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Spatio-temporal changes of land use pattern in response to rapid urbanization

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Abstract
The application of remote sensing based land cover classification coupled with landscape metrics has been effective in assessing and understanding the characteristics of land use pattern. The present study attempts to analyze the spatio-temporal changes in land use/land cover pattern in response to rapid urbanization process of Guwahati Metropolitan Area (GMA) by using four metrics derived from FRAGSTATS software- percentage of landscape (PLAND), number of patches (NP), mean patch size (MPS) and largest patch index (LPI). A period of 25 years from 1992-2016 was considered. The results revealed that the rapid urbanization process has caused massive changes in the areas dominated by vegetation and water bodies. However, apart from built-up, an increasing trend of cultivated and managed areas was also recorded. During the period the landscape underwent substantial transition from a predominant vegetative landscape to urban land use dominant landscape. The paper provides useful inputs in regard to effective policy framing for the urban planners.

Keywords: land use pattern, fragstats, guwahati metropolitan area, urbanization

1. Introduction
In 21st century, one of the important global change issues which have been affecting the human race, particularly in developing countries, is the process of rapid urbanization [1]. This has led to significant impact on the structure, function and dynamics of an ecosystem, thereby, transforming an urban area to a fragile region [2]. Large scale modification of the environment around an urban center is primarily due to its high density of population. Therefore, with the growth of a city the ever increasing population demands more land for various developmental purposes [3], which directly or indirectly affects the biodiversity [4,5], biogeochemical cycles [6] and climate conditions [7]. This is very commonly prevalent in economically developed countries where sustainable urban development is at risk due to large scale urban expansion [8, 9, 10, 11].

Remote sensing techniques have been successfully employed in analysing and monitoring the course of urban expansion and land use transformation [12]. The ability to capture multi-temporal and improve quality multi-spatial data have made remote sensing an appropriate approach for urban analysis. In 2011, India's urban population stands at 377.1 million accounting 31.16% of the total population of the country [13]. Many Indian cities are experiencing tremendous urbanization at an incredible growth rate [14]. In 2011, India's urban population stands at 377.1 million accounting 31.16% of the total population of the country [13]. Guwahati is one such city which has witnessed tremendous population growth in the last few decades. Such unprecedented rise in population has led to unauthorized and unplanned urban growth, consequently, consuming the natural resources and converting the surrounding environment. Thus, the present paper makes an effort to understand and quantify the urban characteristics in Guwahati, from 1992 to 2016, with the application of a series of landscape metrics.

2. Study Area
The Guwahati Metropolitan Area (GMA) lies between 26°2′ N to 26°16′ N latitude and 91°33′ E to 91°52′ E longitude covering an area of 277.19 sq. km. The river Brahmaputra passes through the city forming the northern and, comparatively, larger southern bank respectively (Fig. 1). The northern bank is represented by large stretches of plain open fields and marshy areas, while dense urban setup, prominent hills and numbers of wetlands, also called 'beels' formed the southern bank [15]. The city sits on an undulating topography having varying elevation between 49.5 m to 55.5 m a.m.s.l. The city hills covered around 68.81 sq.km of the total GMDA area [16]. These hills are dominantly covered with forests ranging from mixed moist deciduous, evergreen, sal trees, bamboo etc. [17]. Post-Independence, in 1951, GMA had a population of 97389 persons. As estimated, by 2025, the total population of GMA would be approximately 2.1 million [18].

3. Materials and Methods
3.1 Data
The study has considered three time data viz. 1992, 2002 and 2016 covering a period of 25 years. Landsat TM data for 1992, ETM data for 2002 and OLI TIRS data for 2016 were used to extract the land use/land cover (LULC) maps for Guwahati. Basic pre-processing steps such as geometric and radiometric corrections were carried out. The data were projected to UTM 46 N at WGS 84 datum. The GMDA administrative boundary map was obtained from the GMDA office, Guwahati and a LULC map of 1990 prepared by ASTEC was used as a reference map.

3.2 Methodology
3.2.1 Land use/land cover (LULC) mapping
The Landsat images were used to extract the LULC characteristics of the study area. A supervised classification with maximum livelihood classifier was employed. This was

supported by necessary fieldwork, visual interpretation and information derived from the reference map. Five LULC classes were identified based on the classification scheme designed by Food and Agricultural Organization of the United Nation [19]. They are: artificial and natural water bodies- areas covered with water; built-up areas- areas covered with impervious surfaces; natural and semi natural vegetated areas- areas covered with vegetation; cultivated and managed areas- areas covered with vegetation of anthropogenic origin; and natural and semi natural non vegetated areas- areas that do not have vegetation cover. The accuracy assessments of the classified LULC maps show that they qualify the minimum overall accuracy criteria, which is 85% for a satellite dataset [20].

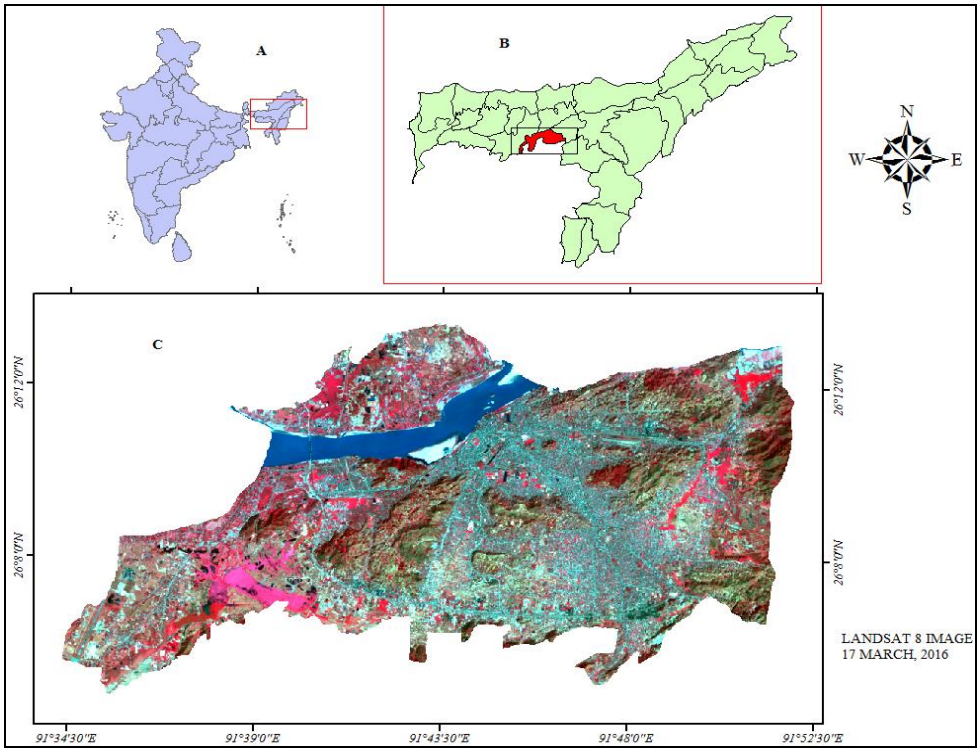

Fig 1: Allocation of the study area: the region of India (A), the state of Assam (B) and the Guwahati Metropolitan Area (C).

3.2.2 Derivation of spatial metrics

In order to assess the landscape pattern and quantify the spatial heterogeneity [21], the spatial metrics available in FRAGSTATS software package [22] was selected following studies of [23]. Four metrics were taken into consideration, namely, (a) number of patches [NP], (b) mean patch size [MPS], (c) percentage of landscape in a particular class [PLAND] and (d) percentage of landscape composed of the largest patch [LPI].

4. Methodology

4.1 Land use/land cover (LULC) analysis

Guwahati has witnessed rapid urbanization during the last 25 years which has brought significant land use changes. The LULC statistics summarized in Table 1 reveal that built-up and cultivated and managed area largely gained while the remaining land cover classes demonstrated losses. A built-up area of 7741.3 ha was added at an annual rate of 297.74 ha. The percent rate of change in built-up between 1992 and 2016 was 256.2% indicating a massive expansion of built-up in the study area. On the other hand, the land under natural and semi natural vegetated class decreased greatly from 58.02% to 30.3% of total geographical area at a rate of 295.5 ha per year. A comparative analysis of the percent change in land cover classes for the two time periods 1992-2002 and 2002-2016 reveal that the land cover transformation process in Guwahati was more intense and rapid during 2002-2016. This could be due to the growing economy of the state in recent years, arrival of many corporate sectors, private educational and health institutions and many more.

Table 1: Land cover change of GMA for various years.

Landuse/land cover categories	1992	2002	2016	% change 1992-2002	% change 2002-2016	% change 1992- 2016	Rate of gain/loss (ha per yr)
Artificial and natural water bodies	2557.4	1977.1	1969.1	-22.6	-0.4	-23.0	-22.6
Built-up	3021.2	5243.3	10762.5	+73.5	+105.2	+256.2	+297.7
Natural and semi natural vegetated areas	16084.9	14337.5	8401.5	-10.8	-41.4	-47.7	-295.5
Cultivated and managed areas	4286.7	4459.6	5289.5	+4.0	+18.6	+23.3	+38.5
Natural and semi natural non Vegetated	1601.55	1534.2	1129.1	-4.2	-26.4	-29.5	+18.1

(Area in hectares)

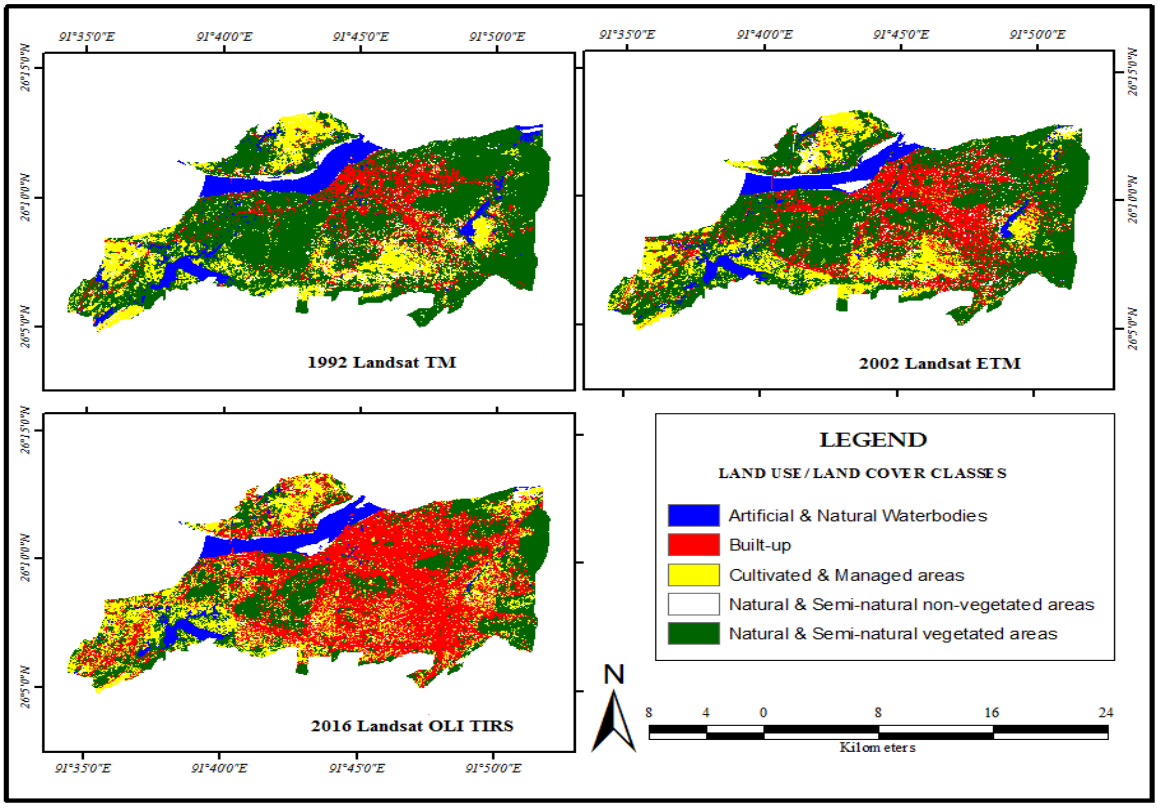

Fig 2: Spatial occurrence of land use changes, 1992 - 2016

4.2 Landscape metrics assessment

The statistics from landscape metric analysis are shown in Table 2. From the table it is evident that the changes in PLAND, NP and MPS indicate an increasing fragmentation of the natural and semi natural vegetated areas. The PLAND for natural and semi natural vegetated land decreased markedly between 1992 and 2016, while built-up land showed an increasing trend of PLAND signifying the continuous built-up expansion. The PLAND for cultivated and managed areas showed a consistent growth over the entire study period due to the transformation of natural and semi natural vegetated areas and natural and semi natural non vegetated areas.

The NP indicates the degree of fragmentation of the landscape. The growing numbers of patches for artificial and natural water bodies, natural and semi natural vegetated areas and cultivated and managed areas demonstrated an increasing fragmentation of the landscape. There has been a more than twofold increase in NP for natural and semi natural vegetated land. However, built-up land and natural and semi natural non vegetated areas recorded a declining trend of NP. This could be due to conversion of vacant plots located between built-up patches, particularly in the central part of the study area.

The MPS for natural and semi natural vegetated land registered significant decrease from 10.26 ha in 1992 to 2.32 ha in 2016, indicating a fragmented urban landscape that is composed of many small patches of vegetation. In contrast, MPS increased gradually for built-up class indicating a moderate degree of aggregation. This can be explained by the fact that development cores grew together to form larger patches through accretion process.

Thus, during the study period rapid urbanization has reduced larger land use patches like natural and semi natural vegetated areas and cultivated and managed areas into smaller ones.

Table 2: Landscape metrics of GMA

		Pland (%)			NP (nos.)			MPS (ha)	
LULC Categories		1992	2002	2016	1992	2002	2016	1992	2002	2016
Artificial & Natural water bodies	9.28	7.18	7.15	792	874	863	3.23	2.26	2.28
Built-up	10.97	19.03	39.06	3727	3628	2635	0.81	1.45	4.08
Natural & Semi-natural vegetated areas	58.38	52.04	30.49	1567	2315	3618	10.26	6.19	2.32
Cultivated and managed areas	15.56	16.19	19.2	3630	3326	6674	1.18	1.34	0.79
Natural & Semi-natural non-vegetated areas	5.81	5.56	4.1	4881	4722	3185	0.33	0.32	0.35

* PLAND = Percentage of landscape in a particular class or patch type,
* NP = Number of patches * MPS = The mean patch size in a particular class or patch type

Of all the various LULC classes, the natural and semi natural vegetated land had the largest LPI value in 1992, which was later reduced by fourfold at a rate of 74.5% by 2016. The artificial and natural water bodies, cultivated and managed areas and natural and semi natural non vegetated areas showed marginal decline. Most importantly, built-up

registered an incredible increase in LPI over the study period. Even its rate of change in LPI was extreme, as it increased by 96.4% during 1992-2002 and later almost doubled to 180.1% between 2002 and 2016.

Table 3: LPI statistics for GMA

	LPI (%)			Rate of change (%)
LULC Categories	1992	2002	2016	1992-2016
Artificial & Natural water bodies	2.91	2.03	2.75	-5.24
Built-up	3.36	6.60	18.49	449.81
Natural & Semi-natural vegetated areas	13.89	11.21	3.49	-74.88
Cultivated and managed areas	1.52	1.90	1.27	-16.33
Natural & Semi-natural non-vegetated areas	0.28	0.40	0.26	-7.58

* LPI = Percentage of landscape composed of the largest patch

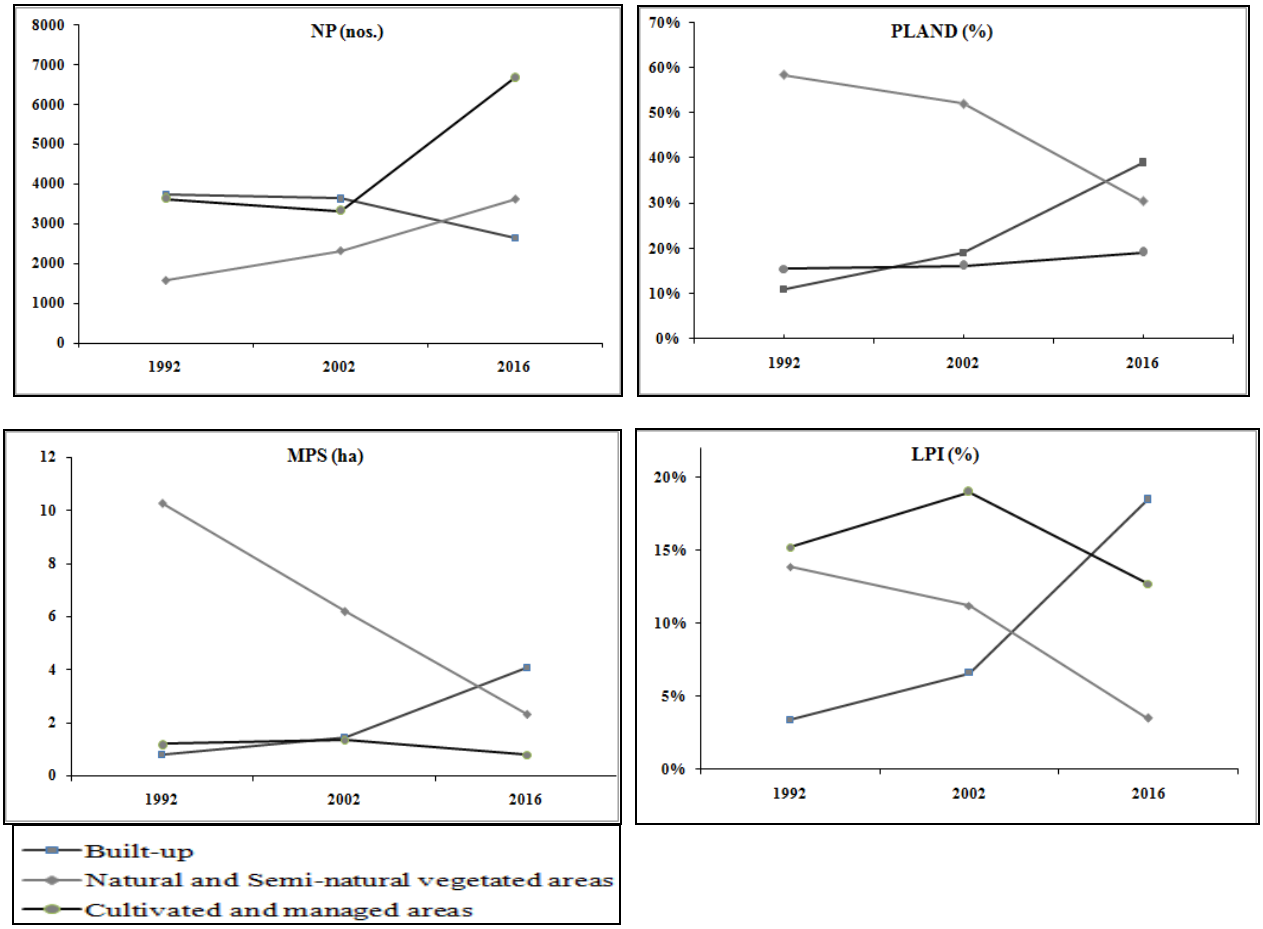

Fig 3: Changes in spatial metrics selected in the study

5. Conclusion

The urban development in Guwahati Metropolitan Area (GMA) was relatively moderate during 1992-2002, but post 2002, when Kamrup Metropolitan was recognized as a district, the urbanization process accelerated many fold. This sudden thrust of urbanization was characterised by unauthorized and unscientific urban growth which caused negative impacts to the limited natural resources like the wetlands and hills of the city.

The present study integrated remote sensing and spatial metrics to evaluate the spatio-temporal change in landscape pattern as a result of rapid urbanization process between 1992 and 2016. The LULC analysis revealed that both natural and semi natural vegetated areas and cultivated and managed areas were the major land use class that were converted for urban development. The results revealed that the land use in Guwahati city has underwent large scale fragmentation. The natural and semi natural vegetated land cover class consistently demonstrated highest degree of fragmentation across the study area. Due to rapid urbanization process, the plots between the individual and fragmented vegetation patches were further urbanized. This was evident by the fact that decline in mean patch size (MPS) was intensified with the decrease in the largest patch index (LPI).

It is clearly evident that Guwahati is undergoing an unhealthy and unsustainable urbanization process. Fragmentation of city's natural vegetation is of serious concern, given the fact that these vegetations are largely confined to the city hills. Thus, Guwahati requires immediate and strict urban planning by the governmental authorities and concerned stakeholders. And effective implementation of the same has to be ensured for successful management of the problem.

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