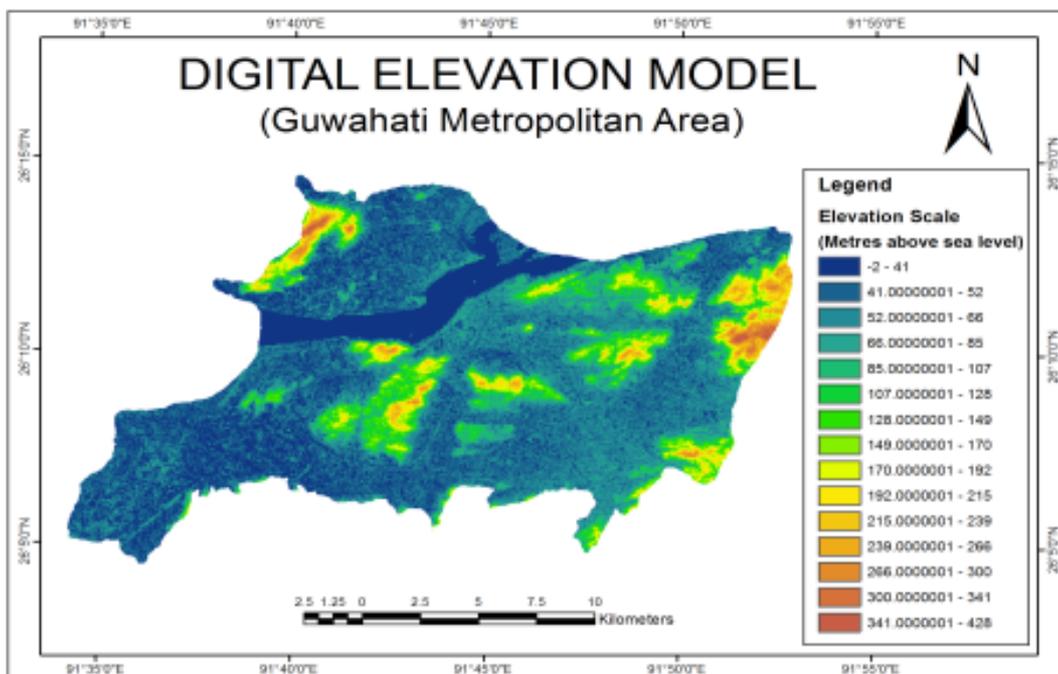


Fig. 2.1 (b) : Digital elevation model of GMA

6. Database and methodology

The preceding four sections outline the data and methodology used in this study. The first section (A) describes the data acquired and used for this study as

well as the methodological approach undertaken. Section (B) outlines the various classification inputs used for this analysis, while section (C) describes how the supervised classification was carried out and finally

section (D) outlines the processing carried out in a GIS environment to arrive at the final change detection maps.

(A) Data

In this study two Landsat images (Landsat5 TM & Landsat8 ETM+) were acquired for the Guwahati Metropolitan study area for built up area extraction and change detection study. Both the images were acquired on Path 137 Row 42. The dates of image

acquisition were: 26 November, 1991 (fig 1.1.a) and 16 December, 2016 (fig 1.1.b). Other ancillary data includes Topographic sheet no. 72N/12 and 72N/16 (1:50,000), maps obtained from Guwahati Metropolitan Development Authority (GMDA), historical imageries acquired from Google Earth along with ground truth and field photographs which provided associated information and were very useful for further analyses and mapping (Table 1.1.b).

Table 1.1 (a) : Details of satellite data used in study

Satellite	Sensor	Path/Row	Data Acquired	Spatial Resolution (in meters)	Data Sources
Landsat5	TM	137/42	26-11-1991	30 meters	GLCF
Landsat8	ETM+	137/42	16-12-2016	30 meters	USGS

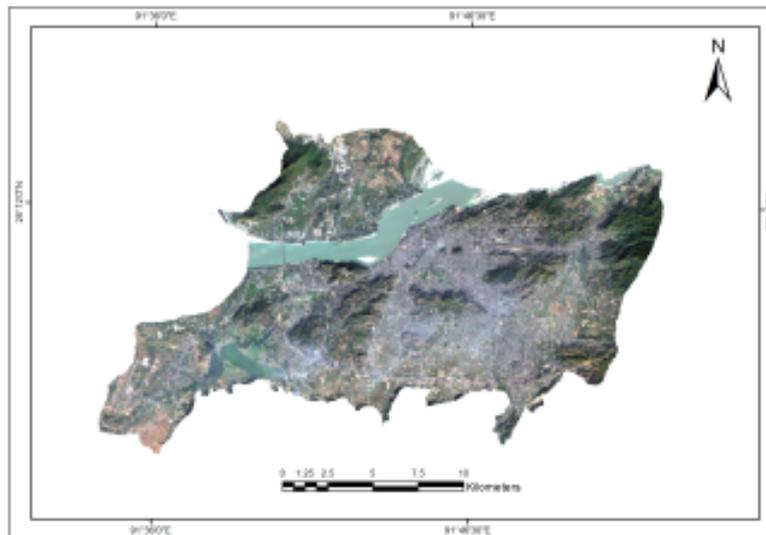


Fig 1.1(a) : November 26, 1991 Landsat5 image of Guwahati Metropolitan Area (GMA)

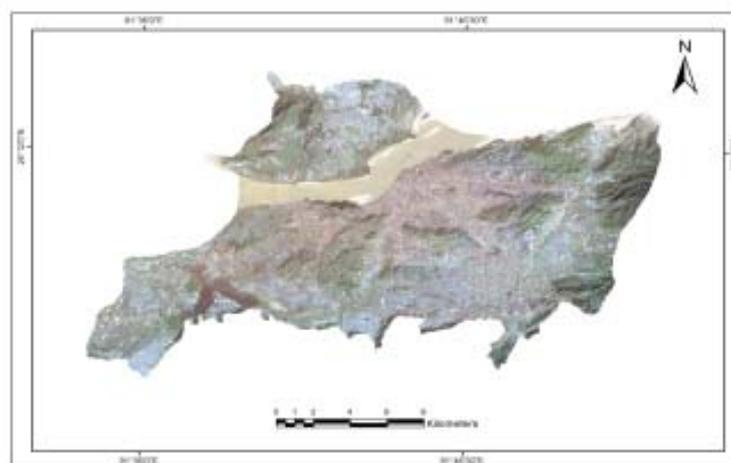


Fig 1.1 (b) : December 16, 2016 Landsat8 image of Guwahati Metropolitan Area (GMA)

Table 1.1 (b): Other data used in the study

Data	Data Sources
Topographic Sheet No. 72 N/12 & 72 N/16(1:50000)	Survey of India (SOI)
GMA Maps	GMDA Master Plan 2025
Historical Imageries	Google Earth Pro

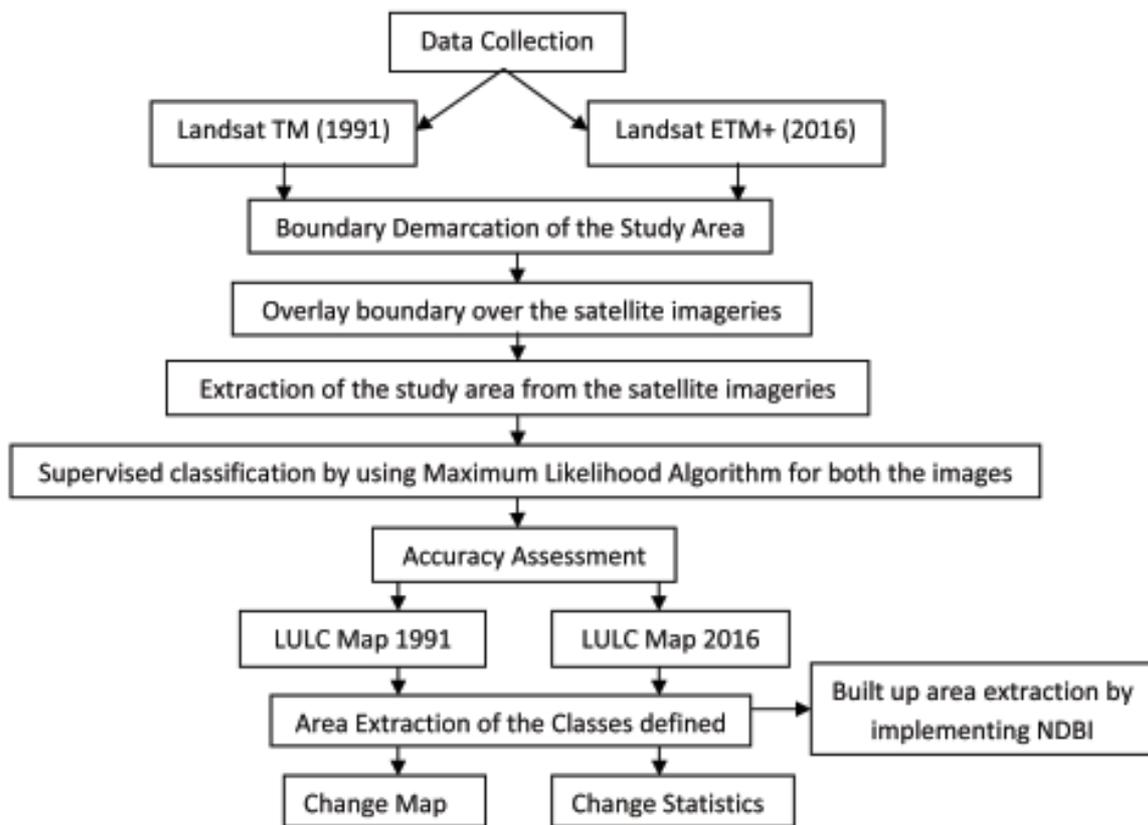
(B) Classification Inputs:**Fig 1.2 (a) :** Conceptual flow chart of research approach

Image classification can be stated as the process of assigning pixels of remotely sensed images into groups of homogenous characteristics (Tinio 2013). The main inputs used in this study were Landsat imageries for the year 1991 and 2001 and a shape file of Guwahati city representing approximately 320 sqkms of the city area along with its sub urban area for a better understanding and analysis of the urban expansion pattern. Topographic sheets from Survey of India and Google Earth images were used as assistance in assigning training samples for performing supervised classification and ground truthing of the classified data.

(C) Supervised classification

Supervised classification involves knowing the identity and location for some of the land cover types prior to the classification process. A known site that represents a homogenous area of a known land cover type is then used for training the classification algorithm. The classification algorithm will then be used to map the rest of the land covers found within the image. During the classification process, every pixel is reviewed by the algorithm and is then assigned a classification to which it has the highest likelihood of being a member (Jensen, 2005).

(D) GIS Processing

In order to perform a supervised classification of an image in a GIS environment, the required bands of the image are added to the workspace for accurate identification of features represented.

7. Findings

Changes in land use pattern

The land use pattern of a city represents the interaction among the physical, historical, social and economic factors, with the character of the city dependant on the present land use (Rahman, 1981). The city life including the city’s functional efficiency is basically governed by its land use pattern. A rationally planned and spatially balanced land use pattern can make the cities functionally more efficient and socio-economically more peaceful (Borah, Bhagabati, 2015). The land use pattern of Guwahati is governed by physical features like the Brahmaputra River and other water bodies, hills, forests, and marshy/ swampy areas etc. The general shape size and plan of the city is influenced by the Brahmaputra River flowing due west along its northern boundary on one hand and hills to the east, south-west and west on the other. The built-up area of the city has been sprawling in a curvilinear fashion and at present has developed a rough crescent

shape. Such a spatial shape of Guwahati is a major problem creating a barrier for its ideal morphological growth as well as planning of the city (Gogoi, 2013).

Land Use/land cover (LULC) changes play a major role in the study of global change. Land use/land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster as well as human induced disaster such as flooding, landslides, erosion, water logging (Dwivedi, R.S. *et.al.*, 2005; Mas, J.F. *et.al.*, 2004; Zhao, G.X., 2004; Das, Choudhury, 2015). The city of Guwahati is no exception in this case with flash floods, landslides, water logging, becoming a perennial concern for the city dwellers.

In preparing the LULC map, choosing a well suited classification scheme is crucial. Considering the standard categories as well as the local factors like topography, land use and the objectives of this research, four separate LULC classes were defined, namely: 1. Water Body (rivers, ponds, wetlands etc.), 2. Vegetation (forests, shrub land, crop land), 3. Barren Land, 4. Built-up area (residential, commercial, industrial, road and railway networks etc.).

The detailed classified images depicting the four different LULC classes for the year 1991 and 2016 are shown in Figure 3.1.a and 3.1.b respectively.

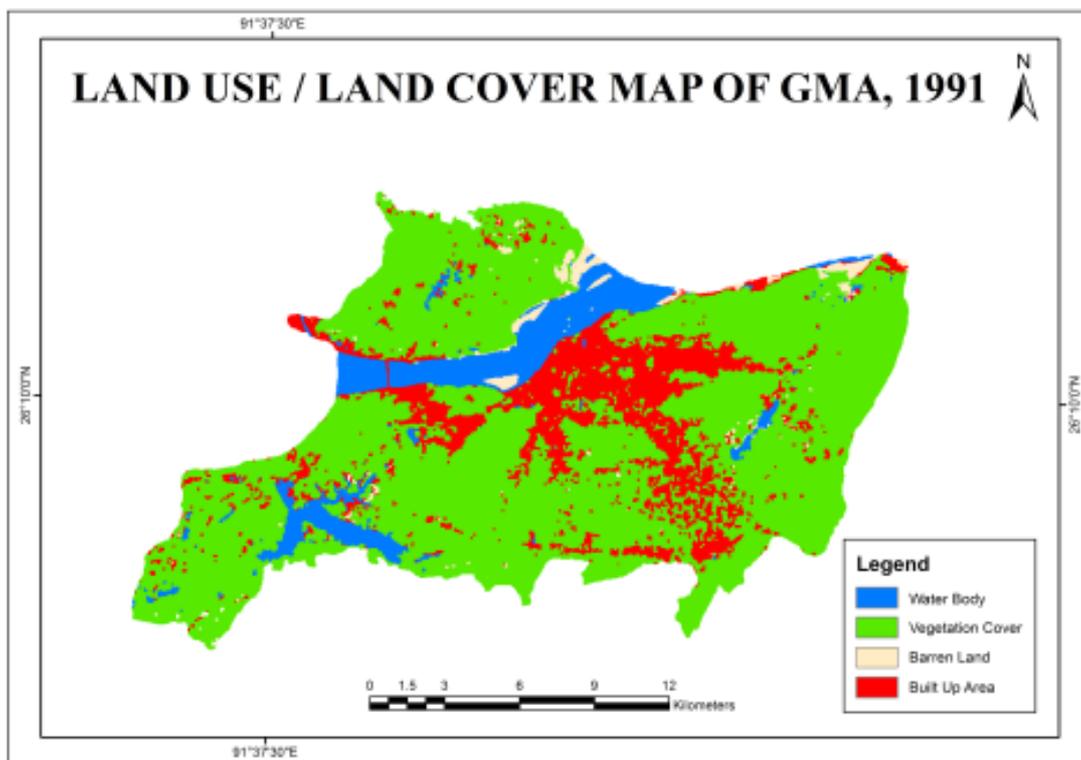


Fig. 3.1 (a) : Land use/ land cover map of Guwahati Metropolitan area, 1991.

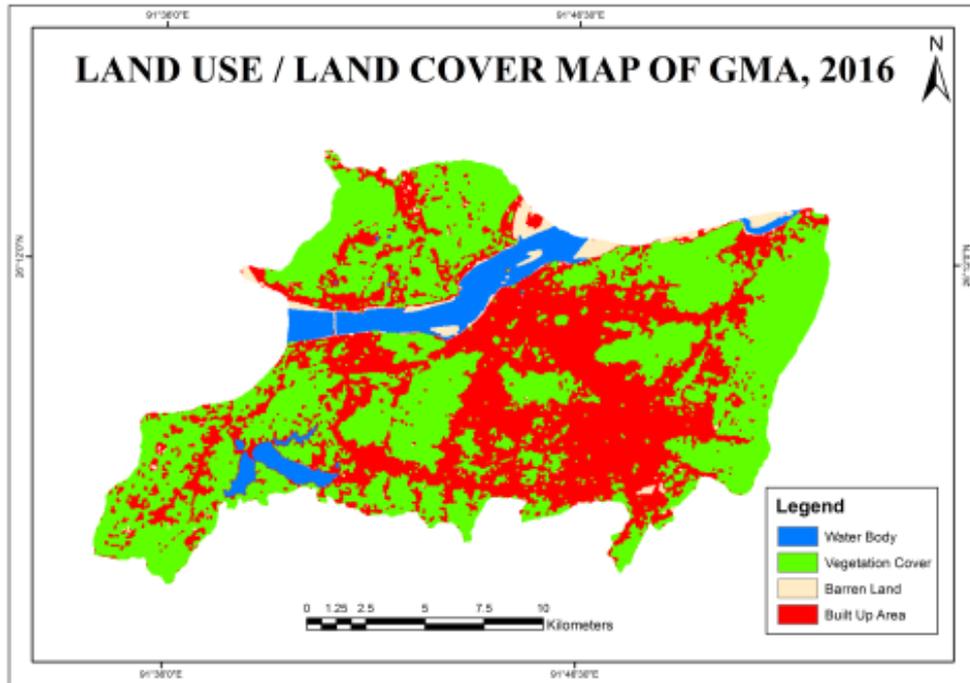


Fig. 3.1 (b) : Land use/ land cover map of Guwahati Metropolitan area, 2016.

Area calculation

The class areas were determined using ArcGIS for the four LULC classes by multiplying the number of raster cells for each class by raster resolution (30m

x 30m = 900m²) and dividing by 1000000 (1000m² = 1km²). The resulting area values for both the classified images are presented in Table 3.2.a and 3.2.b respectively.

Table 3.2 (a) : Class areas-1991 (GMA)

Land Class	Pixel Count	Area (in sq km)
Water body	31689	28.5201
Vegetation cover	254481	229.0329
Barren Land	3660	3.294
Built up area	61291	55.1619
Total		316.0089

Table 3.2 (b): Class areas-2016 (GMA)

Land Class	Pixel Count	Area (in sq km)
Water body	23290	20.961
Vegetation cover	186049	167.4441
Barren Land	8451	7.6059
Built up area	138379	124.5411
Total		320.5521

It can be observed from Fig 3.1.a that dense built up was confined to the old core areas of Guwahati, mainly Pan Bazar, Paltan Bazar, Fancy Bazar and Uzan Bazar along the southern bank of the river Brahmaputra along with built up areas that flourished during sixties and seventies, namely: Gandhi basti, Lachit Nagar, Santipur, Sarania, Jalukbari, Maligaon, Beltola, Fatasil, Dispur, Khanapara, Kahilipara, Basistha, Kalapahar, Narengietc (Master Plan, 1980).

The vegetation cover dominated the landscape with approximately 230 sq km of area making up 72% of the total land area of the city whereas the built up areas mainly commercial and residential in nature made up only 17.4% of the total land area. The water body comprised of 9.02% of the total land area of the city.

On the contrary, Fig 4.1.b depicts a very different picture where the built up area has enlarged manifold in terms of area at the cost of declining vegetation cover and water resources. After 25 years, the built up area constituted 38.8% of the total land area of the city while the area under vegetation and water resources declined to 52.23% and 6.53% respectively. In both the years 1991 and 2016 a meager amount of land fell under the barren land category out of the total land area. However, the area under barren land also increased from 1.04% to 2.37% within these 25 years. The temporal and spatial changes in LULC are graphically represented in Fig 3.2.c and Fig 3.2.d and the positive or negative growth of area in each class is represented in the Table 3.2.c. and Fig 3.2.e.

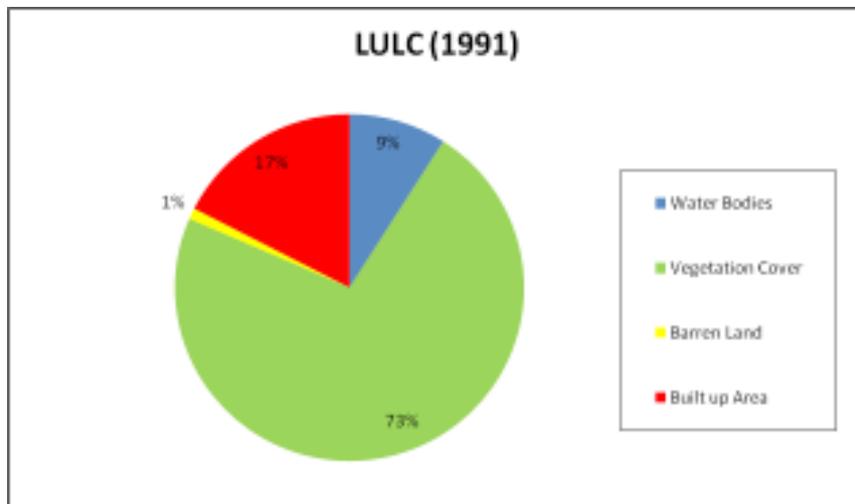


Fig 3.2 (c) : LULC distribution of different classes, 1991.

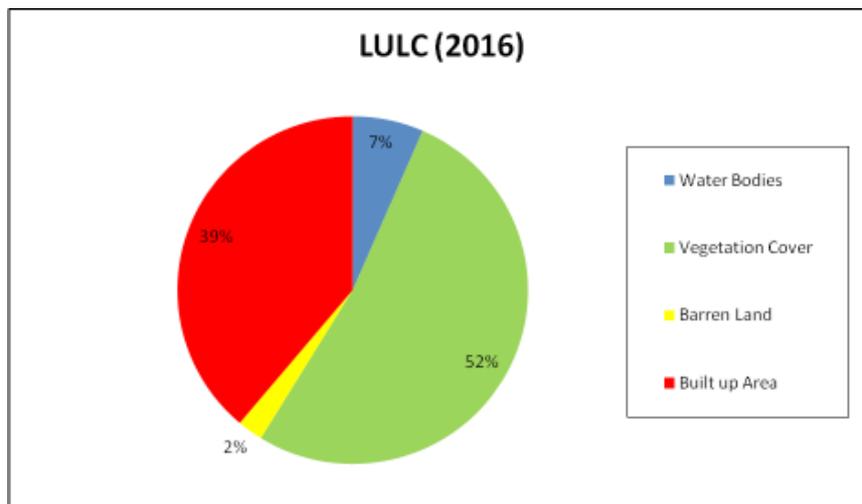


Fig 3.2 (d) : LULC distribution of different classes, 2016

Table 3.2 (c) : Changes in land use from 1991 to 2016 based on the data generated from supervised classification of two Landsat imageries.

Area Type	1991		2016		Difference in Area (%)
	Area in sq km	% of area covered	Area in sq km	% of area covered	
Water Bodies	28.5201	9.02	20.961	6.53	-2.49
Vegetation Cover	229.0329	72.47	167.4441	52.23	-20.24
Barren Land	3.294	1.04	7.6059	2.37	+1.33
Built up Area	55.1619	17.45	124.5411	38.85	+21.4

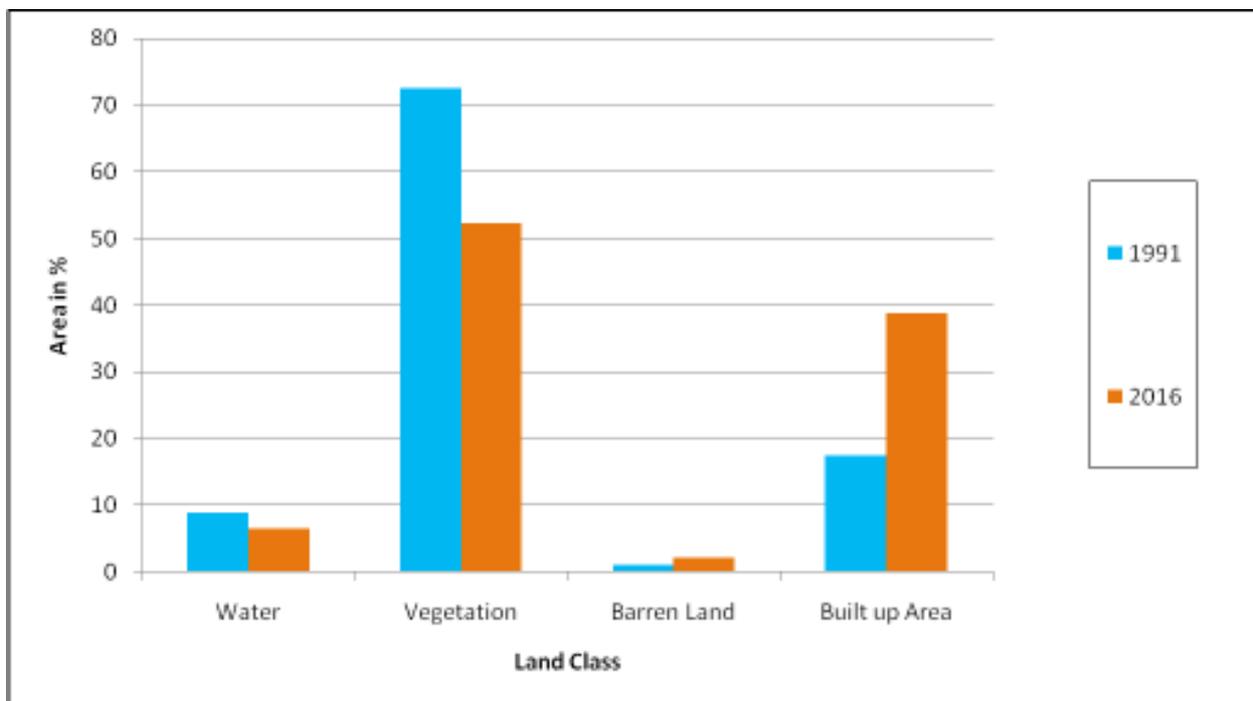


Fig 3.2 (e) : Land use pattern of Guwahati, 1991 and 2016

Identification and extraction of built up area with the Normalized difference built up index (NDBI)

Mapping urban built-up areas using moderate resolution remote sensing data such as from Landsat TM/ETM+ data is complex because urban areas comprise of manmade and natural features like vegetation, waterbody, bareland etc. These urban areas often display heterogeneous spectral characteristics and significant spectral confusion between land cover classes and as a result reduce mapping accuracy. For example, barren land and asphalt concrete share similar spectral properties and, as a result, can be readily

confused. To overcome this spectral confusion, numerous techniques have been developed for built-up and urban landcover mapping using satellite data (Sinha *et.al*, 2016). These techniques can be broadly grouped into two categories (He *et al.*, 2010): (a) classification-based that involves use of different classification algorithms to improve mapping accuracies at pixel- and object-levels (e.g., Cleve *et al.*, 2008) and (b) index-based that involve development of different indices to enhance a particular built-up area and determination of optimal threshold level to separate built-up areas from other landcover types (e.g., He *et al.*, 2010; Zhang *et al.*, 2005, Sinha *et.al*, 2016).

One such reliable method of automated extraction of built up area is Normalized difference built up index (NDBI) proposed by Zha *et al.*, (2003). The development of the index was based on the spectral response of built-up lands that have higher reflectance in the middle infrared (MIR) wavelength range (such as TM 5), than in the near infrared (NIR) wavelength. This application is very useful for urban monitoring and land use planning .

The Normalized difference built up index was originally developed for its application with Landsat TM bands 5 and 4. However, it also works with multi spectral sensors with SWIR bands between 1.55 – 1.75m and NIR bands between 0.76 – 0.9m. In case of Landsat8 OLI ETM+, NIR (Near Infrared) band 5 and SWIR (Short wave Infrared) band 6 is used. The

NDBI index is expressed as follows:

$$NDBI = \frac{MIR - NIR}{MIR + NIR}$$

For identification and extraction of built up areas the same Landsat imageries used for supervised classification were put into application. In ArcGIS environment, the NDBI equation was applied to the imageries with the help of Raster Calculator. The NDBI value, which ranges from -1.0 to 1.0 for each pixel in each of the imageries; helps identify areas of varying levels of built land. Higher values indicate high concentration of built up areas. Moreover, for efficient extraction of built up land the NDBI images were further processed by spatial filtering with a window size of 3 pixels by 3 pixels (Fig 3.3.a).

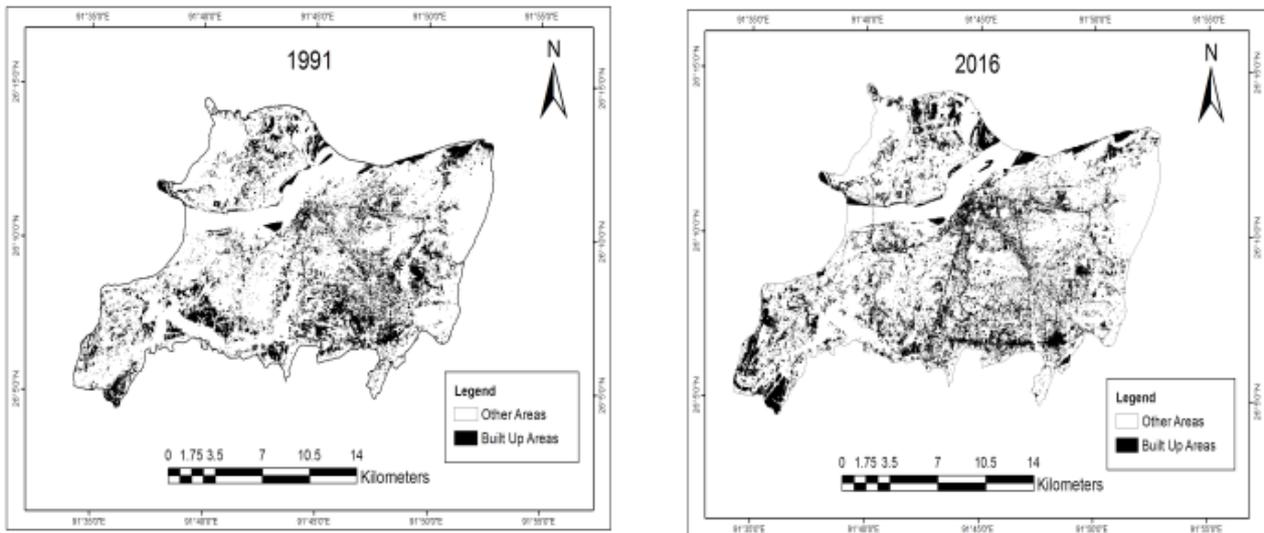


Fig 3.3 (a) : Results of automatically mapped urban land use using NDBI after spatial filtering with a window size of 3 pixels by 3 pixels.

However, it was found out that the built up areas and barren lands share the same spectral radiance in some areas of the image. Therefore, the images were further reclassified by carrying out an unsupervised classification, adopting the Iso Cluster algorithm. The obtained images were then converted into shape files

and further manipulated with the help of Google earth imageries and top sheets obtained from Survey of India. Both the layers were then overlaid upon each other to detect changes and spatial growth pattern of built up area from 1991 to 2016 (Fig 3.3.b).

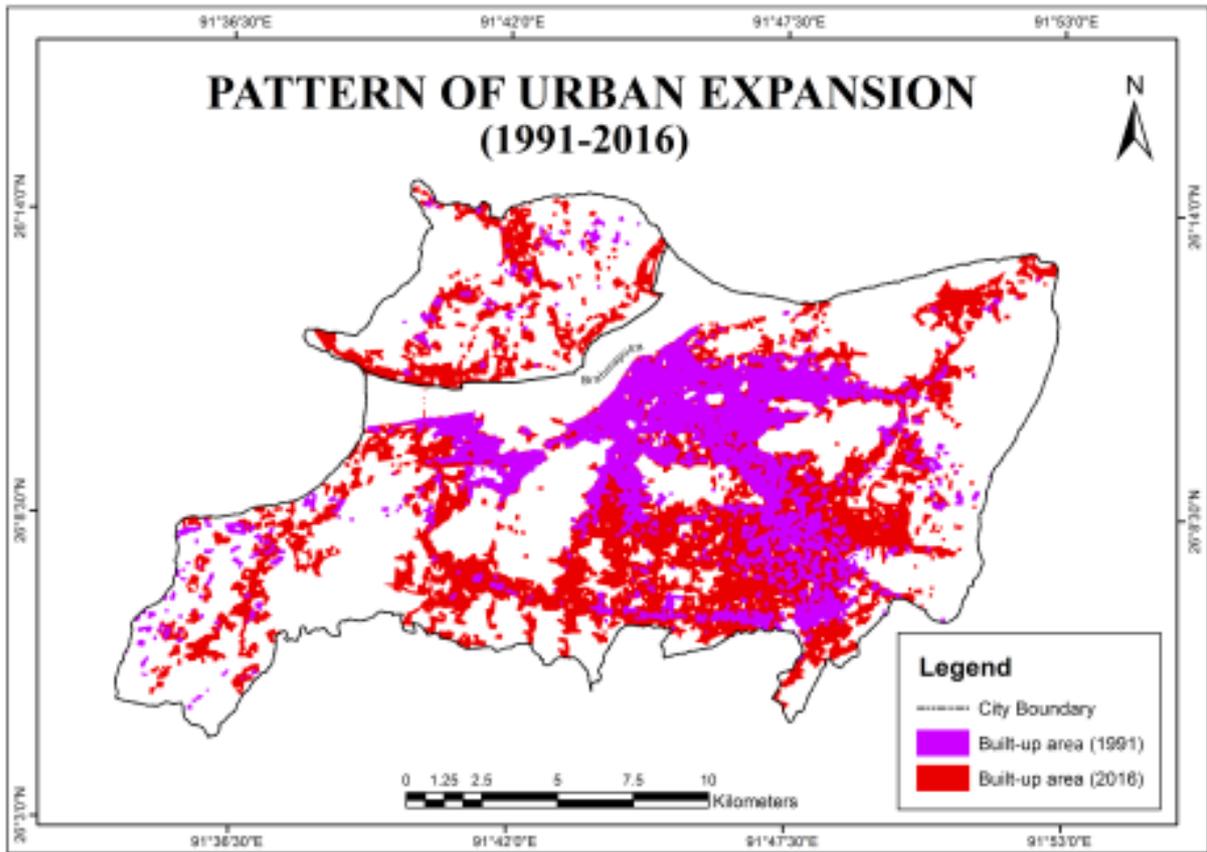


Fig. 3.3 (b) : Urbanization Pattern of Guwahati from 1991 to 2016.

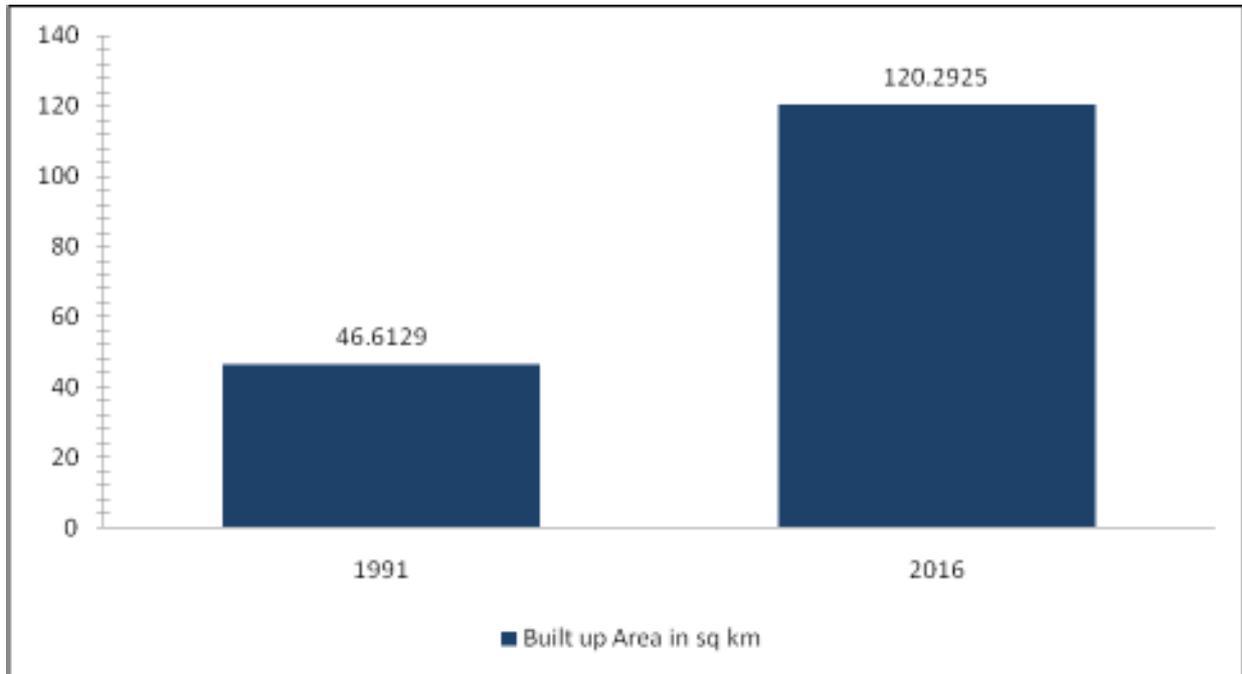


Fig. 3.3 (c) : Built up area growth pattern of Guwahati city.

Accuracy Assessment

In the context of information extraction by image analysis, accuracy “measures the agreement between a standard assumed to be correct and a classified image of unknown quality” (Campbell, 2007).

Accuracy assessment is performed by comparing the classified image obtained by remote sensing analysis to another reference image based on a different information source. In order to be compared, both the image to be evaluated and the reference image must be accurately registered geometrically to each other. One simple method of comparison is to calculate the total area assigned to each category in both maps and to compare the overall figures known as thenon-site-specific-accuracy. On the other hand, site-specific accuracy is based on a comparison of the two images at particular locations (i.e., individual pixels in two digital images). In this type of comparison, it is obvious that the degree to which the pixels in one image spatially align with the pixels in the second image contributes to the accuracy assessment result. Errors in classification should be distinguished from errors in registration or positioning of boundaries.

Classification error occurs when a pixel or a feature belonging to one category is assigned to another category. Commission error represents pixels that belong to another class but are labeled as belonging to the class. Omission error represents pixels that belong to the truth class but fail to be classified into the proper class. An error of omission in one category will be

counted as an error in commission in another category.

Accuracy of an image classification is most often reported as a percentage correct. The consumer’ s accuracy is computed using the number of correctly classified pixels to the total number of pixels assigned to a particular category. It takes errors of commission into account by telling the consumer that, for all areas identified as category X, a certain percentage are actually correct. The producer’s accuracy informs the image analyst of the number of pixels correctly classified in a particular category as a percentage of the total number of pixels actually belonging to that category in the image. Producer’s accuracy measures errors of omission. Kappa coefficient (Khat) is a discrete multivariate technique utilized in accuracy assessment. Khat>0.80 represent strong agreement and good accuracy, 0.40-0.80 is middle and < 0.40 is poor.

The accuracy assessments for land use land cover classified images for the year 1991 and 2016 were performed by selecting ten times the number of pixels for each class from the original Landsat imageries. The reference points were visually identified from the imageries. The test pixels were evenly distributed throughout the imageries and class accuracies were determined by comparing the test pixels for each class with corresponding locations in the classified images. The error matrix tables were constructed with the help of Microsoft Excel software and the results obtained are depicted in Table 3.4.a and 3.4.b below.

Table 3.4 (a) : Error Matrix of the Supervised LULC of GMA, 1991

		Columns: Reference Data					
Rows: Classified Data		Vegetation	Barren Land	Built Up	Water Body	Row Total	Users Accuracy (%)
	Vegetation	41	0	8	0	49	83.67
	Barren Land	0	9	0	0	9	100
	Built Up	0	1	33	0	34	97.05
	Water Body	0	0	0	21	21	100
	Column Total	41	10	41	21	113	
	Producers Accuracy (%)	102.5	90	82.5	160		

Overall Accuracy (%) = 92.03

Kappa Index = 0.88488

Table 3.4 (b) : Error Matrix of the Supervised LULC of GMA, 2016.

		Columns: Reference Data				Row Total	Users Accuracy (%)
Rows: Classified Data		Vegetation	Barren Land	Built Up	Water Body		
	Water Body	19	0	0	0	19	100
	Vegetation	1	40	1	2	44	90.90
	Barren Land	0	0	7	0	7	100
	Built Up	0	0	2	38	40	95
	Column Total	20	40	10	40	110	
Producers Accuracy (%)	95	100	70	95			

Overall Accuracy (%) = 94.54

Kappa Index = 0.9203

Drivers of Urban Expansion and its impact on the land use dynamics

Unprecedented population growth is one of the important factors causing land use changes and geo-environmental degradation, particularly in the cities of the developing countries of the world and the city of Guwahati is no exception to it. The increasing population has resulted in an increased number of residential and commercial units, additional infrastructures, transportation arteries and networks over time and is still an ongoing trend at the cost of green cover exploitation of the city. Guwahati registered a relatively fast growth in recent decades compared to the other cities and towns of Assam. One important fact is that the fast demographic growth of Guwahati has not been accompanied by an adequate economic prosperity.

In 1961, the population of Guwahati Metropolitan area was 199482. The decadal growth rates were 46.99% (1961–71), 48.45% (1971 – 81), 48.45% (1981 – 91), 37.85% (1991 – 01), and 44.15% (2001 – 2010) (Table – 4.3.a).

The pattern of growth kept pace with the pattern of socio-economic development. In 2010, population

of the city was 1,244,713 which crossed 2.052 million as the recent studies revealed. It is estimated that Guwahati metro will house 2.8 million residents by 2025 (GMDA Master Plan, 2025). Although having a fair amount of population is necessary for development, its excessive increase is a problem. Currently, Guwahati is in a state of overpopulation. The main factor behind this is migration (1951–1961, 1971- 1991), which is social and economic in nature. Poor people in rural areas facing extreme poverty and hardship come to Guwahati for survival, slightly better earning and a better life. Students in large numbers from rural areas, other towns and from some North Eastern states come to Guwahati expecting quality education. There is also a steady flow of people from other states to earn their livelihood in different economic activities and to start their own venture. Women flock in large numbers to work as domestic help. The decade-long insurgency problem has raised the feeling of insecurity; a growing tendency is seen amongst the people of middle class to own a house in Guwahati. Recently, such tendency has also been observed among some affluent people of some northeastern states.

Table 3.5 (a) : Growth of Population in Guwahati Metropolitan Area (1961 – 2010)

Year	Population in GMA	Decadal Growth Rate (%)
1961	199482	69.40
1971	293219	46.99
1981	435280	48.45
1991	646169	48.45
2001	890773	37.85
2010	1244713	44.15

Source: Census of India, Statistical Handbook of Assam (1971-2011).

Guwahati also serves as the locus of economic and manufacturing activities and plays an important role in controlling the economy of Assam. Manufacturing sector in Guwahati contributes a substantial share to the economy of the city and the state. The major manufacturing units of the city includes a oil refinery unit and tea manufacturing and processing units along with several small and medium scale industries particularly located in North Guwahati. Analysis shows that remarkable changes of the city occurred during 1991 to 2016. During this period, the total urban area coverage by the city increased by nearly 21.4%. The city also witnessed decrease in proportions of water bodies (-2.49%) and marginal increase in barren lands (+1.33%), which indicates that a considerable utilization of land holdings had taken place between 1991-2016 due to the need for coping up with substantial increase in population and economic activities. It can be rightly concluded that land is not easily available in plains and alternatively higher grounds of hills are utilized for the same resulting in huge land use transformation from vegetated land and forests to built up land.

8. Summary and conclusion

Urbanization is a development process which draws heavily on natural capital. The forest reserves within the city limits of Guwahati have declined with increase in urbanization. The impacts of forest depletion manifest in the form of increased flash floods in the city, landslides and air pollution which the city has been witnessing too often these days (Daly HE, 2005), (Yadav R, Barua A, 2016).

Geographical Information System (GIS) and Remote Sensing have been used to derive accurate information on the spatial and temporal distribution of land use/land cover changes over large areas conducted by organizations and institutions around the world. The capability of GIS lies in the fact that large amount of data can be analyzed and visually

represented within no time. Arc GIS has been used in this study to visually project Land use / land cover (LULC) changes. It is approximated from the data of year 1991 and 2016 of Guwahati that vast changes over the land use and land cover can be evaluated with the amalgamation of Remote Sensing and GIS Techniques.

This study examined remotely sensed Landsat imageries to identify and quantify the changes of the land use land cover (LULC) along with growth pattern of built up areas in Guwahati. The dynamics of LULC analysis was done for the study area. This study examined changes between 1991 to 2016 in the study area and the results show that there are substantial exchanges of areas between vegetation and built up land. The other prominent transitions are vegetated land to barren land; decrease in the area under water bodies and in between river and sandy area. These transitions are probably due to increased land values caused by the growing socio-economic activities and population growth in the city of Guwahati.

The largest transitions are exchanges between forests and built up land followed by forest to barren land. Built-up gain occurs mainly in the outskirts of existing Built up lands. Dense forest loss is occurring mainly in the hills and foothills in and around Guwahati. The analysis have concentrated only on the larger categories and missed the systematic transformations in the landscape. It is deduced that LULC patterns in the area are generally controlled by agro-climatic conditions, ground water potential and many other factors like irrigation facilities, soil characteristics, socio-economic status and demography. Deeper explanation of the driving factors of LULC dynamics will be the subject of future study. Finally, it can be advocated that the transition from vegetated area to built-up area constitutes a large percentage of the total landscape of Guwahati. This transformation contributes a substantial ecological footprint and thus increase in built-up areas needs to be scrutinized in the terms of environmental monitoring and sustainability.

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