International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 09
August 2017

Spatial-Temporal Dynamics of Urban Green Space in Guwahati Metropolitan Area, India

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***Abstract**:*

Urban green spaces (UGS) are an integral part of any city's environment. It plays an important role in maintaining the quality and health of an urban ecosystem. However, rapid urbanization in the last few decades has caused an adverse impact in the spatial distribution of UGS. This paper attempts to analyse the status of UGS in Guwahati Metropolitan Area (GMA) between 1990 and 2016. Satellite imageries for 1990, 2002 and 2016 were used for the study. The Normalized Difference Vegetation Index (NDVI) thresholding technique was employed to assess the health of vegetation for respective years. Further, based on the percentage of greenness in each cell, the vegetation quality was categorized into four classes, low green, moderate green, high green and very high green. The results revealed that the health of vegetation in GMA has notably declined; even area under vegetation has reduced remarkably. The low quality vegetation cover has considerably expanded, contrarily; very high quality green has diminished during the study period. The study demonstrated the need of effective greening policies from the concerned stakeholders.

Keywords

Urban green space, NDVI, Greenness, Vegetation, Guwahati Metropolitan Area.

1. Introduction

The world's population has increasingly moved towards urban areas in the last few decades. As a result, it is expected that by 2025 about 65% of the world's population will be residing in urban areas (Schell and Ulijaszek, 1999). UGS represented areas such as gardens, parks, green spaces occupying river and sea fronts, at historical sites and also industrial sites and overgrown gardens (Venn and Niemela, 2004; Gupta, Kumar, Pathan and Sharma, 2012). The urban residents are very much benefitted from UGS which acts as urban lungs-absorbing pollutants and releasing oxygen (Hough, 1984; Haughton and Hunter, 1994), preventing soil erosion (Binford and Buchenau, 1993), sustaining biodiversity (Attwell, 2000), ensuring energy flow (Yeh and Huang, 2009) and lessening urban heat island effects (Miller, 1997;

Stanners and Bourdeau, 1995). Another utility of UGS is that it enhances the quality of urban living, improves the health and well-being of residents, helps in climate change adaptation and mitigation and it increases the land and property value.

It is expected that by 2030 most of the future population growth will be in the towns and cities of developing countries accounting 80% of total urban population (UNFPA, 2007). In 2011, India's urban population accounted about 31.16% of the total population of the country (Census, 2011). Guwahati, the most critical city in the Northeast India also acts as the gateway to the entire North Eastern India (CDP, 2006). In 2011, the city had a population of 968,549 which had well over surpassed a million by now. Such increasing population coupled with rapid urbanization has taken a toll on the city's green space. The application of remote sensing technology has proved to be effective in understanding the spatial and temporal variability of UGS (Schopfer, Slang and Blaschke, 2004; ThiLoi, tuan and Gupta, 2015). Thus, the present study attempts to understand the dynamics of UGS in Guwahati city.

2. Study Area

The Guwahati Metropolitan Area (GMA) lies on the either banks of the river Brahmaputra between 26°2′ N to 26°16′ N latitude and 91°33′ E to 91°52′ E longitude. The northern part of the city is dominated by vast plain area with few wetlands while the southern part, which is comparatively larger, is comprised of as many as eighteen hills and some major wetlands such as Deepor beel. Some of these hills are recognized as reserve forest (Yadav and Barua, 2006). The city had a low population of about 43000 in 1950 which increased to 1,059,000 in 2016 and is expected to reach 1,430,000 by the year 2030 (UN, 2014). The Guwahati Municipal Corporation, the Amingaon Census Town, the North Guwahati Town Committee area and adjacent 21 revenue villages comprises the GMA (GMDA, 2009).

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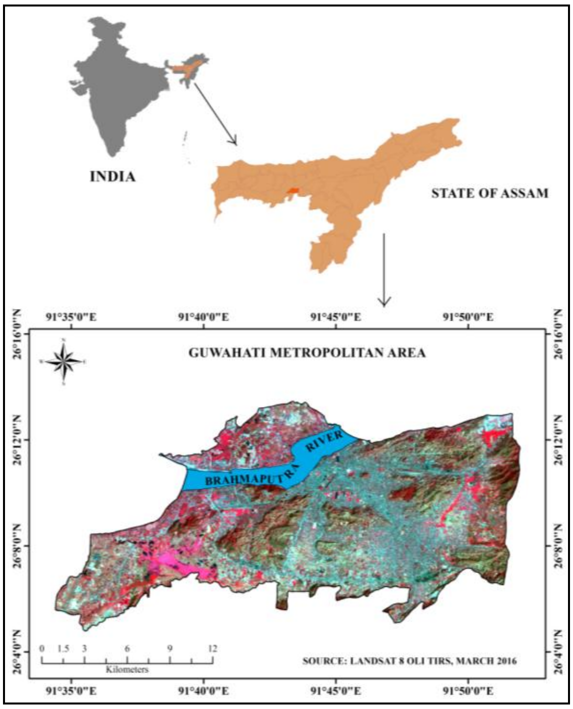

Figure 1. Location of the study area.

3. Materials and Methods

3.1 Data

Multi-temporal Landsat data for three time periods, 1990, 2002 and 2016 were downloaded from the USGS website (www.usgs.glovis.gov). All the datasets had the same spatial resolution of 30 m. The optical bands of these datasets have been used in the study. The GMA boundary map was obtained from the office of Guwahati Metropolitan Development Authority (GMDA), Bhangagarh, Guwahati.

Table 1. Satellite data used in the study

Satellite	Resolution(m)	Path/row	Observation date
Landsat TM	30	137/42	March, 1990
Landsat ETM	30	137/42	February, 2002
Landsat OLI TIRS	30	137/42	March, 2016

3.2 Methodology

The obtained satellite imageries were subsetted to the GMA boundary demarcated by the Guwahati Metropolitan Development Authority (GMDA). Each dataset were geometrically rectified through nearest neighbor algorithm and were geo-referenced to UTM 46 N projection at WGS 84 datum. The Normalized Difference Vegetation Index (NDVI) was estimated to quantify the health of the vegetation. Due to the sensitivity of NDVI towards atmospheric effects, the standard atmospheric correction was conducted to derive the reflectance value for the three imageries under consideration. Accordingly, the NDVI was calculated following the given equation:

$$NDVI = \frac{\text{Near Infrared (NIR)} - \text{Red}}{\text{Near Infrared (NIR)} + \text{Red}}$$

However, for Landsat TM and ETM: NIR = Band 4 and R = Band 3

for Landsat OLI : NIR = Band 5 and R = Band 4

Following the works of (ThiLoi, Tuan and Gupta, 2015), the derived NDVI images were further categorized based on binary classification into vegetated, non-vegetated and water classes. Again based on the percentage of greenness, each cell were classified into four classes of greenness quality at a scale from 0.25 to 1, where less than 25% of green in a cell signified low quality green, 50% of green denoted moderate quality green, 75% green indicated high quality green and 100% of green was designated very high quality green. It is important to note that the aquatic vegetation in the wetlands was also considered during NDVI estimation.

4. Results and Discussions

4.1 NDVI Estimation

The NDVI images generated are summarized in Figure 2. The NDVI values ranges from - 1.0 to + 1.0, where areas such as barren rock, sand or snow represents very low NDVI values usually below 0.1; area with sparse vegetations like shrubs and grasslands shows moderate NDVI values between 0.2 and 0.5; however areas with dense vegetation records high NDVI values approximately from 0.6 to 0.9 (USGS, 2015). The observation of the NDVI values reveals that between 1990 and 2002 the maximum NDVI values have diminished from 0.70 in 1990 to 0.64 in 2002. This demonstrated that there has been deterioration of the health of vegetation in the study area. The changes are quite prominent towards the central and southern part of the city. This can be attributed to the rising residential complexes in the area, broadening of the National Highway 27 and setting up of new public and private institutions. Such developments had disturbed the infiltration of rain water in the area which indirectly affected the NDVI (Farrar, Nicholson and Lare, 1994). A visual interpretation of the NDVI images clearly depicted that the development of urban built-up have persisted to grow. Conversely, the maximum NDVI value recorded for 2016 was 0.80 which is comparatively higher than the 1990 and 2002 NDVI values respectively. This was due to the presence of extensive dense aquatic vegetation in the wetlands, particularly, in the Deepor beel which is situated at southwestern periphery of the Guwahati city. However, the terrestrial vegetation in the study area has continued to decrease and diminish in its health through out the study period. Such trend can be attributed to the increase of vegetation fragmentation caused by the rapid urbanization process (Pawe, 2017a).

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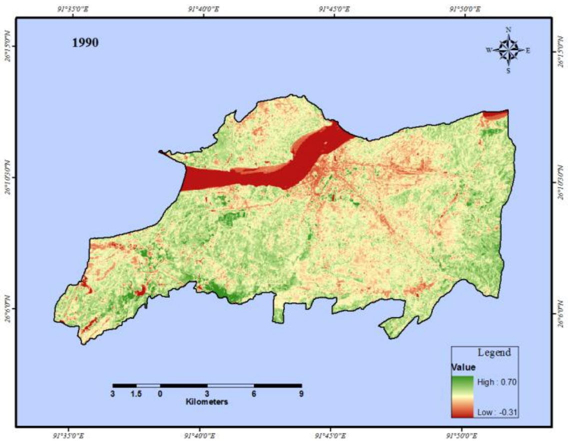

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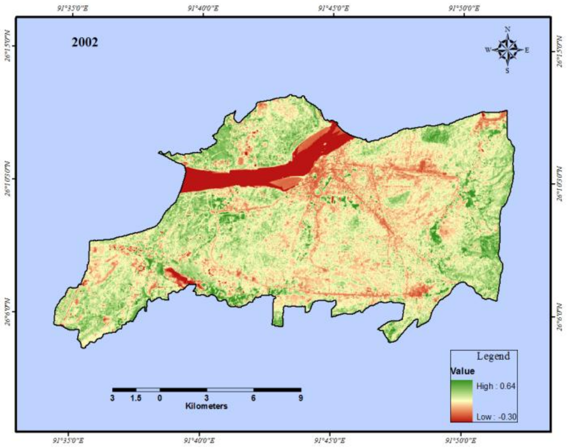

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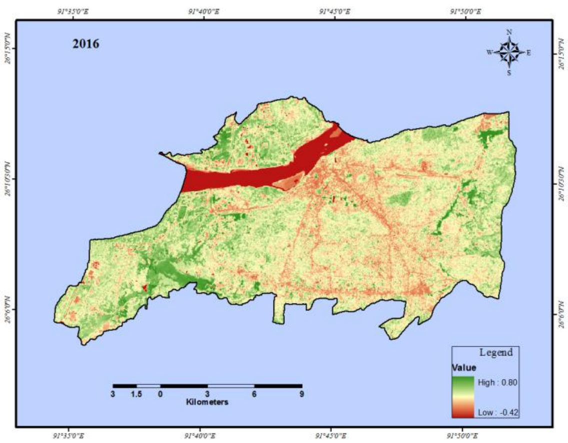


(c)

Figure 2. NDVI estimation for different time periods (a) 1990, (b) 2002 and (c) 2016

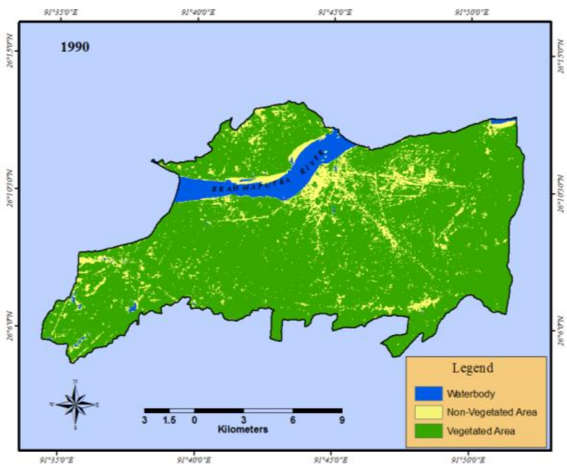
4.2 Binary Classification of NDVI

The NDVI images derived were further classed based on binary classification i.e. vegetated and non-vegetated classes. This was computed to examine the changes in vegetated and non-vegetated area both spatially and quantitatively. In this regard, three classes were identified, namely, vegetated area, non-vegetated area and water body. The results revealed that the vegetated class experienced a declining trend in its total area from 230.88 in 1990 to 209.02 in 2002 and further to 162.13 sq. kms in 2016 (Table 2). Contrary, the non-vegetated class has gained by more than three times from 26.20 sq. kms in 1990 to 95.75 sq. kms in 2016. It was observed that during the time period from 2002 to 2016 the non-vegetated area has almost doubled indicating that the pressure of urban expansion has intensified causing significant changes to the natural landscape. Spatially, the region towards the south and south eastern part of Guwahati came under severe stress. Subsequently, urban areas like Basistha, Khanapara, Six mile, Beltola, Lokhra and Gorchuk developed (Figure 3). During the study period, these areas experienced rapid urban development such as establishment of Sarusujai Stadium, the Barsapara stadium, the Games Village, the construction of Inter-State Bus Terminus, numerous private hotels including Radison Blu etc., private educational institutions like Royal Group, Delhi Public School, and National Public School etc. Of all, the growth of numerous residential units including mega housing complexes and apartment, major commercial establishments and small business outlets along the National Highway 27 were the primary urban developments which had contributed to the rise of non-vegetated areas and consequent diminishing of vegetated areas.

Table 2. Area under various classes for the different time periods

Classes	1990 Area	2002 Area	2016 Area
Vegetated Area	230.88	209.02	162.13
Non-vegetated Area	26.20	48.43	95.75
Water	1.36	0.99	0.56

Area in sq.kms



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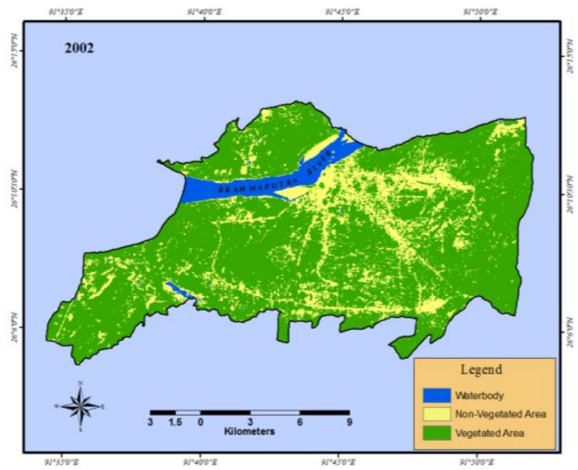

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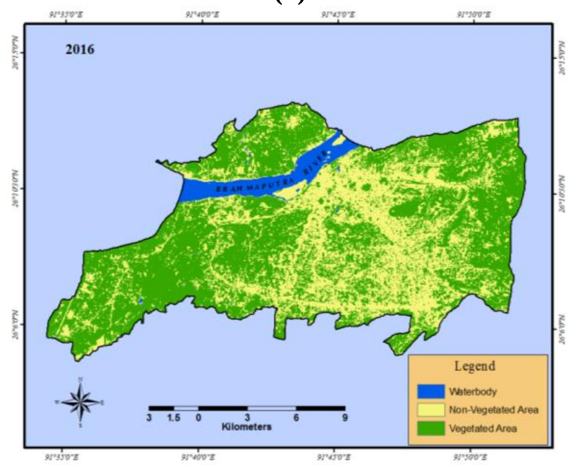

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Figure 3. Reclassified land cover maps for (a) 1990, (b) 2002 and (c) 2016

4.3 Percentage of Green Analysis

The percentage of green maps for the three time periods 1990, 2002 and 2016 are summarized in Fig 5. The derived statics shows that Guwahati had considerable amount of moderate quality green covering 37.7% of the whole area in 1990. The percentage of low quality green over the years has increased from 48.2% in 1990 to 53.3% in 2016 (Table 3). The rate of change in low quality green is insignificant when compared to the growth of non-vegetated area and deterioration of moderate quality green during the study period. The non-vegetated area occupied only one-tenth of the total study area in 1990 which later expanded to become the second largest dominant land cover by 2016. It was reported that between 1976 and 2015 built-up land increased by 9119 ha in Guwahati (Pawe, 2017b). The percentage of high and very high quality green was significantly low and they included the vegetations found in areas near and around the water bodies, the demarcated reserve forests and the aquatic vegetation in the wetlands.

Table 3. Area under various classes of percentage of green

Classes	1990 Area	2002 Area	2016 Area
Water body	1.36	0.99	0.55
Non-vegetated area	26.20	48.43	95.74
Low quality green (<25%)	124.6	133.5	137.94
Moderate quality (25-50%)	97.42	67.73	17.48
High quality green (50-75%)	7.98	7.05	6.23
Very high quality green (>75%)	0.88	0.70	0.49

Area in sq.kms

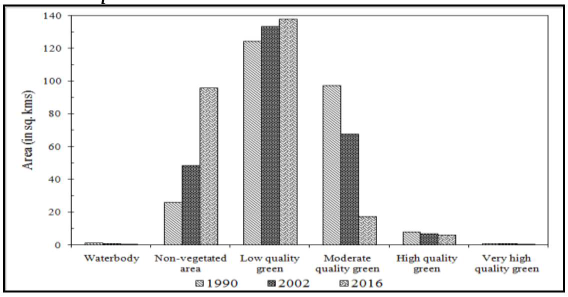
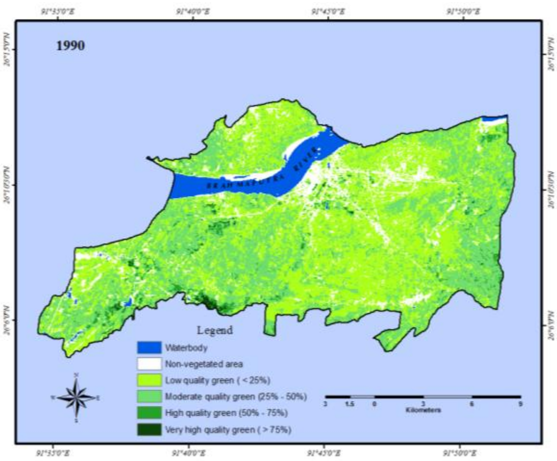


Figure 4. The spatial extension of different percentage of green classes

The graph (Figure 4) depicting the trend of change in non-vegetated area and moderate quality green demonstrated a similar positive and negative growth pattern. This illustrated that the increase in non-vegetated area has been compensated by the decrease in moderate quality green and also the conversion of moderate quality green to low quality green. A spatial analysis of the percentage of green maps exhibited that between 1990 and 2002 non-vegetated class emerged in areas along the National Highway 27, the Lalmati area, the Basistha, the Ganeshguri area, the Gorchuk and Dharapur area. However, during 2002-2016 period there was significant growth of non-vegetated area which chiefly took place in the vast expanses of plain areas towards the south of Narakasur hill and around the Sonaighuli hill. These areas included the localities like Sarusajai, Hatigaon, Dakhin gaon, Teteliya, Kahikuchi, bakarapara, Fatasil, Saukuchi etc.



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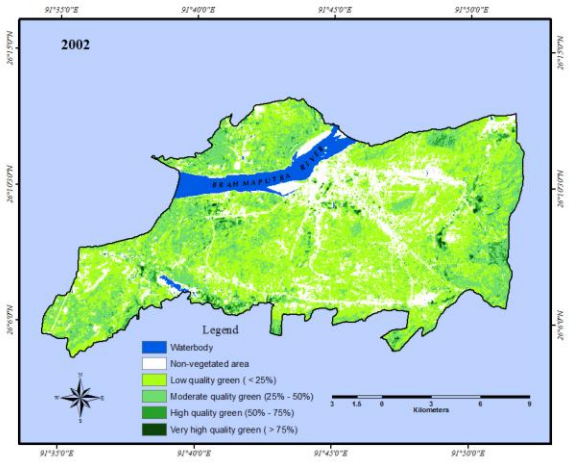

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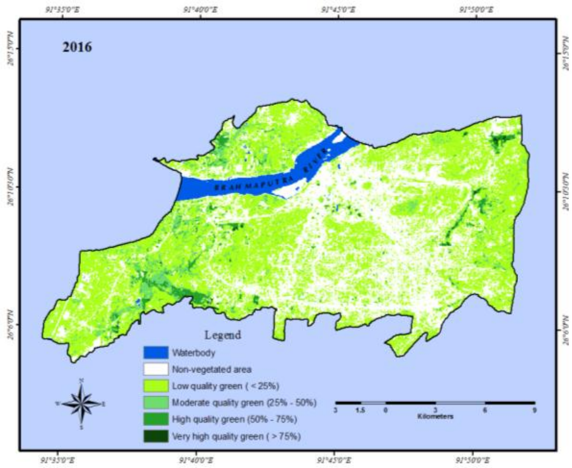

(c)

Figure 5. Percentage of green for the three periods (a) 1990, (b) 2002 and (c) 2016

5. Conclusion

The present study employed NDVI analysis to understand the health of vegetation in Guwahati city. It classified the NDVI images into vegetated and non-vegetated areas to quantitatively record the trend of change in the vegetation cover and growth of non-vegetated area during the study period. Lastly, it classified the percentages of green in each cell into four classes to characterize the quality of green in the study area. The results showed that the health of vegetation over the years has diminished. Although the maximum NDVI value for 2016 was high, it was because of the presence of dense aquatic vegetation over the Deepor beel wetland. The over all deterioration of vegetation health questions the applicability our green policies and their effective implementation. Even though the growth of non-vegetated area is obvious, given Guwahati city is recognized as the hub of Northeast India, the intensity of loss of vegetated area is a growing concern for the general public and administration. The city requires a combine effort of public and governmental organizations towards the protection of environment. A strict law for the protection of reserve forest, wetlands and city hills needs to be in place to restrict further encroachment of human settlements in to these areas. The results of percentage of green analysis depicted a poor picture of the quality of vegetation in the study area. The quantity of high and very high quality green is very low but the increasing trend of low quality green is noteworthy. Spatially, the low quality green has been distributed all over the study area while moderate, high and very high quality green are concentrated to some specific pockets like the reserve forests, wetlands and city hills. Therefore, it is necessary to identify such pockets and areas of low and high quality green and accordingly initiate large scale plantation drive.

The study explored the applicability of Remote sensing data and GIS in UGS studies. However, use of high resolution data could help in better planning and monitoring of UGS and also in effective implementation of green policies. Presently, Guwahati is under tremendous pressure from rapid urbanization process which is posing serious threat to the natural vegetation in and around the city. Thus, an effective, rigid and working environmental plan is very much important at the grass root level.

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