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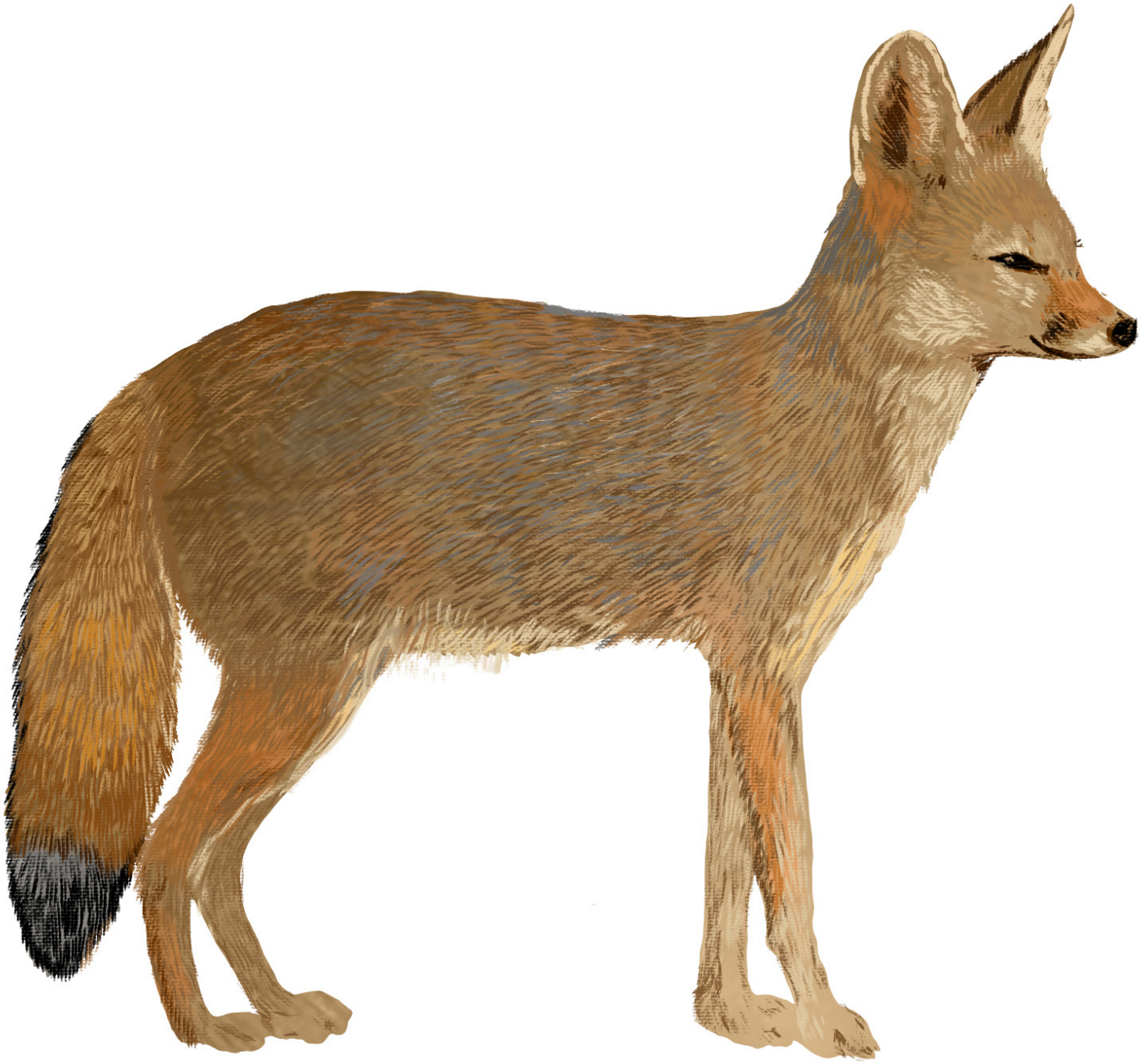

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ARTICLE

Tree community structure of selected green patches of Guwahati, Assam, India with special reference to spatio-temporal changes in vegetation

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Abstract: Green spaces are key aspects of urban ecology. The current study aims to estimate temporal changes in green spaces of Guwahati Metropolitan Development Authority, and also to investigate the tree community structure of three selected green patches. Change detection analysis of identified green spaces was done by comparing the normalized difference vegetation index (NDVI) maps of satellite images from 2022 with those from 1972. NDVI maps were classified into three threshold categories: no vegetation (NV), moderate vegetation (MV), and high vegetation (HV). The results show changes in the area of selected green patches as well as NV, MV, and HV regions between 1972 and 2022. The tree community structure in the three selected patches indicates a low diversity of plant species. The result of the current study prioritizes patch-wise management of urban green spaces in Guwahati city with the help of both remotely sensed and ground data. Thus, the present study can significantly contribute to plant community conservation and management of urban green spaces.

Keywords: Green spaces, GMDA, NDVI, QGIS, plant community, satellite images, urban ecology.

Abbreviations: Girth at breast height (GBH)—measurement of the circumference of a tree trunk at 4.5 ft (1.4 m) above ground level | Importance value index (IVI)—the measure of how dominant a species is in a given ecosystem | Normalized difference vegetation index (NDVI)—quantification of vegetation cover by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs) reflection in images.

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Author contributions: Conceptualised by Kuladip Sarma; Material preparation, data collection, draft preparation by Maitreyee Goswami and analysis done by Kuladip Sarma and Maitreyee Goswami. The final draft of the manuscript was written by Maitreyee Goswami and was read and approved by all the authors.

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INTRODUCTION

Less than 3% of the earth's surface is covered by cities (Schneider et al. 2010), which are often located in regions rich in biodiversity. Rapid urbanisation is considered to be a major cause of declining natural habitats and resources, posing serious threats to many plant and animal species, and the expansion of cities in size and density (Turrini & Knop 2015) in some developing countries (Seto et al. 2012) has contributed to a particularly high rate of urbanization in southeastern Asia (Cohen 2006; UNDESA 2012). A potential measure of the impacts of urbanization can be made by identifying urban green spaces that are maintained and conserved. As urban green spaces by its definition are inclusive of all the public and private open spaces, primarily covered by vegetation (Tuzin et al. 2002), it can be an effective interdisciplinary approach towards sustainable development and encompass environmental, economic, social, and psychological values. They also act as protected areas for the breeding of various animal species and the conservation of plants, soil, and water quality (Haq 2011). Although urban areas are known to have a lesser number of native species (Emlen 1974; Rebele 1994) as compared to natural habitats, urban green spaces house a number of different species and also act as dispersal corridors (Bolger 2001). Quality urban green spaces in higher numbers can also be a refuge habitat for a numbers of forest-dwelling species (Mortberg & Wallentinus 2000; Park & Lee 2000).

The study of urban green spaces in India is limited. A few papers are available (Birkmann et al. 2016; Pawe & Saikia 2018) on population aspects and forest cover change. In the global context, urban landscapes are being studied for various aspects including the conservation importance of green spaces (Bolund & Hunhammar 1999; Baycan-Levent & Nijkamp 2004; Tian et al. 2011; Jennings et al. 2016). The nature of urban green spaces has been evaluated by certain criteria viz. their quantity in a particular city (Oguz 2000), their existing qualities like activities and experiences, and their benefits as perceived by users (Van Herzele & Wiedemann 2003), and their services determined by location, distribution, and accessibility (Grahn & Stigsdotter 2003; van Herzele & Wiedemann 2003; Neuvonen et al. 2007). Different methodologies have been used to study the urban green spaces and the plant communities within them such as random stratified sampling (Nowak et al. 2008), GBH and NDVI calculation (Nero et al. 2017), analytic hierarchy process (AHP) modeling and use of GIS (De Ridder 2004; Sharma et al. 2022).

Owing to various consequences of urban sprawl, green spaces are at risk of vast changes and degradation, which will ultimately affect urban wildlife and human residents. In India, nearly half of the 100 million new urban residents are expected to occupy the secondary or mid-sized cities including the cities of northeastern India (Birkmann et al. 2016). Guwahati is one such secondary city that is likely to experience population outbursts in a few decades. Guwahati, like many other Indian cities, faces problems of unplanned land use land cover (LULC) change due to negligible or even non-existent planning efforts added by the rapid urban population growth (Pawe & Saikia 2018).

With this background, this study aims to determine the temporal changes in the urban green spaces within the boundary of GMDA and also to detect the changes in three selected green patches between 1972 and 2022 in terms of area with the help of remote sensing (RS) and geographic information system (GIS), which shall shed light on the impact of urbanization on urban green spaces. The plant community structure of three selected urban green patches of Guwahati has also been studied to emphasize the importance of urban green spaces in the conservation of wildlife.

MATERIALS AND METHODS

Study Area

Guwahati city, situated on the southern bank of the Brahmaputra River, is the biggest and one of the most important cities in northeastern India. It falls under the jurisdiction of the Guwahati Metropolitan Development Authority (GMDA). The GMDA boundary currently covers an area of 262 km^2. As per the report, the area is scattered with a great number of hills that are mostly covered with forests and some exposed rocky surfaces.

The selected sites for studying tree community structure include three urban green spaces within Guwahati city (Figure 1), viz., patch 1 (P1) with Navagraha Hill at its entrance, patch 2 (P2) at the entry point of Kamakhya Temple and patch 3 (P3) including the area around Basistha Temple. The first patch is at the Navagraha Hill, also known as the Chitrachal Hill and is located at the southeastern part of the Guwahati city in Assam. It is known for the Navagraha Temple located at its top. The second patch which is at the entrance to the world famous Kamakhya Temple, is located at the Nilachal Hill in the western part of Guwahati. Basistha, where the third patch has been designated, is located at the south-east corner of Guwahati and it stands at

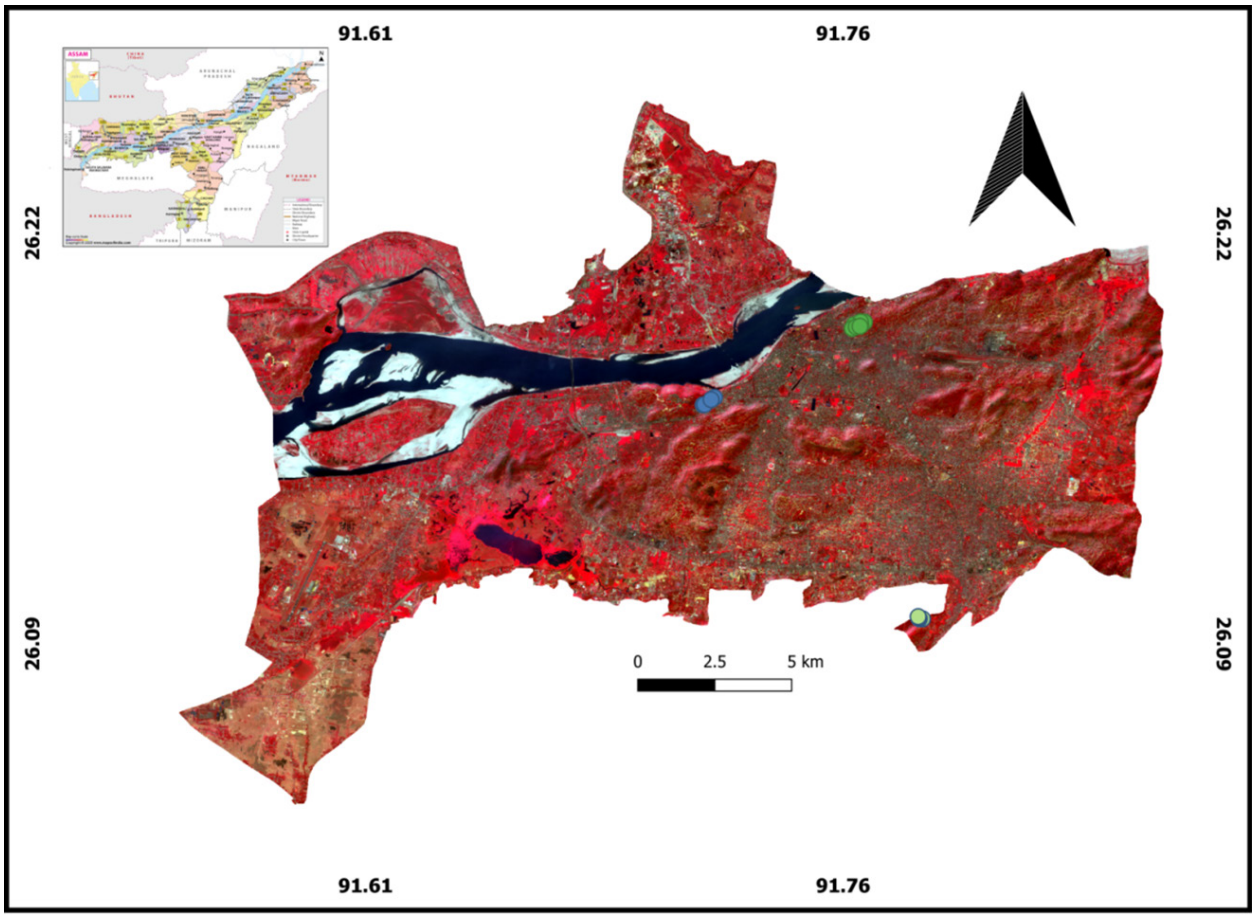

Figure 1. Map of GMDA area in 2022 showing the study sites with the dark green dots indicating patch 1, blue dots indicating patch 2, and light green dots indicating patch 3.

the bank of the mountain streams coming from the Meghalaya Hills, which ultimately form the rivers Basistha and Bahini or Bharalu flowing through Guwahati. These particular study sites were selected as they are some of the extant green patches within Guwahati city which are also easily accessible. Moreover, all of the selected sites are having an area greater than 1 ha in order to be considered as green patches for this specific study.

Methods

Acquisition of Satellite Images and Identification of Green Spaces using normalized difference vegetation index (NDVI)

Satellite imagery of 1972 (Landsat MSS) and 2022 (Sentinel) were downloaded from the websites of United States Geological Survey (USGS; https://www.usgs.gov) and Copernicus (Table 1). The band designation for Landsat MSS satellite image is – Band 4: Red spectral range; Band 5: NIR spectral range. Similarly, the band information for Sentinel satellite image is- band 4: red spectral range; band5, 6 and 7: vegetation red edge spectral range and band 8: NIR spectral range. The NDVI values were calculated for the downloaded satellite images using the following formula-

NDVI = (NIR - Red) / (NIR + Red)

After calculating the NDVI values, the NDVI maps for the years 1972 and 2022 were prepared. The urban green spaces in and around Guwahati were identified from this final map and the study sites were selected.

Table 1. Data acquisition details

Satellite	Sensor	Spatial resolution	Acquisition date	File format	Source
Landsat2	MSS	80	22.xi.1972	Geotiff	USGS
Sentinel-2	A	10	18.iv.2022	Geotiff	Coppernicus

Tree community structure of three selected green patches

Three green patches were selected from the NDVI map of 1972 and these are – Navagraha or Chitrachal Hill, Nilachal Hill, and Basistha Hill. Different numbers

of quadrats of 10 x 10 m were randomly placed in each patch. A total of 16 quadrats of size 10 x 10 m were placed in all the three patches. Eight quadrats were taken for P1, four quadrats were drawn in P2 and four quadrats placed in P3. A fiber measuring tape of 15 m was used to lay the random quadrats and also to calculate the GBH of plants. The coordinates of the quadrats were recorded using a handheld Garmin etrex 30x GPS device.

Mapping of selected study sites and calculation of their area Using QGIS

Estimation of change in the geometric area of the three selected patches, viz., P1, P2, and P3 was done between the years 1972 and 2022 in QGIS platform. The selected green patches and their temporal changes over the years in terms of area were then made into maps.

Reclassification of the NDVI maps and detection of temporal change of the classified zones between 1972 and 2022

The NDVI maps for 1972 and 2022 were reclassified into three major zones, viz., no vegetation (NV), moderate vegetation (MV) and high vegetation (HV) zones based on their NDVI values (Figure 2). The range of NDVI values for the three zones are 0–0.2, 0.2–0.4, and >0.4 for NV, MV, and HV zones, respectively. The change in total area covered by each of these three zones was calculated using Q-GIS.

Data analysis

The data collected on trees in every quadrat were then analyzed for determining their density, frequency, basal area, relative frequency, relative density, relative dominance, importance value Index (IVI), and Shannon-Weiner index of species diversity. A diversity dominance curve was plotted for the three urban green patches comparing their species diversities (Figure 5).

RESULTS

Identification of urban green spaces of Guwahati City and the estimation of area change in the three selected urban green patches

The NDVI maps of 1972 and 2022 (Figures 3, 4) show all the green spaces within the boundary of GMDA. These maps show around 20 urban green spaces in and around Guwahati city. When compared, the satellite image of 2022 shows reduction and fragmentation in the urban green spaces of Guwahati from 1972 (Figure 4). The area of the selected study sites in 1972 were approximately 1593.95 ha, 253.68 ha, and 85.81 ha for P1, P2, and P3, respectively; while the same in 2022 are approximately 233.36 ha, 220.36 ha, and 92.78 ha, respectively. P1 and P2 show decrease in their area over the span of 50 years and the differences in their area between 1972 and 2022 are 1360.59 ha for P1 and 33.32 ha for P2. Contrarily, P3 shows an increase in area of about 6.97 ha within the given time period (Table 2).

Table 2. Change in area (1972–2022), number of plant species, and diversity indices of three selected urban green patches of Guwahati City, Assam, India

	Patch ID	Change of area in hectare (1972–2022)	Number of plant species	SWI for plant diversity
1	P1	1360.59	14	2.43
2	P2	33.32	6	1.68
3	P3	-6.97	4	1.29

Table 3a. Tree community parameters of selected patch 1 of GMDA, Assam

Name	Density/m²	Frequency	Basal area (m²)	IVI
Albizia procera	0.125	12.5	0.29	14.62
Bombax ceiba	0.25	12.5	0.19	17.56
Musa sp.	0.125	12.5	0.09	11.78
Cocos nucifera	0.125	12.5	0.09	11.85
Mangifera indica	0.125	12.5	0.02	10.88
Artocarpus heterophyllus	0.125	12.5	0.05	11.23
Melia azedarach	0.125	12.5	0.18	13.05
Tectona grandis	0.125	12.5	0.88	22.63
Syzygium cumini	0.125	12.5	0.62	19.09
Albizia saman	0.5	37.5	2.73	73.62
Unknown sp. 1	0.125	12.5	0.10	11.94
Sterculia sp.	0.75	12.5	0.60	40.51
Unknown sp. 3	0.125	12.5	1.04	24.90
Unknown sp. 4	0.125	12.5	0.42	16.32
Total			7.29	

Study of the plant communities of the selected urban green patches

For the first green patch P1 (Table 3a), it has been found that *Albizia saman* is the most frequent species, while *Sterculia* sp. has the highest density of all. Eleven species out of 14 having the same density were each present in one number in the eight quadrats laid in patch 1. *Albizia saman* and *Mangifera indica* occupies the highest and the lowest basal area in the study site,

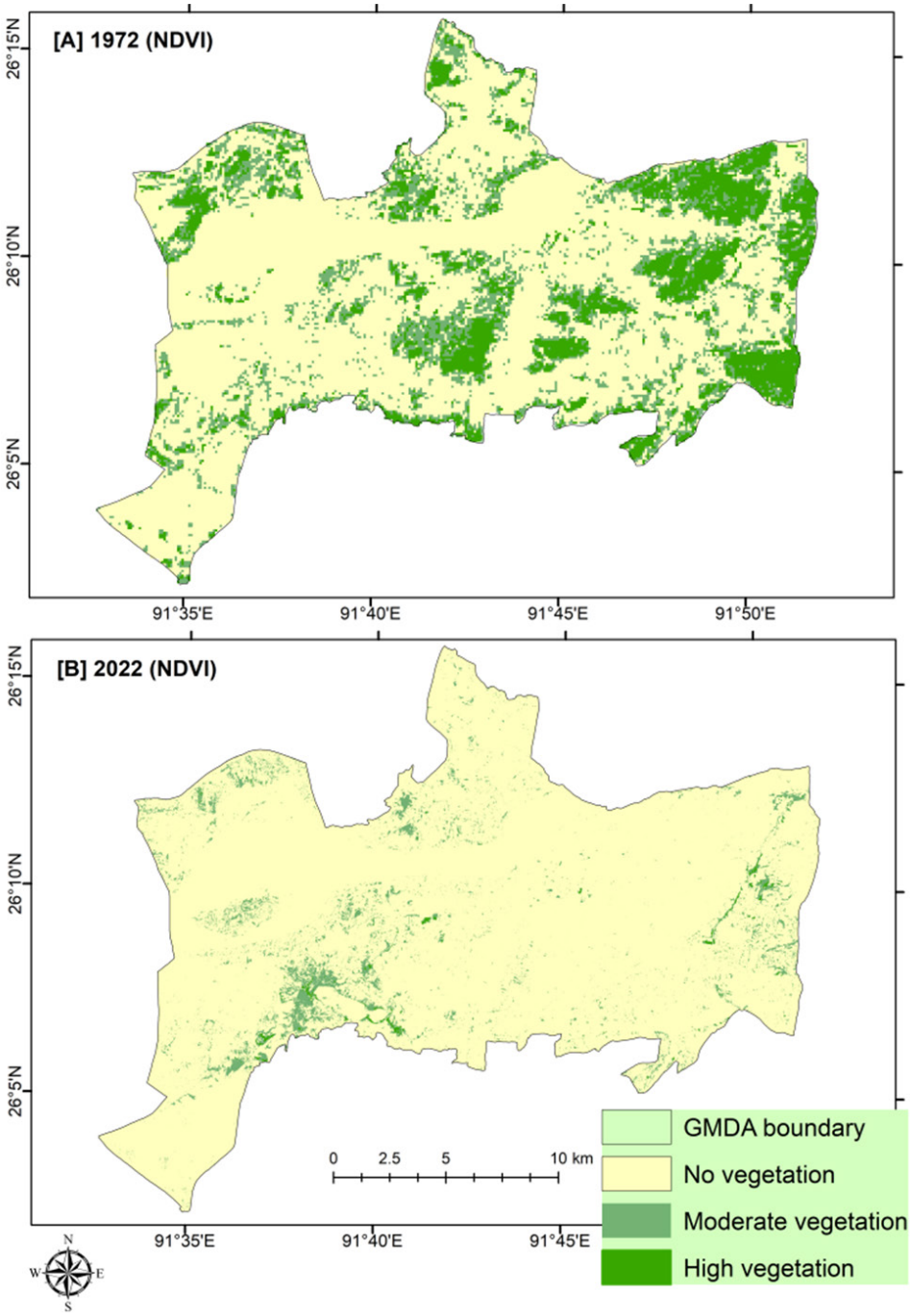

Figure 2. NDVI-based reclassified zones, i.e., No Vegetation, Moderate Vegetation, and High Vegetation zones.

respectively, with *Albizia saman* showing the highest IVI value. The species diversity as calculated by Shannon-Weiner index is found to be 2.43.

In the second urban green space P2 (Table 3b), *Delonix regia* and *Albizia procera* have the highest frequency and density, respectively. All the remaining five species have the same frequency, whereas *Albizia saman* and *Shorea robusta* exhibit the lowest density of 0.25. The basal area as well as the IVI is largest for *Delonix regia*. The Shannon-Weiner index for species diversity is 1.68 for the green patch under consideration.

In the third study site P3 (Table 3c), the highest and the lowest densities are shown by *Shorea robusta* and *Ficus religiosa* and the most frequent species is *Albizia procera* with a frequency of 75%. The basal area is greatest for *Shorea robusta* and so is the IVI. The

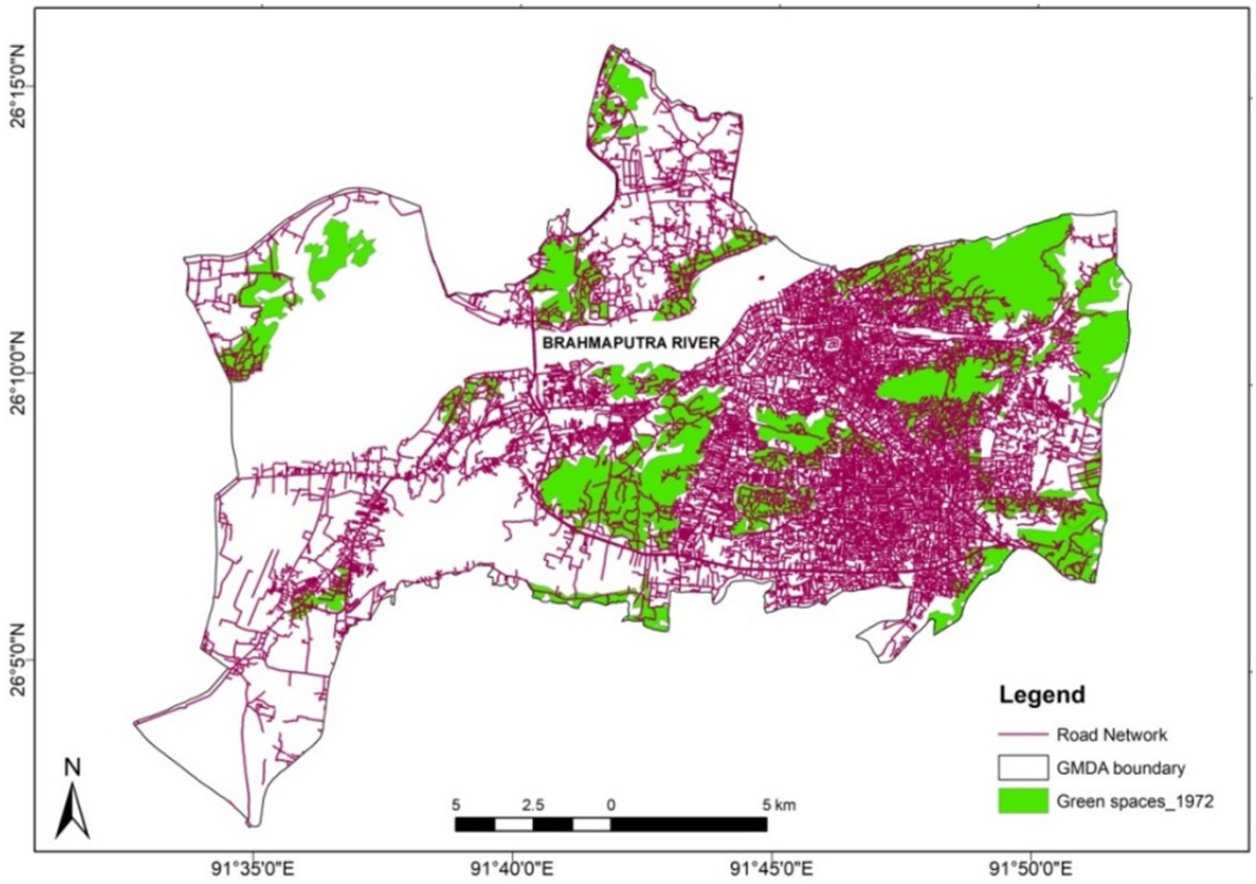

Figure 3. Identified green spaces within the GMDA area in the year 1972.

Table 3b. Tree community parameters of selected Patch 2 of GMDA, Assam.

Name	Density/ m^2	Frequency	Basal area (m^2)	IVI
Delonix regia	0.75	50	1.75	89.26
Albizia saman	0.25	25	0.82	40.05
Shorea robusta	0.25	25	0.19	25.46
Magnolia champaca	0.5	25	0.10	29.94
Plumeria sp.	0.5	25	0.43	37.60
Albizia procera	1.5	25	1.01	77.69
Total			4.29	

Table 3c. Tree community parameters of selected Patch 3 of GMDA, Assam.

Name	Density/ m^2	Frequency	Basal area (m^2)	IVI
Albizia procera	1	75	0.55	82.56
Tectona grandis	0.5	25	0.36	36.40
Ficus religiosa	0.25	25	1.34	56.06
Shorea robusta	2.25	50	1.51	124.98
Total			3.77	

Shannon-Weiner index is 1.29 for the area.

From the above data, a diversity dominance curve is plotted comparing the species richness and abundance of the selected sites having species rank on the X-axis and IVI value on the Y-axis (Figure 5), indicating that P1 has the greatest and P3 has the lowest plant diversity in terms of species richness and abundance.

Temporal change detection from NDVI map between 1972–2022

The three zones, viz., No Vegetation (NV), Moderate Vegetation (MV), and High Vegetation (HV), into which the green spaces of Guwahati have been classified based on their NDVI values, show drastic changes over the last 50 years from 1972 to 2022 (Figure 6). The % area of each of the three classes or zones for 1972 and 2022 respectively are shown in the table given below (Table 4).

Table 4. shows an increase (in %) of 26.75 in the NV zone in the year 2022 from 1972, whereas MV and HV zones show sharp decrease (in %) of 12.09 and 14.66, respectively, from 1972 to 2022. The NV zone has

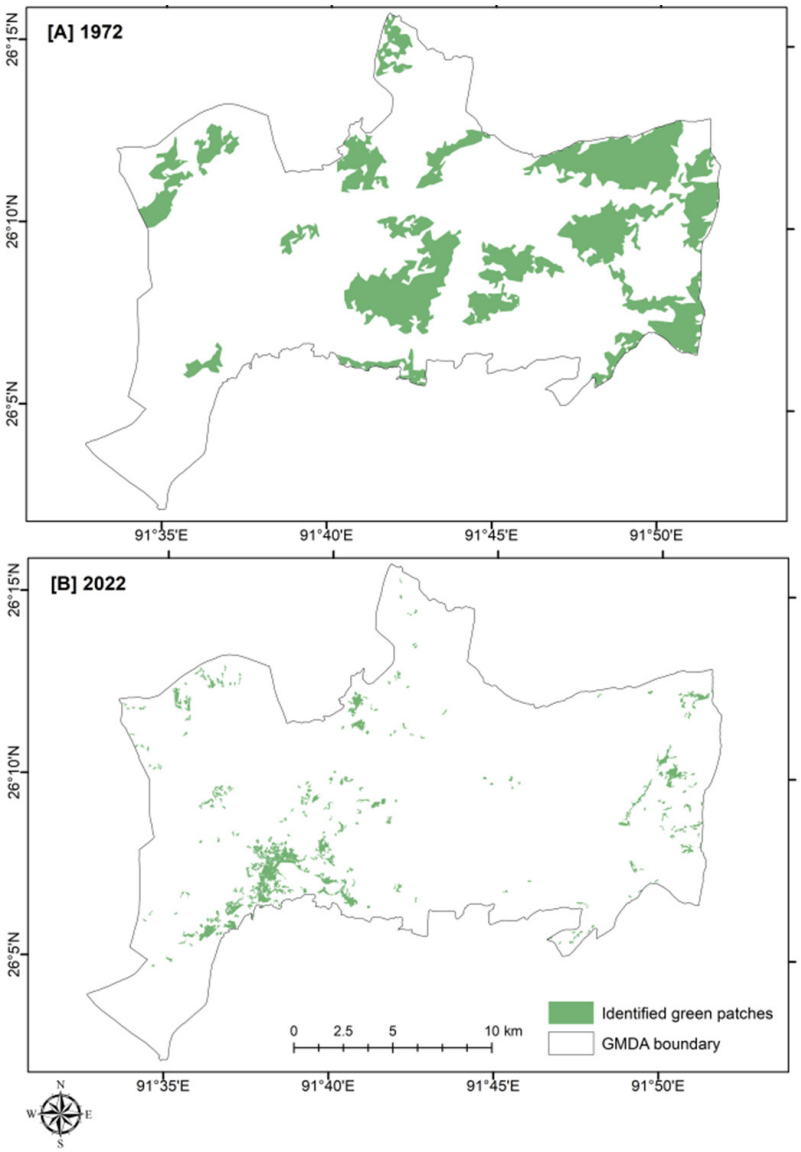

Figure 4. Comparison of the identified green spaces within GMDA between the years 1972 [A] and 2022 [B].

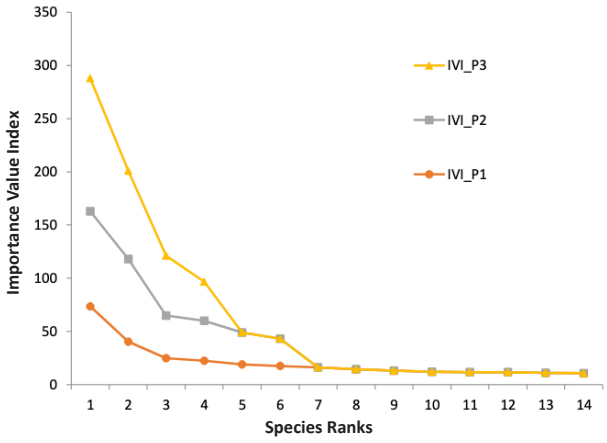

Figure 5. Diversity Dominance Curve of the plant communities of the Study Sites, where P1, P2 and P3 are Patch 1, Patch 2 and Patch 3.

remained the same throughout those 50 years whereas, the HV and MV zones have mostly been converted to NV zone directly (Table 5).

DISCUSSION

The area changes of the urban green spaces of Guwahati including the selected study sites are a clear indication that the urban green spaces are facing depletion due to various reasons, among which the primary reason can be attributed to anthropogenic activities. The increase in the total area of the no vegetation zone and the subsequent decrease in the areas covered by moderate and high vegetation zones

(Figure 6) suggest the expansion of human settlements and built-up areas and the subsequent decline of vegetated areas or green spaces. The dynamics of the changes in the three zones are as such that the NV zone has not changed from 1972 to 2022, but the HV and the MV zones have changed directly into NV Zone and only a small fraction (2.62%) of HV zone has been converted to MV zone. The increasing establishment of human settlements has brought about the fragmentation of urban green spaces and has led to a reduction in the total area occupied by these green spaces in Guwahati. With the influx of people into the city from various other parts of Assam as well as from different corners of the country, the relatively uninhabited green spaces are being occupied at a much faster rate. This can negatively affect the biotic communities within the green spaces and can also interfere with the role of urban green spaces in biodiversity conservation. A similar type of observation has been made in a study by Sangwan et al. (2022), which mentions the challenges faced by

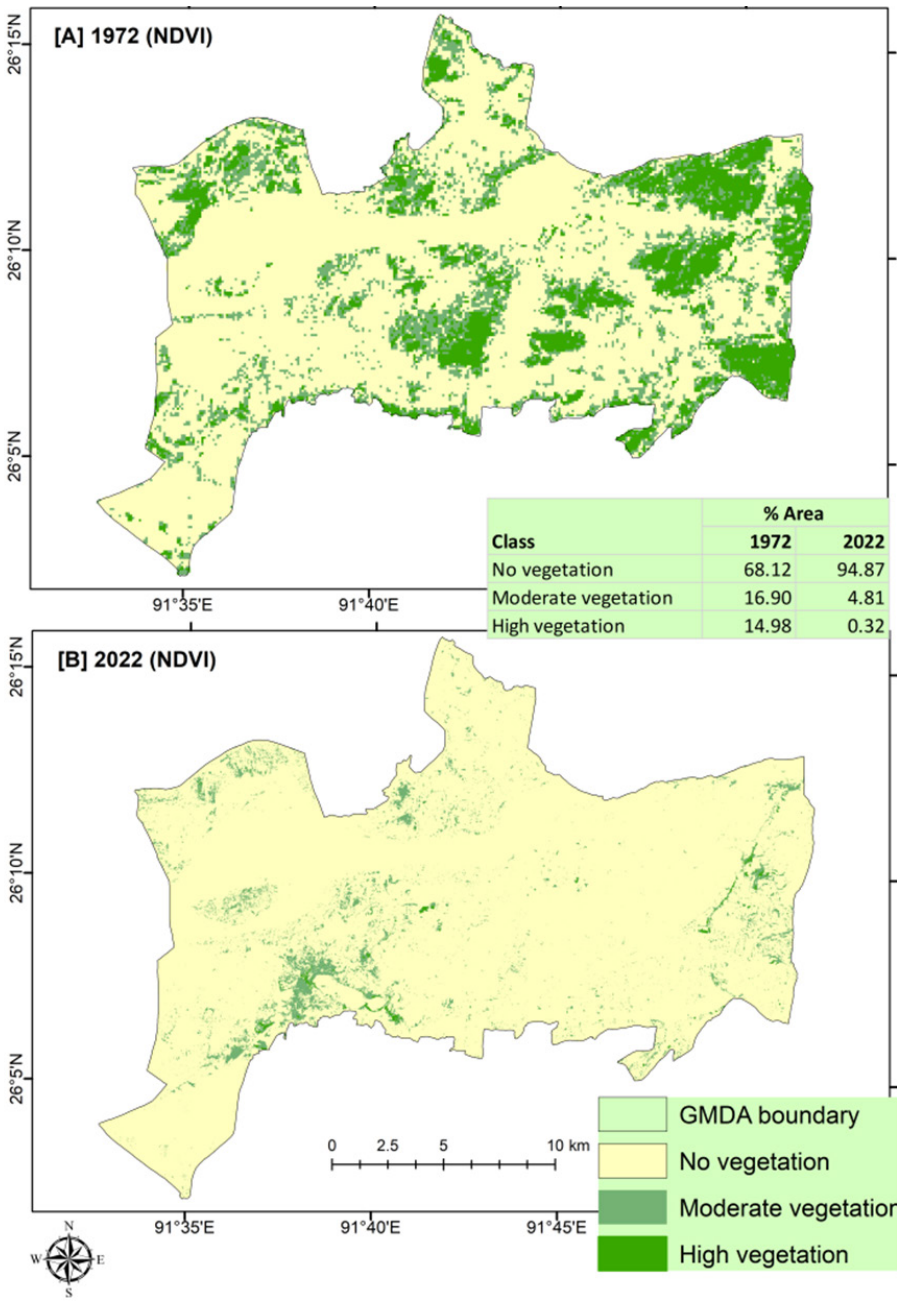

Figure 6. Comparison of the % change in the area of the three NDVI zones between 1972 [A] and 2022 [B].

Table 4. Area statistics of the green patches between 1972 and 2022.

Class/Zones	% Area	
	1972	2022
No vegetation	68.12	94.87
Moderate vegetation	16.90	4.81
High vegetation	14.98	0.32

Table 5. Change detection matrix of three vegetation classes in the study area between 1972 to 2022.

Class name		2022 (Area in %)			
		No vegetation	Moderate vegetation	High vegetation	Total
1972	No vegetation	68.12			68.12
	Moderate vegetation	14.61	2.19	0.1	16.9
	High vegetation	12.14	2.62	0.22	14.98
	Total	94.87	4.81	0.32	100.00

the urban green spaces of many Indian cities due to competing economic interests and demand on land for various purposes such as residential, commercial, industrial and institutional. In a case study of Noida (Sharma et al. 2022), it has been noticed that the green spaces are isolated and fragmented limiting the additive benefits that can be derived from larger interconnected green spaces. Nevertheless, they are an integral component of urban ecosystems harbouring a wide array of animal and plant communities.

As a whole, the species richness of plants was found to be higher in the urban green spaces as compared to urban built-up areas which may be due to the presence of a variety of microhabitats and greater resource availability in the green spaces (Nielsen et al. 2013). According to the diversity-dominance curve (Figure 5) that was plotted for the plant communities of the green patches, species evenness is more in P1, as all the species are relatively equally abundant than in the other two sites where one species is much more abundant as compared to the other species of that particular area. A greater biodiversity of an area indicates more productivity and hence greater availability of resources leading to a healthy and stable ecosystem that can provide various ecosystem services. Thus, urban green spaces are very much necessary for the maintenance of urban ecosystems. Moreover, they have an undeniable impact on the health and well-being of humans, encouraging human positive emotions (Cameron et al. 2020); and master planning is required to keep these green spaces intact (Nora et al. 2017).

CONCLUSION

Urban green spaces—open areas within cities covered with vegetation—are an important aspect of urban ecology, and due to rapid urban sprawl, they are changing. This study shows that these changes can be detected and determined with the help of remote sensing (RS) and GIS software by highlighting the changes occurring in green patches within Guwahati City. Using satellite imagery, it was shown that most of the green spaces are undergoing degradation and fragmentation. These green spaces also play an important role in preserving the biodiversity of urban areas. In the current study, observations have been made regarding the plant communities of selected green patches with the help of random quadrate sampling. The diversity dominance curve for the plant communities of the study sites is included in comparing the plant diversity among the selected green patches. The challenges faced by these green spaces within the city should be addressed properly through appropriate planning in order to maintain the overall well-being of the urban ecosystem as well as the city dwellers.

There is scope for more work that can be done on the urban green spaces of Guwahati which can shed light on the condition of the extant green spaces and can highlight their importance. The study of the plant communities can be performed more comprehensively. These data would help in the formulation of plans to improve and protect the green spaces in the city of Guwahati.

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