

# Chapter 6

## ‘Green Placemaking’ in Kolkata: Role of Urban Greens and Urban Forestry



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**Abstract** Widespread urbanisation has depleted green cover increasing vulnerability to climate change, especially in the developing countries with India being no exception. While a handful of cities have been able to come up with integrated urban greenery provisions; the megalopolis of Kolkata having rich colonial legacy have failed to hold on to its green spaces due to rampant urbanisation waves. Urban greens and urban forestry are probable ways to bridge the gap between city dwellers and their much-needed greenery, which has now been actively taken up by the governmental agencies. But urban greenery development relies largely on the attitude and involvement of urban residents. The apt species selection for plantation in the heavily built-up milieu is lacking in the city. Kolkata is trying hard to have its desired share of man-made urban forest through the sprawling greens of over 7 acres, in New Town Rajarhat-east Kolkata, mirroring the centralised ‘Nagar Van’ scheme. This paper attempts to describe the global, national urban green scenario and specifically concentrates on Kolkata’s Urban Green Spaces (UGS) through preparation of tree-inventory, analytical study of spatio-temporal changing green cover with the help of land use and land cover (LULC), Normalized Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) analysis from LANDSAT imageries. The indices clearly show the declining trend of the green cover (1980–2020), and the regression analysis of NDVI and land surface temperature (LST) shows a strong negative correlation. After investigating the loopholes in arboricultural practices,

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zones for peri-urban forest development have been chalked out. The perception studies of urban dwellers about the diverse role of urban forestry bring out that the residents are aware of the dire need to protect the green and have been taking part in developing the green spaces in the city.

**Keywords** Green cover · Species selection · Urban Green Spaces (UGS) · Urban forestry · Arboricultural practices

## 6.1 Introduction

In the era of global climate change and rapid urbanisation, innovations in the urban system are a critical requirement for tackling the serious environmental challenges it is facing. It is foreseeable that almost two thirds of the world's population will live in the urban areas by 2025 (Schell and Ulijaszek 1999). In the developed countries, presently, most of the population dwells in the cities, like more than 80% of the USA (Wolf 1998) and about 85% of Australia (Brack 2002) are urbanised. On the other hand, in the developing countries, about 44% of the population currently resides in urban areas and is likely to increase sharply over a span of a decade (UN-Habitat 2009; Montgomery 2008). Rapid urbanisation in India has brought complex changes to ecology, economy and society (DeFries and Pandey 2010). Urban greenery and forestry are one of the possible ways to bridge the gap between the people and their environment. Numerous policy instruments over the past two decades have stressed the critical requirement of the green zones within the urban socio-ecological systems to address several problems related to city living. Urbanisation, a human-induced process, refers to the gradual alteration in the land use/land cover (LULC) of a city, especially in the peri-urban areas which occurs due to the evolving societal priorities emphasising more on built-up segment (Maiti and Agrawal 2005). Pull migration creates immense pressure on urban land and housing, and the availability of green space becomes scarcer for the urbanites (Ministry of Environment and Forest 2010). But in case of such rapid urbanisation, urban forestry, through mixed plantations, needs to play a vital role in the urban renewal programmes. Importance of urban vegetation and forest has been harped by many, but most of the forest managers do not have much idea about appropriate species selection, care and maintenance (Chacalo et al. 1994) and even lack the information about the streets to formulate holistic urban forestry plan (Jim and Chen 2008). Chaudhry et al. (2011) compared the urban forest scenario of Indian cities with that of the counterparts in Europe and America and highlighted the need of increased urban greenery in the Indian cities to bridge the gap. The authors suggested to follow the Chinese model where similar high population density has been negotiated while enhancing the urban greenery through formation of over hundred 'National Garden Cities' along with that of Singapore.

## 6.2 Previous Works

Konijnendijk (2008) noted that the idea of urban forestry was germinated long back in 1894. The most inclusive definition of urban forestry was provided by Grey & Deneke (1986) who defined that urban forestry is all about tree management involving woodlands, tree groups – parks and greenbelts, standalone trees along the streets and utility corridors, in the urban fringes and in every nook and corner of the city be it public or private land which ultimately contributes positively to the ecological, physiological and economic well-being of urban society. To make the concrete jungles habitable in the long run, the concept of urban forest seemed befitting for the developed countries. The trend was followed in the developing world too as urbanisation wave hit them; the potential of urban forest in generating livelihood options was also harnessed (Carter 1995). There is a contentious issue regarding the jurisdiction on which urban forestry is developed, i.e. the government initiated and community/private owned (Brendler and Carey 1998). Urban forestry was first theorised in North America during late 1960s (Miller 1988). Konijnendijk (2000) pointed out a very important distinction between classic and urban forestry – urban forestry has come up as a response to specific demands (social, environmental, aesthetic) of the local urban community, while traditional forestry is more focussed on the economic value generated through the timber and non-timber forest produces. In recent times there have been reinvigorated efforts by the government to create urban forestscape for ecological benefits leading to the development of 'eco-cities' (Hall 2002). leading to development of 'eco-cities'. to more accessible public-space greenery can be documented (Konijnendijk 2008) which has made urban parks representatives of 'social forest' where community and vegetation interact directly. Gerhold penned down the all-inclusive definition of urban forestry which highlights the importance and utilities of greenscape in urban societies. Urban forestry thus embraces the supervision of individual as well as groups of trees, and arboriculture is an important section of urban forestry (Krishnan 2007).

Urban trees provide both tangible and intangible benefits to the city dwellers (Table 6.1). Tangible benefits include food, fodder, fuel wood, etc. and parks, shades and shelter are the intangible benefits enjoyed by the city residents. As various scientific studies on urban green space stressed on the manifold benefits of green areas (Lyytimäki and Sipilä 2009), worldwide, there have been concerted efforts to set up parks and squares under the aegis of International Federation of Parks and Recreation Administration, World Urban Parks Initiative. Green infrastructure is indispensable for enhanced quality of urban life. The services rendered by urban forests are myriad – helps in pollution reduction, noise abatement, improvising micro-climate, providing local recreation, increasing real estate values, etc. (Jones et al. 2008). In 2006, the Food and Agricultural Organisation (FAO) threw light on how urban greens generate economic activities around them like amusement park-related small businesses, and another interesting aspect which also surfaced is that of food security involving urban forests and urban agriculture (Basu and Kar 2021). Preservation or creation of green spaces is important in urban areas for leisure or

**Table 6.1** Manifold benefits reaped from urban greenery

Parameters	Beneficial aspects
Ecological	Acts as source of oxygen, absorbs pollutants improving air quality (Brack 2002; Nowak et al. 2006)
	Plays important role in carbon sequestration through carbon storing (McPherson and Simpson 1999)
	Helps in lowering temperature, reducing urban heat island impact (Gill et al. 2007)
	Improves micro-urban climate in general (Vailshery et al. 2013)
	Preserves limited urban biodiversity (Attwell 2000)
	Reduces surface water runoff, flood control (Armson et al. 2013)
	Mitigates effects of climate change (Munang et al. 2013)
	Controls the noise impact in urban regions (Fang and Ling 2003)
Social	Provides refreshing contrast in the monotonous urban landscape creating aesthetic appeal (Attwell 2000)
	Acts as space for social interaction for people of different age groups like youngsters and elderlies (Konijnendijk et al. 2013)
	Encourages persuasion of cultural life through local festivals, fairs leading to social cohesion and boosting of local economy (Konijnendijk 2000)
	Helps refresh the health and minds of the urban dwellers through creation of recreation spaces reducing stress and anxiety and helping in general wellbeing (Maas et al. 2006)
Economic	Plays a vital role in alleviating poverty, advancing livelihoods and improving wellbeing for the marginalised poor people in developing countries by offering environmental services like grazing and fuelwood collection (Kuchelmeister and Braatz 2001).
	Helps in creating pricier residential units with neighbourhood parks where posh urban dwellers are eager to pay a fortune to live within or nearby urban greenery (Grinspan et al. 2020)
	Aids in reducing building air-conditioning load by keeping the surroundings cool through shady trees (Simpson 1998)
	Boosts the local economy with increased paid leisure visits to the parks generating urban leisure and tourism (Konijnendijk et al. 2013)
	Provides shelter to the roadside vendors under the shady trees (Bhattacharya and Nigam 2010)

Source: Compiled by authors, 2021

recreation purposes; it is also essential to maintain the biodiversity chain (Zaman et al. 2014). However, creating only isolated green pockets is not the actual purpose; to make the crowded cities truly sustainable, the UGS need to be systematically integrated with the urban landscape.

To maintain a minimum level of urban green spaces (UGS), there are several recommendations regarding standardised quantum of green space (20–40% of total area); most of the developed countries have adopted a policy of having 20 sq.km of green space per capita, while the World Health Organization (WHO) prescribed 9 sq. m of open green space for each inhabitant, so that all residents can have access to an open space within a walking distance of 15 min (Town and Country Planning

**Table 6.2** Estimates of urban green spaces in selected cities of India

City	Per capita green space (sq.m/inhabitant)
Gandhinagar	162.80
Varanasi	24.78
Nagpur	31.00
Allahabad	24.06
New Delhi	21.43
Chandigarh	54.45
Noida	16.49
Ahmedabad	3.90
Kanpur	3.76
Bengaluru	17.79
Amritsar	0.95
Chennai	1.03
Trivandrum	0.55
Jaipur	2.30
Hyderabad	0.50
Vishakhapatnam	0.18
Mumbai	2.01

Data Source: Govindarajulu 2014; Town and Country Planning Organisation 2014; Chaudhry 2016; and Imam and Banerjee 2016

Organisation 2014). Leadership in Energy and Environment Design Neighbourhood Development (LEED ND) went a step ahead to recommend a green cover of >20 sq. m per capita or to maintain a minimum of 1.25 ha of open space per 1000 residents to ensure that within a distance of 200 m of residential area, there is some sort of urban green space (Govindarajulu 2014). Konijnendijk (2001) carried out a survey on 26 large European cities which had an average 18.5% green coverage with per capita being around 104 sq.m. In case of Paris, France and Canberra, Australia Moigneu (2001) and Brack (2006) noted that per capita green space was around 80 sq.m. But for unprecedented urban growth with very high population density, it becomes difficult for the Indian cities to maintain a high urban green space percentage barring few to maintain the WHO prescribed norm (Table 6.2).

Few worth mentioning studies are on Bangalore (Nagendra and Gopal 2010), Chandigarh (Chaudhry and Tewari 2011) and Delhi (Khera et al. 2009). A comparative study by Chaudhry (2016) shows that Gandhinagar in Gujrat state has the maximum per capita green space.

At a regional scale, West Bengal too is facing the problem of rapid urbanisation and population rise. The urban population of the state rose from 27.8% in 2001 to 31.8% in 2011 (Census of India 2011a). This kind of urban population explosion has led to emergence of about 35 million-plus cities (Ministry of Housing and Urban Affairs 2011), several smaller cities and towns causing widespread depletion of green cover impacting biodiversity and climate in the long run. Foreseeing the rapid

rise in urban population, the government published the township policy emphasising sustainable, eco-friendly, resilient and affordable housing. Kolkata, like any other speedily growing metropolis in the country, is facing critical glitches of rapid urbanisation and, therefore, needs the enactment of a strategic regional planning (Kolkata Metropolitan Development Authority 2005). Mukherjee et al. (2018) while dealing with urban water scarcity scenario in Kolkata, highlighted the changing LULC of the city and emphasised on the uncontrolled urbanisation leading to decreasing green cover too. Apart from expansion of cities, other factors that contributed to the shrinking of green space are increasing population, reduction in residential gardens and kitchen gardens giving way to skyscrapers. This leads to concretized surroundings which ultimately snatches away the wee bit of urban green cover (Gangopadhyay and Balooni 2012). In case of Kolkata, the per capita green space is not readily available, but as per a World Bank study of 2011, the city had only 9.5% in the form of parks and open spaces. As per municipal records, there are 711 parks in total of varying sizes in the city. As per the study conducted by a research group from the Indian Institute of Science based on satellite imageries, it was derived that Kolkata including a 10 km buffer zone surrounding the city had a sharp declining tree cover from 33.6% in 1980 to 7.36% in 2010 and was predicted to become as low as 3.37% in 2030 (Padmanabhan 2016). Ramachandra et al. (2014) carried out a temporal LULC on Kolkata while modelling the urban structure and exposed a decline of vegetation from 33.6% in 1980 to 7.36% in 2010.

Mandal et al. (2019) studied the spatio-temporal land use/land cover changes (1991–2018) in the megacity of Kolkata and predicted the future urban growth trajectory. They emphasised the negative relationship between urbanisation and vegetation cover and expressed concern over further decreasing green cover as derived from prediction through CA-Markov chain model. Kundu et al. (2020) focused on urban change detection analysis at Kolkata (1978–2017) through usage of multi-temporal satellite data highlighting that at the expense of urban built-up area, other land use categories including vegetation suffered a setback. Rahman et al., 2019 Sahana et al., 2018 and Sahana et al., 2019 has assessed the landscape fragmentation and its relation with the urban green space in Kolkata Urban agglomeration. Mallick et al., 2021 explore the impact of future urban growth and its impact on the urban green space for a small city near Kolkata. The impact of roadside vegetation on air pollution in the megacity of Kolkata has been studied by Karmakar et al. (2021) and showed that increasing vehicular pollution had reciprocal correlation with species richness and species diversity highlighting the few selected tolerant species. Dinda et al. (2021) adopted an integrated simulation approach to predict the LULC dynamics of 2025 and 2035 and prior to that examined the loss in urban green space in Kolkata (1980–2018). The study projected a loss in urban vegetation of about (–)17.42% and (–)11.69% for the period of 2025–2035, respectively.

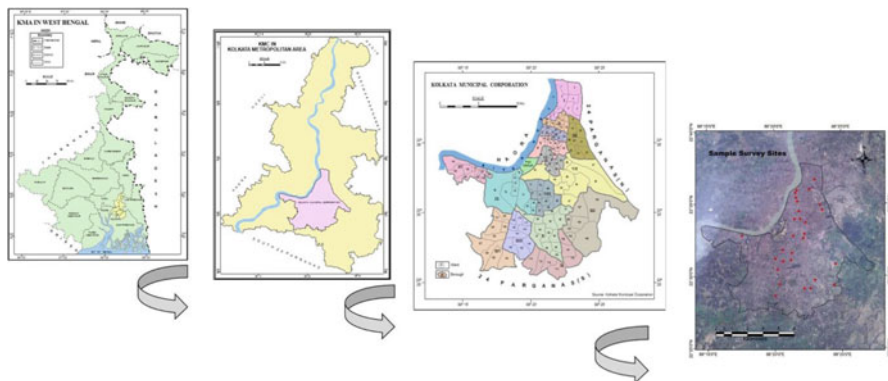
### 6.3 Rationale of the Study

From the above discussion, it is clear that there has been extensive research about UGS at global and national scale along with a handful studies on megacity of Kolkata identifying the gradual shrinkage of urban greenery. There have been a number of studies on the changing LULC and shrinking UGS of the city, but the novelty of the present study is that it is not limited to the use of geospatial techniques to inspect spatio-temporal LULC changes and declining vegetation health. The study attempts to address few lesser discussed aspects like calculation of person-park ratio, preparation of tree inventory and investigation of loopholes in arboricultural practices within the city limits. Besides, identification of suitable zones for peri-urban forest development and perception studies of urban dwellers about the diverse role of urban forestry adds to the holistic overview.

### 6.4 Study Area

Kolkata (formerly Calcutta), the city with rich colonial heritage, is tenth-largest urban agglomeration of the world, the largest metropolitan city of eastern India and the second highest populated one in the entire country. The study area encompasses the Kolkata Municipal Corporation (KMC), located at the eastern bank of the Hooghly river along with the satellite urban entities like Bidhannagar municipality and New Town, Rajarhat, situated in the lower deltaic plains of the Ganga-Bhagirathi-Hooghly river system. The region experiences tropical wet and dry climate [Aw as per Köppen's climatic classification system] (Maplecroft 2016).

KMC having an approximate area of 206.08 sq.km comprising of 144 wards (141 wards till August, 2016) grouped into 16 boroughs (previously 15), i.e. administrative units, is a part of the greater identity Kolkata Metropolitan Area having an area of 1887 sq.km (Fig. 6.1). It is one of the densest cities of the world with population density of 24,306 per sq.km (Census of India 2011b). With the increasing urbanisation, there has been overcrowding within city of joy and causing change in LULC and continuous environmental degradation. Keeping in mind the IUCN Aichi Biodiversity Targets, Paul and Bardhan (2017) felt that it was high time to benchmark the urban biodiversity of the city of Kolkata and carried out an index-based survey which revealed Kolkata being a 'Brown city in Green Background' having rich native biodiversity but facing random deforestation alongside introduction of exotic species due to high urban sprawl. This necessitates the need for a comprehensive urban land use planning giving due importance to create and sustain urban greenery.



**Fig. 6.1** Introducing the study area – Kolkata Municipal Corporation with ward boundary and sample survey sites

**Table 6.3** Details of satellite imageries taken into account

Satellite type	Sensor ID	Path/row	Date of capture	Spatial resolution (m)
Landsat_8	OLI_TRS	138/44	15/11/2020	30
Landsat_7	ETM (+)	138/44	17/11/2000	30
Landsat_3	MSS	148/44–45	14/11/1980	80

Source: USGS, 2020

## 6.5 Database and Methodology

This paper is based on secondary data collected from different literature sources, reports, etc. as well as on intensive field based primary observations. Both qualitative and quantitative data have been used for the analysis. Satellite images of over a period of time (1990, 2010 and 2020) have been collected for determining the evolving scenario of urban greenery in the study area. Three cloud free Landsat images of the month of November are selected and downloaded from the US Geological Survey (USGS) website for further processing (Table 6.3).

For the digital image processing of the satellite imagery, ArcGIS v10.3 has been used. To minimise the different errors of standard images from varied sensors, noise from different sources and lens distortions, etc., geometric and radiometric corrections were done, and in this case, after necessary atmospheric corrections and instrumental error removals, image enhancement techniques like histogram equalisation and contrast enhancement were carried out. Besides, the images were co-registered to match the overlay with sub-pixel accuracy; then for resampling, nearest neighbourhood technique were applied. The transformation error recorded was 0.45 pixel in all instances. On the basis of Survey of India, topographical sheets of 1:50,000 and municipal ward map of Kolkata Municipal Corporation, the study area was delineated, and a vector layer of the KMC region was used for clipping and subsetting.



**Table 6.4** Land use and land cover changes in Kolkata Municipal Area, West Bengal, India (1980 to 2020). Spatio-temporal land use/land cover statistics LST

Land use and land cover	1980		2000		2020	
	Sq.km.	%	Sq.km.	%	Sq.km.	%
Built-up	91.63	49	132.77	71	151.47	81
Water bodies	14.96	8	9.35	5	7.48	4
Vegetation	57.97	31	37.4	20	20.57	11
Open field and others	13.09	7	5.61	3	5.61	3
Bare land	9.35	5	1.87	1	1.87	1

Source: Computed by authors from satellite imageries of Landsat 3, Landsat 5 and Landsat 8 for 1980, 2000 and 2020, respectively

Then supervised classification of the desired area from the pre-processed images was done with the help of maximum likelihood algorithm on the basis of training sets (signature) assigned by the user on the basis of reflectance characteristics and corresponding ground truth verification.

The training data given by the user guides the software as to what types of pixels are to be selected for certain land cover type. The classification yielded the land use/land cover image of the area with five main classes, namely, built-up, water bodies, vegetation, open field and others and bare land (Table 6.4).

Table 6.4: Land use and land cover (LULC) classification schemes

Class name	Description
Built up	Residential areas, functional areas, utilities zones, industrial, roadways, railways, other built-up or urban land
Water bodies	Rivers, canals, lakes, ponds, reservoirs and wetlands
Vegetation	Mixed trees, scrublands, grasslands, urban agriculture
Open field and others	Permanent fallow land, unused land, landfill sites
Bare land	Barren land

Source: Classified by authors from satellite imageries of Landsat 3, Landsat 5 and Landsat 8 for 1980

Accuracy assessment has been done to ensure the performance quality of the classifiers. To assess the accuracy level of the classification, ground truth verification has been done with the help of handheld GNSS device (Garmin GPS Etrex-30) with a positional accuracy of 3 m through field surveys held in two phases and high-resolution Google Earth imagery of similar corresponding periods from Google Earth Pro. By using the random sampling method, a total of 200 points are selected from different LULC classes with a minimum 40 points from each class for each year, and then it is reviewed with Google images. Kappa coefficient ( $k$ ) [ $k = (P_o - P_e)/(1 - P_e)$ ] is used to measure inter- and intra-reliability for categorical entities (Cohen 1960), where the score varies from 0 to 1; the higher the value, the greater is the degree of agreement. Error matrix is computed to reflect the overall accuracy and the Kappa coefficient value for each year concerned.

To have an idea about the health of the urban greens, Normalized Difference Vegetation Index (NDVI) has been used, which has proved to be an efficient technique in vegetation change detection and derivation of canopy biophysical characteristics of a particular region. The NDVI is calculated as a ratio between measured reflectivity in the red and near-infrared portions of the electromagnetic spectrum. The NDVI transformation is computed as the ratio of the measured intensities in the red and near-infrared (NIR) spectral bands (ones most affected by the absorption of chlorophyll by the green plants).

$$\left( \text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}} \right)$$

The value of NDVI ranges from 0 to 1. A value closer to 1 represents healthy vegetation, and a value closer to 0 represents unhealthy vegetation.

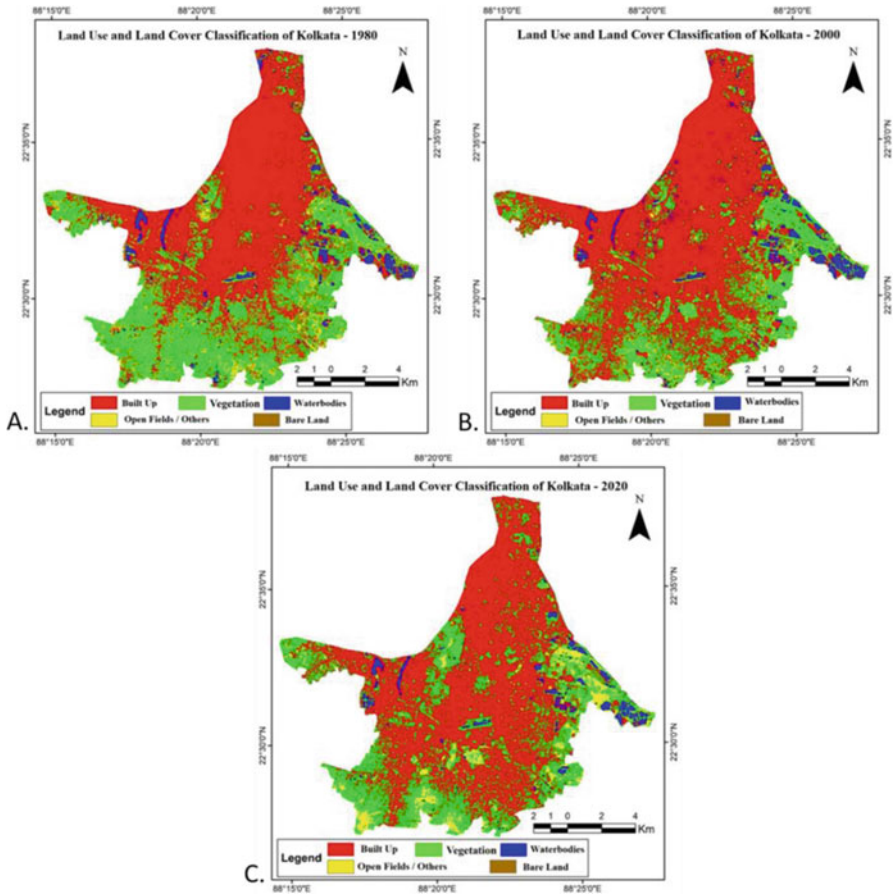
The Enhanced Vegetation Index (EVI) is an advanced vegetation index created with higher sensitivity to biomass, atmospheric background and soil condition. It is contemplated as the modified version of NDVI with high potentiality of vegetation monitoring by correcting all the external noises. Vegetation indices are calculated from the bilateral surface reflectance that has been concealed for cloud, smoke, aerosols, water, cloud shadows, etc. EVI uses the blue and red NIR band (band 1, 3 and 4 for Landsat 5 TM and band 2, 4 and 5 for Landsat 8 OLI) with the correction coefficient C1, C2 and L (Gao and Li 2000). In recent times, EVI has proved to be an efficient technique in vegetation change detection and derivation of canopy biophysical characteristics of a particular region, so it has been applied in the study area for vegetation analysis.

Besides, intensive field survey in two phases (January–March 2020 and August–October 2020) was carried out to cover the entire city at length keeping the season and COVID-related movement restrictions in mind to classify urban greens and prepare a detailed inventory of the urban greens of the city along the major thoroughfares and locate the few major pockets of urban greens and forests within the city limits. During the surveys, identification of common loopholes in arboriculture practices was noted too. To access how the citizens of Kolkata are involved with urban greenery amidst their busy daily schedules and through dendrogram, key factors for generating people's perception on urban greenery have been analysed. To understand the people's perception regarding urban forestry and its management practices, online questionnaire survey was conducted on randomly selected residents ( $n = 1410$ ).

## 6.6 Results

### 6.6.1 Spatio-temporal Change Analysis

The supervised classification has been applied to detect the LULC changes within KMC area (Fig. 6.2). It can be identified that the spatial pattern of the city shows major changes in built-up area, vegetation cover and water bodies along with open spaces and bare land.



**Fig. 6.2** Gradual transformation in land use and land cover of Kolkata, West Bengal. The LULC maps (1A, 1B, 1C) with the help of satellite imageries of Landsat 3, 5 and 8 for 1980, 2000 and 2020, respectively, show the extent of growing urbanisation and diminishing vegetation in the region

The land use classes have been mapped covering the period of 1980, 2000 and 2020. Distinct changes can be observed in the major LULC classes (Table 6.4). In 1980, the built-up area covered 49% (91.63 sq.km.) of the total KMC area, while in 2020, it almost engulfed the whole KMC area covering 81% (151.47 sq.km.) of the total area. The rate of urbanisation was much rapid during the phase 1980–2000 (22% increase in built-up) than that of the time frame 2000–2020 (10% increase in built-up). This has resulted in decrease in the vegetation patches throughout the city.

The vegetation cover includes roadside trees, green fields and other green patches. During the 1980s, the vegetation of the city comprised mainly of big trees which covered an area of 31% (57.97 sq.km.) of the total KMC area. In the year 2000, the green cover drastically shrank to 20% (37.40 sq.km.) of the total KMC

**Table 6.5** Error matrix for land use and land cover changes in Kolkata Municipal Area, West Bengal, India (1980–2020)

Year	Class name	Reference total	Classified total	Number of correct points	Producer's accuracy	User's accuracy	Kappa statistics
1980	Built-up	46	42	38	82.61	90.48	0.88
	Water body	30	24	20	66.67	83.33	0.80
	Vegetation	54	58	40	84.21	64.00	0.56
	Open fields and others	28	34	26	92.86	76.47	0.67
	Bare land	42	40	34	88.24	78.95	0.68
	<b>Total</b>	<b>200</b>	<b>200</b>	<b>158</b>	<b>79.00</b>		<b>0.72</b>
2000	Built-up	48	54	46	95.83	85.19	0.81
	Water body	32	34	32	100.00	94.12	0.93
	Vegetation	52	44	34	68.18	75.00	0.67
	Open fields and others	30	34	20	52.63	83.33	0.93
	Bare land	38	34	32	76.47	76.47	0.64
	<b>Total</b>	<b>200</b>	<b>200</b>	<b>164</b>	<b>82.00</b>		<b>0.76</b>
2020	Built-up	96	104	98	100	94.23	0.88
	Water body	28	35	28	100.00	77.78	0.74
	Vegetation	46	26	22	52.63	83.33	0.79
	Open fields and others	13	7	6	84.21	64.00	0.82
	Bare land	17	28	20	92.86	76.47	0.72
	<b>Total</b>	<b>200</b>	<b>200</b>	<b>174</b>	<b>87.00</b>		<b>0.81</b>

Computed by the authors from satellite imageries of Landsat 3, Landsat 5 and Landsat 8 for 1980, 2000 and 2020, respectively

area and ultimately to 11% (20.57 sq.km). It is interesting to note that vegetation patches showed a slight increase in the eastern part of the city along with the southern fringes where scattered vegetation pockets could be located. Sharp decline in vegetation and consequent increase in built-up can be seen in the boroughs X, XI and XII between 1980 and 2020. The changes for the vegetation patches were major in the boroughs of II, VI and V.

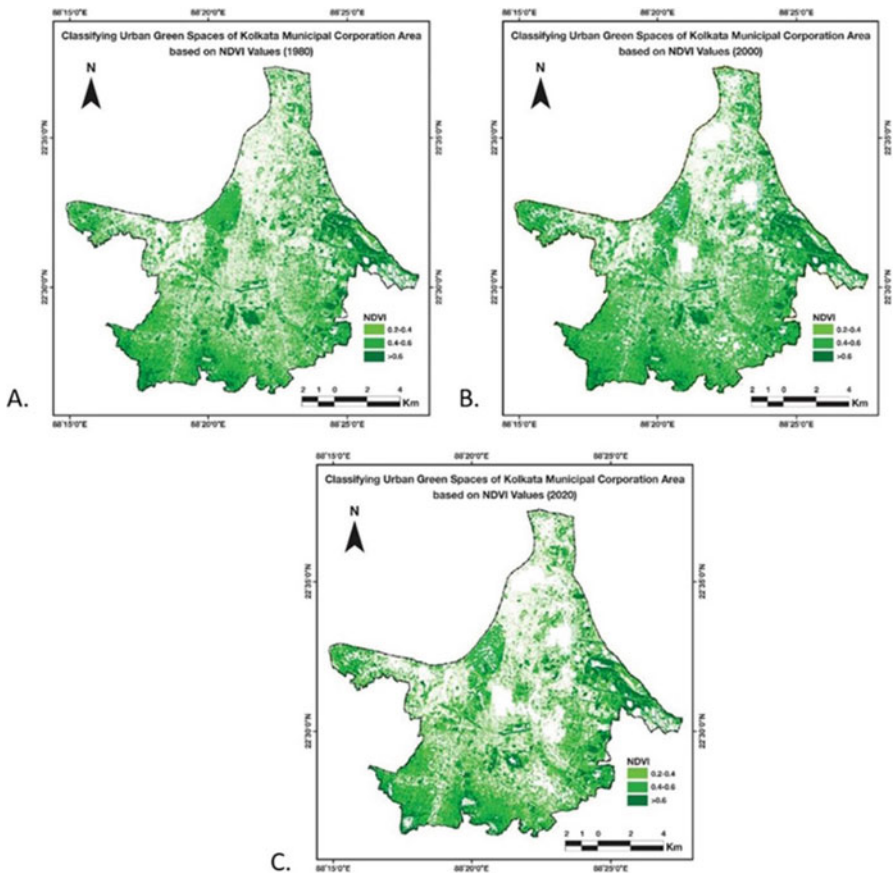
For accuracy assessment of the classification, user's accuracy and producer's accuracy for each land cover types have been conducted along with kappa statistics for each land cover types (Table 6.5). The kappa statistics has been used to verify the inter-rater reliability. The higher observer accuracy highlights the overall agreement level. In general, the overall accuracy of the imagery interpretation ranges from 72% to 81%.

With the growing urbanisation process, the green cover in Kolkata has shown a declining trend. Rapid population growth leading to rigorous urbanisation has led to the clearance of a fair share of the green areas of the city. The population growth

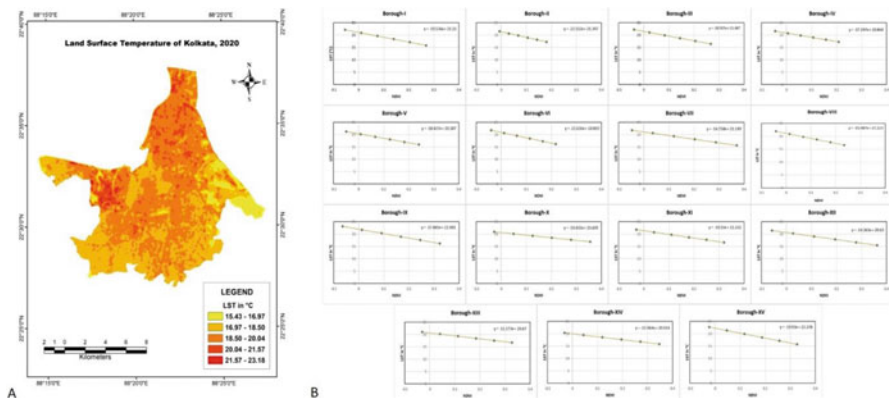
mostly due to pull-factor-based migration and the resultant hanging nature of the LULC within KMC area cause a sharp decline in the urban greenery in the city which is gradually becoming a 'concrete jungle' acting home for more than 4.5 million residents.

### 6.6.2 Urban Green Space Analysis

In this study attempt has been made to identify the urban green spaces which are at high risk due to rapid growth of urbanisation. The risk vulnerability of the urban greenery has been highlighted using NDVI values categorised as low, high and very high (Fig. 6.3). The values ranging within 0.2–0.4 indicate sparse vegetation cover.



**Fig. 6.3** Classifying urban green spaces based on NDVI values (1980–2020), Kolkata, West Bengal, with the help of satellite imageries of Landsat 3, 5 and 8 for 1980, 2000 and 2020, respectively



**Fig. 6.4** Borough-wise graphs showing negative co-relation between NDVI and LST (2020)

It is well established that since 1980, the vegetation cover has shown a decline. The zones having value above 0.6 are the areas that are stable and are expected to survive the stress of the rapid urbanisation.

Land surface temperature (LST) refers to the ‘skin’ temperature of the surface, which depends on insolation alongside the nature of the surface. It indicates the terrestrial thermal behaviour; normally vegetated areas, water bodies are cooler in comparison with sand or concretised surfaces. So, a positive relation exists between LST and urbanisation. In case of Kolkata too, the LST (of 2020) approximately varies from 15 °C to 23 °C; the lower temperatures are located where presence of vegetation is higher, i.e. predominantly in the southern and eastern parts (Fig. 6.4).

The growing population and extreme exploitation and utilisation of natural resources result in a severe change in land use and land cover pattern in the urban areas. The connection between the land use and land cover pattern and the different materials like bricks, asphalt, concrete, etc. used in urban areas has become necessary to understand its impact on the environment (Stone and Rdgebers 2001). All these materials have high thermal inertia, greater absorption of solar radiation and high thermal conductivity (Arrau and Peña 2010). The evaporation regime gets altered due to the conversion of vegetated areas into concrete surfaces. The lowest LST values are found in areas with high NDVI. The regression analysis of LST and NDVI shows a linear negative correlation which becomes an important parameter for studying urban climate. For all the 15 boroughs, the relationship is negative to strongly negative where correlation coefficient ranges between  $-0.89$  and  $-1$ . North Kolkata and parts of central and western Kolkata show a strong negative correlation. This indicates that areas with least vegetation are experiencing higher land surface temperature.

Constant monitoring of vegetation is necessary to get an overview about the strength and dynamics of canopy structure which may indicate the change due to developmental activities and climate change. EVI similar to NDVI corrects the noises – background, atmospheric noise and saturation – and can be used to quantify vegetation greenness. EVI is similar to Normalized Difference Vegetation Index

(NDVI) and can be used to quantify vegetation greenness. The Enhanced Vegetation Index (EVI) has been done to augment the vegetation signal with a better sensitivity in the areas of green cover. The improved green monitoring is possible by separating the canopy background signal and reducing the atmospheric influences. It incorporates an 'L' value to adjust for canopy background, 'C' values as coefficients for atmospheric resistance and values from the blue band (B). These enhancements allow for index calculation as a ratio between the R and NIR values while reducing the background noise, atmospheric noise and saturation in most cases (USGS 2019). EVI has been calculated using below formula:

$$EVI = G \times \left\{ \frac{(NIR - Red)}{(NIR + C1) \times (R - C2 * B + L)} \right\}$$

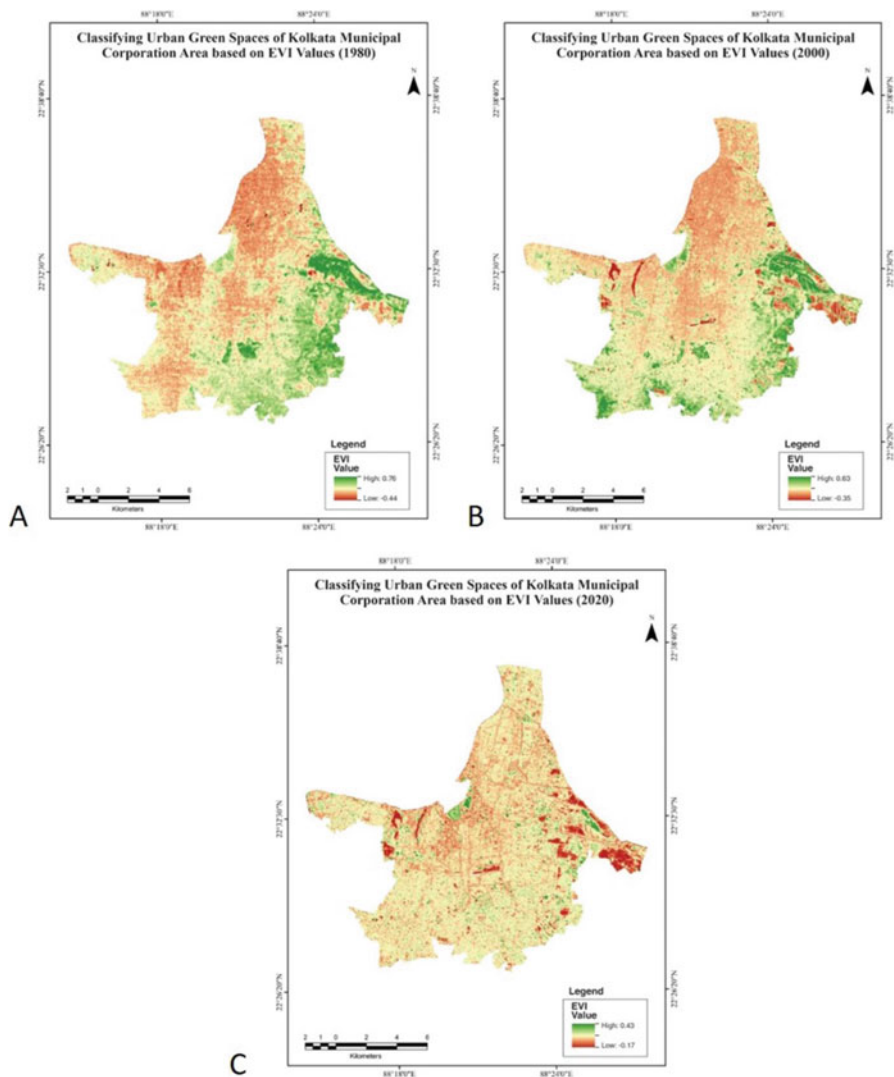
The green cover for the three selected years 1980, 2000 and 2020 has been shown in Fig. 6.5. The increasing urbanisation is the most important factor that has led to the continuous decrease in the green cover in the urban area like Kolkata. The 2020 EVI map clearly shows the decrease in the green cover in Kolkata compared to 1980.

The city is dotted with many parks of varying sizes (small, medium and large) though there is a kind of underlying inequality in distribution. Based on the municipal records, it was calculated that the average value of number of persons served by a single park was as high as 9081. Borough X, followed by boroughs of XI and XIII all in south Kolkata, provides the least value of persons served by a single park – having a value ranging between 3000 and 4000. North Kolkata (boroughs IV, V and VII) has lesser scope for urban greens as the degree of urbanisation is very high providing higher person-park ratio. Borough XV shows an exceptionally skewed ratio of 30,891 as not much effort has been taken in developing formal urban green spaces (Fig. 6.6).

Li et al. (2005) developed an integrated ecological network for green, sustainable development of Beijing, China; Uy and Nakagoshi (2007) created a framework for urban green space development in Hanoi City, Vietnam; and Kong et al. (2010) developed green space network for Jinan City, China. Scholars like Teng et al. (2011) emphasised on integrated green space planning involving recreation and conservation side by side. This sort of approach is needed for Kolkata too to do away with the gross areal disparities and ensure somewhat equal access to greenery for all its citizens.

### 6.6.3 Preparation of Tree Inventory

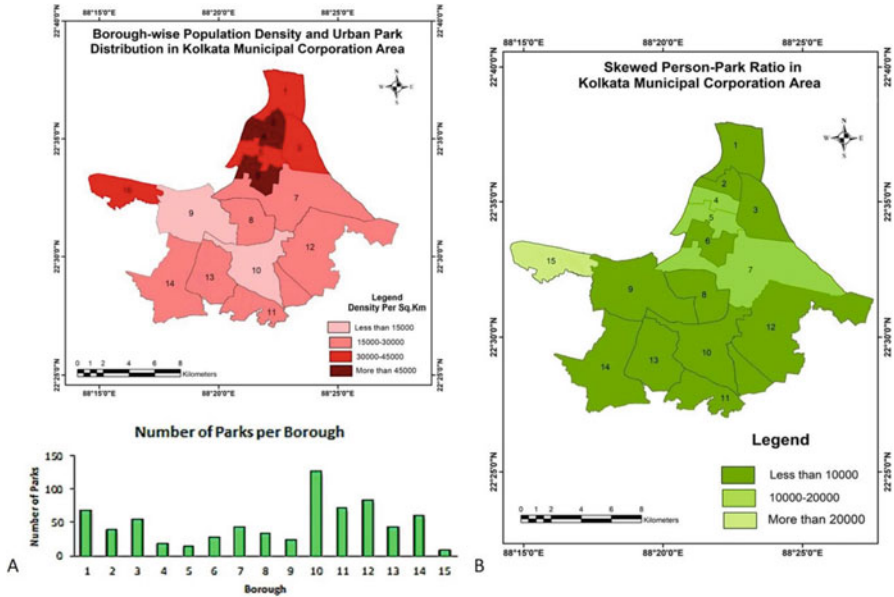
Apart from the planned green spaces, avenue and median plantations also play an important role in maintaining the green cover of the city. But taking a close look at the prominent species involved will help in understanding the treescape (Table 6.6). Intensive field survey in two phases (January–March, 2020 and August–October, 2020) was carried out across the city, and on the basis of their canopy structure, characteristics and predominant locational presence, classification has been done (Fig. 6.6).



**Fig. 6.5** Classifying urban green spaces based on EVI values (1980–2020), Kolkata, West Bengal, with the help of satellite imageries of Landsat 3, 5 and 8 for 1980, 2000 and 2020, respectively.

In a city like Kolkata where automobile pollution and dust smoke are highly prevalent, certain species are highly suitable and are commonly seen like Sirish/rain tree (*Samanea saman*), white Sirish (*Albizia procera*), Indian Sirish (*Albizia lebbek*), Bael/wood apple (*Aegle marmelos*), Palash/flame of the forest (*Butea monosperma*), Bakul/Spanish cherry (*Mimusops elengi*), etc. However, an attempted detailed inventory would help in having a clearer overview (Fig. 6.7).





**Fig. 6.6** A. Borough-wise population density of Kolkata Municipal Corporation Area with corresponding park distribution; B. skewed park presence and high population density leading to unsatisfactory person-park ratio in Kolkata Municipal Corporation Area. Data Source: Kolkata Municipal Corporation 2020

### 6.6.4 People’s Perception on Urban Greenery

UGS assists in various primary functions mostly preservation and nourishment of natural processes like the biogeochemical cycles, sustenance of flora and fauna and upkeep of mental health through remodelling and enhancement of the appearance of any area. Theoretically, among the academicians, there is a consensus that increased citizen involvement in urban forestry initiatives will increase its efficacy. To facilitate such involvement for the state of Pennsylvania, Thompson et al. (2005) recommended techniques like stakeholder mapping, key informant interview and snowball sampling. To further investigate the matter of citizens' concern for urban greenery and the resultant municipal eagerness to involve locals in urban forestry initiatives of various municipalities have been studied. Scholars like Reeder and Gerhold (1993), Ricard (1994) and Kuhns et al. (2005) tried to gauge about the perception of both the stakeholders and mostly highlighted a gap indicating lesser empowered role of the citizens in terms of decision-making involving wise-practices, management, budgetary allocation, etc. In case of Indian cities, such studies are conspicuous by their absence.

The dendrogram represents the relationship of similarity among the response collected from the primary survey (Fig. 6.8). The diagram has four clades with seven leaves. The height of the dendrogram indicates the order in which the clusters were

**Table 6.6** Treescape of Kolkata City, West Bengal, India

<b>Trees with roundish crown</b>		
<b>Scientific name</b>	<b>Common name</b>	<b>Location</b>
<i>Mimusops elengi</i>	Bakul	Avenue plantation
<i>Azadirachta indica</i>	Neem	Avenue plantation and private garden
<i>Neolamarckia cadamba</i>	Kadamba/burflower	Avenue plantation
<i>Ficus religiosa</i>	Peepal/Bodhi	Avenue plantation, exceptionally beneficial for carbon storage
<i>Swietenia mahagoni</i>	Spanish mahogany	Avenue plantation
<i>Terminalia arjuna</i>	Arjun	Avenue plantation
<i>Mangifera indica</i>	Mango	Avenue plantation and private garden
<b>Trees with umbrella-like crown</b>		
<b>Scientific name</b>	<b>Common name</b>	<b>Location</b>
<i>Ficus benghalensis</i>	Banyan	Parks
<i>Lagerstroemia speciosa</i>	Banaba/Pride of India	Median plantation with ornamental flowers
<i>Thespesia populnea</i>	Indian tulip tree	Avenue plantation
<i>Delonix regia</i>	Gulmohar/flame tree	Though popular as avenue plantation is highly susceptible to strong winds and thus more suitable for parks and private garden providing vibrancy
<i>Alstonia scholaris</i>	Saptaparni/Devil's tree	Though popular as avenue plantation is highly susceptible to strong winds and thus more suitable for parks and private garden
<i>Sterculia foetida</i>	Wild almond tree	Scattered avenue plantation
<i>Samanea saman</i>	Rain tree	Avenue plantation
<i>Tamarindus indica</i>	Tamarind	Avenue plantation
<i>Averrhoa carambola</i>	Kamranga/starfruit	Median plantation
<i>Eugenia operculata</i>	Jamun	Avenue plantation
<b>Trees with columnar crown</b>		
<b>Scientific name</b>	<b>Common name</b>	<b>Location</b>
<i>Putranjiva roxburghii</i>	Putranjiba/lucky bean tree	Avenue plantation

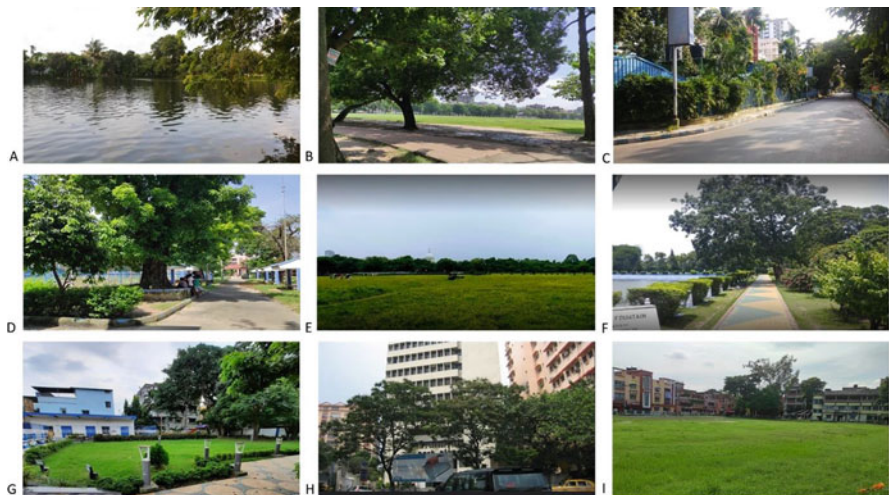
(continued)

**Table 6.6** (continued)

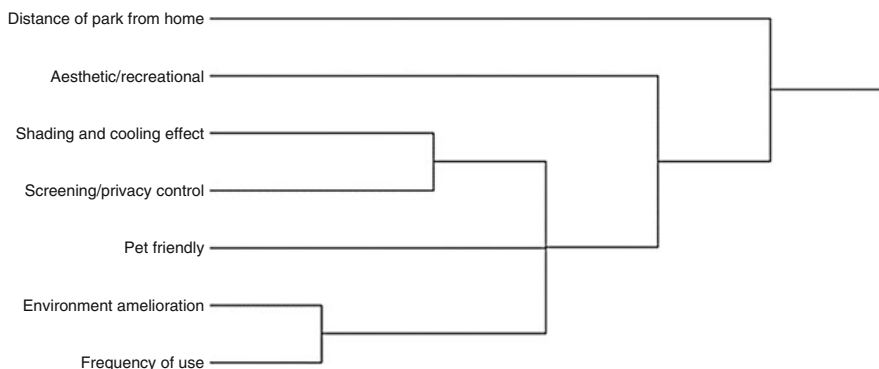
<i>Spathodea campanulata</i>	African tulip tree	Ornamental purpose
<i>Peltophorum pterocarpum</i>	Copper pod	Avenue plantation though susceptible to strong winds
<i>Terminalia catappa</i>	Indian almond tree	Avenue plantation though susceptible to strong winds
<i>Bombax ceiba</i>	Simul/silk cotton	Parks
<i>Swietenia macrophylla</i>	Honduras mahogany	Parks
<i>Alstonia scholaris</i>	Saptaparni/Chhatim/Blackboard tree	Avenue plantation
<i>Ficus religiosa</i>	Peepul/sacred fig	Avenue plantation
<b>Diverse flowering trees</b>		
<b>Scientific name</b>	<b>Common name</b>	<b>Location</b>
<i>Cassia fistula</i>	Amaltas/golden shower	Brightening avenue scenario
<i>Bauhinia purpurea</i>	Kanchan/purple orchard	
<i>Colvillea racemosa</i>	Kilbili/Colville's glory	
<i>Peltophorum ferrugineum</i>	Swarnachura/yellow flame	
<i>Spathodea nilotica</i>	Rudrapalash/fountain tree	
<i>Jacaranda acutifolia</i>	Nilkantha/blue Jacaranda	
<i>Grevillea robusta</i>	Rupashi/silver oak	

Source: Primary Survey (2020) and Sarkar (2016)

joined. The arrangement of the clades highlights the similarity among the leaves. The greater the height of the branch, the greater is the difference. In this dendrogram, seven basic questions were enquired regarding the surrounding green space, and thus seven chunks were derived. In this diagram chunk, one which represents the distance of park from home has been separated and is categorised as simplicifolious. The separation of this category from the others indicates that most respondents were of opinion that the green spaces are always not at walkable distance. As the distance of the first parameter increases, it denotes a common general view of the respondents that most parks are located at a distance that is often difficult to travel. The second clade shows a separate branching highlighting people's acceptance of aesthetic values of the greenery. With people admitting to the need for the green space, the recurring constructional works and growing urbanisation have made it difficult to maintain the greenery. The third clade has three branching with a separated branching highlighting the green space like parks for pets. Shading and privacy



**Fig. 6.7** Glimpses of greenery from across the city: A. Subhas Sarovar; B. Park Circus Maidan; C. Southern Avenue; D. Maddox Square; E. Maidan; F. Elliot Park; G. KMC Park, Behala; H. Sarat Bose Road; I. Javadpur Yuba Sangha Ground



**Fig. 6.8** Analysing the key factors for generating people’s perception on urban greenery. Source: Primary Survey, 2020

issues show similarity indicating a dissimilarity with the first two parameters. People are, however, less acquainted with environmental amelioration. Frequency of use is often affected by the distance of the parks from the residences. This distance has shown a separate branching indicating the most vital criteria for usage of green space.

Through contingent valuation method (CVM), the annual recreational usage value of UGS of Chandigarh was estimated to be around 120 million rupees taking 2002–2003 as the base year, and Willingness to Pay method indicated that maintenance cost of the existing greenery per family per year agreed to pay little over

150 rupees (Chaudhry 2006). In Kolkata also, it can be very well gauged that urban greenspace can provide the least requirements of natural setting to avoid psychological isolation of people from their immediate environment. The respondents have opined that establishment of new parks, roadside plantation and adoption of mass tree plantation programmes can be beneficial for developing urban greens. There has been a positive attitude toward environmental development, its management and protection. The optimal carrying capacity of the urban greens and recreational areas can be improved if more trees are planted alongside the maintenance of the greenspaces.

## 6.7 Discussion

### 6.7.1 *Classifying Urban Greens*

Like any other urban centre, urban greens in Kolkata comprise an extensive range of different components – planted forests, parks, tot lots, woodland, street tree and square plantings, avenue planting, green strip, cemeteries, private gardens, community gardens, green roofs, playgrounds, sports complexes, green belts and so forth (Helms 1998). According to Urban Development Plans Formulation and Implementation (UDPFI) Guidelines (Ministry of Urban Affairs and Employment 1996), the percentage of this recreational space to total developed area needs to be 12–14% for small towns, 18–20% for medium and small towns and 20–25% in case of million plus cities; but for the city concerned, it is only around 15%.

### 6.7.2 *Urban Greens and Forests Within Kolkata*

Tree plantation was initiated since the inception of Calcutta Municipal Corporation in 1727 (Kolkata Municipal Corporation 2020). Initial tree plantation was mainly adopted by the local residents, which soon gained importance. Planting of trees along the streets of Kolkata officially started in the year 1869 (Goode 1916). Thereafter, successive legislature made provisions to facilitate the planting of trees within the city of Kolkata. In the early eighteenth century, Maidan and Eden Gardens were created along with Dalhousie square and other large park and greens. Conservators were appointed by the corporation during 1905 for maintaining the greens in public places involving arboriculture (Kolkata Municipal Corporation 1997). In 1911, after the establishment of Calcutta Improvement Trust (CIT), the brainchild of Lord Curzon, stressed on expansion and improvement of Kolkata and its surroundings which mainly included parks and open spaces (Kolkata Improvement Trust 2015).

Historical facts have suggested a fair share of vegetation cover in and around Kolkata. The paleontological evidences of the peat depositions which was found at a depth of 70 to 80 feet in and around Kolkata found in and around Kolkata at a depth

of 72–82 feet have revealed the presence of both arboreal and non-arboreal pollen types, the latter comprising both wild and cultivated grass of fluctuating concentrations (Nair 1986). Studies have shown that the Sundari trees have been found in different parts of Kolkata at the very initial stages. During 1702, the East India Company had built floristic rich gardens encircling the ponds (Ghosh et al. 2013). The growth of the city has been unplanned and haphazard, thus leading to clearing of the green cover. The British period saw much of clearing of forest for expanding settlement and construction of roads. During 1790, much of the forests were cleared for giving a new cityscape for the then Calcutta (Ghosh 1988). The first detailed documentation of vegetation of Kolkata was carried out by Benthall (1946), who provided a comprehensive account about the location, characteristics and evolution of the trees available (enlisting 276 varieties) in the then city and its neighbourhood. At a later date, Ghosh (1991) and Ghosh et al. (2013) threw light on the status of urban vegetation of Kolkata, highlighted the ecosystem services rendered by them and compared the present situation with that of the Benthall's time – identifying that almost 56 species (21%) have disappeared from the city's urbanscape and emphasised on the need of conserving the species.

The largest patch of green which have been maintained since the colonial times is the 'Maidan' area, central Kolkata, which is popularly referred to as 'lungs of the city'. The other prominent green spaces are Rabindra Sarobar Lake with its adjoining greenery in Southern Avenue, Agri-Horticultural Society of India and Alipore Zoological Garden in south Kolkata, the grounds of Raj Bhavan in central part of the city and green patches in and around eastern Kolkata along East Kolkata Wetlands (Dhali et al., 2019). Besides there are several parks and squares of varied dimensions, but these cannot be really referred to as forests but mere UGS which have been carved out. In case of the city of Kolkata, there is no official presence of urban forest. But on a 1-kilometre stretch of land in south Kolkata between Majherhat and New Alipore along the railway line spanning over two decades, on personal initiative a lawyer, Mantu Hait planted around 30,000 trees, encompassing over 250 varieties – mostly fruit-bearing ones (The Better India 2019).

Atal Mission for Rejuvenation and Urban Transformation (AMRUT) was launched by the Ministry of Urban Development (MoUD) in June 2015 through which initiatives were taken to develop green spaces within the cities aiming to increase the green cover by 15% in a period of 5 years under the aegis of Urban Local Bodies (Ministry of Housing and Urban Affairs 2019). The areas on which Department of Municipal Affairs, Government of West Bengal emphasised were sanctioning building plans of new housing, industrial and other related projects only if they had a minimum provision of 15% of tree cover in the form of dedicated open spaces and plantation of trees along the driveways, creating sufficient nurseries for good-quality planting stocks and also taking efforts in protecting the existing greens. The scheme also noted that to improve the urban quality of life, recreational urban forest can be developed in the peripheral areas identifying suitable large blocks of land. Scholars like Teng et al. (2011) emphasised on integrated green space planning involving recreation and conservation side by side. This sort of approach is needed for Kolkata too to do away with the gross areal disparities and ensure somewhat equal access to greenery for all its citizens.

### 6.7.3 *Identifying Loopholes in Existing Urban Greenery Management Practices*

Several steps have been taken by all stakeholders to improve the green quotient of the city, but the yielded results have not been much promising. From the prolonged field observations, quite a few glaring issues were identified:

*Type of trees chosen.* The policy of 'right place, right tree' needs to be followed while selecting the tree species keeping few criteria in mind – fast-growing, low-maintenance, wind-resistant, deep-rooted, robust ones are most appropriate taking into account the varying soil and climatic conditions. But often, aesthetic preference takes over the other important factors.

*Spacing of trees.* There is no stringent norm about tree spacing as it depends of the tree species and the type of area where the plantation is carried out. However, for avenue trees, the general convention is 10–12 m of spacing.

*Unscientific pruning of trees.* Regular pruning is done for the tree branches to maintain a manageable height and also to make way for overhead utility lines, but often it is done in a lopsided manner by untrained workers affecting the shoot ratio for which the roadside trees are unable to stand strong winds.

*Concretisation of pavements.* Of late, a number of Urban Development Authorities and Urban Local Bodies have undertaken large-scale concretisation of pavements which has resulted in restricted growing space of the root zone of a number of roadside trees by first rendering them weak lives and consequently making them easy prey for uprooting during norwesters or gusty storms, apart from damaging the footpath itself. If situation demands, pervious tiles can be used for the purpose leaving the root zone uncemented.

*Maintenance planning.* It starts with creating nurseries from where economical large-scale planting of selected species could be done. After planting of seedlings in suitably soiled pits – regular watering and periodic manuring need to be done for healthy growth; then constant supervision is essential for removal of parasites and unhealthy branches. Modernised technology of transplantation of trees needs to be emphasised more, trying to improve the survival rate, in urban areas where due to large-scale constructional activities, often, full-grown trees are chopped off.

*Involvement of stakeholders.* Since all the burden cannot be borne by the governmental agencies, there is need for private players to chip in in creation and maintenance of urban parks too. In the new urban housing development, a part of the project area and estimated project cost has to be earmarked for green landscaping. Public participation is another aspect which is weak, active participation of residents, large private landholders, engineering professionals and non-governmental organisation are needed to play the role of catalyst to develop a common vision and review the versions of the plan.

*Lack of comprehensive documentation.* There is dearth of detailed information about UGS both quantitatively and qualitatively, regarding species type, age, recent condition, etc. which stands in the way of further planning regarding urban greenery. There is a dire need of an inventory of urban biodiversity for proper monitoring and planning.

To remove the above said obstacles, help of a central organisation might be sought with experienced members who can advise the state and local agencies about horticulture and landscaping. To maintain adequate green cover, ecological development of the city has to imbibe certain conscious efforts from urban local bodies even in some cases through legal provisions like imposing building codes, etc.

### ***6.7.4 In Search of Amendments: Emerging Urban Forest in the City Fringes***

In 2020, on the occasion of World Environment Day, the Ministry of Environment, Forest and Climate Change announced the Nagar van scheme to develop 200 Urban Forests across the country in next five with governmental collaboration funded by Compensatory Afforestation Fund Management and Planning Authority and supported by people's participation to nurture 'lungs' in congested urban areas (Ministry of Environment, Forest and Climate Change 2020). For Kolkata, to mirror such initiatives, open spaces were hard to come by in the main city, so the satellite townships were the areas offering better living quality with probable planned green spaces. Several such sub-cities have been proposed by Kolkata Metropolitan Development Authority in The Perspective Plan of Kolkata which includes New Town, Rajarhat, Bidhan Nagar (popularly known as Salt Lake), Kalyani, West Howrah, etc. with large share of the land earmarked as UGS in the master plans. The planning of UGS in New town became a key concept with the growing urban sprawl. It aimed at connecting the greens at sector level and the neighbourhood through walkability.

New Town, Rajarhat, the fast-growing satellite city of Kolkata, is now referred to as 'Green City' as it encourages an eco-friendly lifestyle in an urban area maintaining the balance between urban development and environment (Ahern 1995). The 480 acre of land and 112 acres of water body have been transformed into a well-maintained eco-park established in 2012. 99 different species of plants are found in the eco-park including tropical tree garden, rose garden and bamboo garden (West Bengal Biodiversity Board 2019). With an aim to increase the green cover, the Housing Infrastructure Development Corporation (HIDCO) has planned to set up an urban forest over an area of 7 acres of land in Action Area II. HIDCO and New Town Kolkata Development Authority (NKDA) have been planning strategies for plantation.

Urban afforestation and beautification have been continuing for a long period. The government of West Bengal has considered a comprehensive Plan of Action to meet the challenges of rapid urbanisation under the project 'Green City Mission'. The project aims at urban greening along with 'Blue-ing' by conserving water bodies, waterfront greening and beautification (Urban Update 2020).

The tropical cyclone Amphan (16 May, 2020) shattered Kolkata with heavy rains and strong winds uprooting more than 4000 trees (Times of India 2020), which made the planners more concerned about the proper species selection for venue plantation; to sustain the gusty storms, slender trees like rosy trumpet and foxtail are being



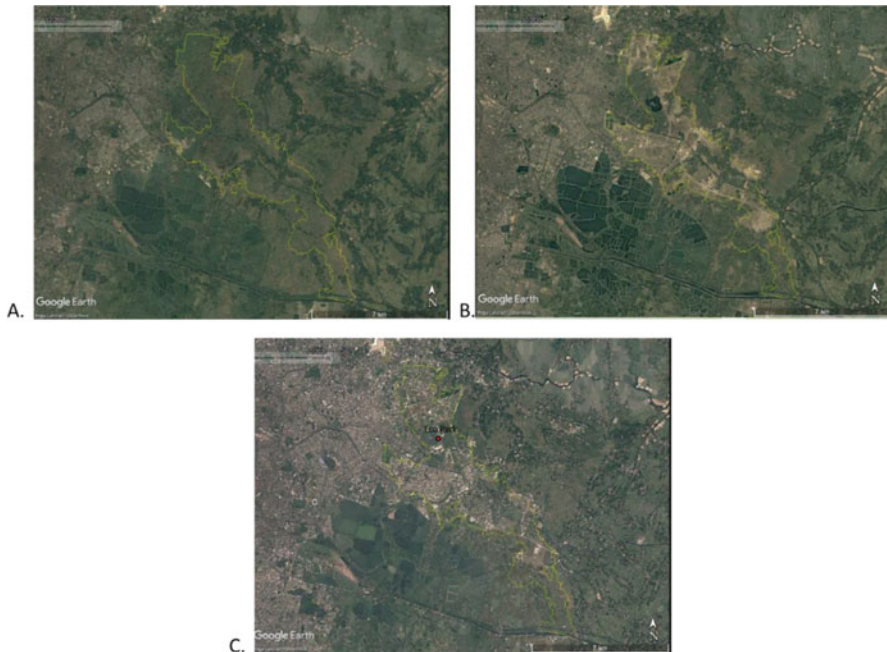
preferred (The Telegraph 2021). Trees like neem, betel nut, coconut and palm were considered for plantation. Besides, planting of grape fruits and guava on open lands was also decided by NKDA (Millennium Post 2020). About 3738 trees have been restored in New Town, and the State Pollution Control Board has also taken the initiative to plant 2000 trees on HIDCO land emphasising on species like neem, arjun, palash, kadamba and Ashoka (Times of India 2020). Slender and flexible trees have been planted in New Town. Palm, cherry blossom and coconut trees, which are less likely to topple down, have been planted along the median divider and sidewalks. HIDCO along with the forest department has come up with plantation planning in New Town where considering the soil character, two types of plantation have been sought of, one resilient to storms and the other to air pollution.

New Town has come up with the unique idea of creating an urban man-made forest for a sustainable environment and which enables urbanites to connect with nature (Fig. 6.9). The initiation of creating an urban forest over 4 acres of land near Tall Tree nursery, Rajarhat has been taken by HIDCO along with the NGO Green for Life Foundation and the Forest Department. More than 700 trees have been planted which included saplings like *Bokul*, *Krishnachura*, *Akashmoni*, *Neem*, etc. A fair number of rubber trees have been planted. Over 8000 trees have been planted which will make a huge difference in absorption of carbon dioxide and help in wildlife conservation (Biswas 2018).

## 6.8 Conclusion

The rapid and uncontrolled urbanisation is the major source of the environmental degradation and decline in the green spaces within the city of Kolkata. Unparalleled population growth, changing climate, migration and expansion of infrastructure translate the green scenario of the urban areas. This research work is thus a snapshot of the effects of land use-land cover change and the continuous decrease in the urban green space within the city hindering the sustainable urban development. Green spaces are an indispensable component of a built environment. The presence of green spaces is an indication of better health and social wellbeing which also helps in controlling climate change (Tu et al. 2016). Thus, protecting and preserving the greenery within the urban city is of utmost necessity.

In the developing countries, there are extensive areas where low-income residents live in congested neighbourhoods without much option of open or green spaces; so, provision of green walls and roofs can help in cooling the microclimate of the area. Curtis et al. (2014) flagged caution about the tree species emitting Biogenic Volatile Organic Compounds (BVOCs), but Singh et al. (1998) pointed out that in Indian cities, there are several such ornamental avenue trees which emit isoprene (a common VOC), and those need to be omitted from future plantation programmes. While shortlisting the suitable species, Air Pollution Tolerance Index (APTI) and Particulate Abatement Capacity (PAC) can be used as important indicators especially for roadside plantations to abate the air pollution preferring species like *Ficus benghalensis*, *Mangifera indica* and *Carissa carandas* (Kuddus et al. 2011).



**Fig. 6.9** Growing urbanising trend identified with the help of Google Earth images (A, B, C) of 2000, 2010 and 2020 corroborating the presence of distinct green cover along with the marked presence of Eco Park in New Town, Rajarhat area

The management of urban green spaces which are constant under the scrutiny of the public eye needs to be transparent and efficient. But a lack of up-to-date detailed inventory of urban forests and other greeneries in the cities often leads to insufficient financial allocation for maintenance and further expansion. To increase the urban green space, integration of green patches has to be made at different levels following a certain hierarchy; in the master plans of cities, maintenance of ecological balance has to be prioritised with provisions for green belts-corridors and social forestry in the derelict lands. To reduce the impact of air pollution due to heavy traffic, regulated, selective greening of transport corridors may be attempted. As per Town and Country Planning Organisation (2014), the ones which are recommended to be highly avoided for urban planation are the ones with weak stem which are prone to easy breakage during windstorms and cause accidents like *Eucalyptus* and the thorny varieties which might cause injury to the children and lead to tyre leakages.

On the 4th of July 2016, the concept of Green City Mission for Kolkata was approved by the Urban Development and Municipal Affairs Department. The main areas of concern for it were to increase green areas, conserve water bodies and beautify public spaces. The schemes were widely accepted by the Urban Local Body, but the issue of maintaining the assets has been widely debated as most of these greening schemes are not revenue generating. The scope of involvement of

private players is being thought of through development of theme parks (New Town Kolkata Developmental Authority 2019).

As per guidelines of UDPFI, Government of India, protection of open spaces is of utmost importance from ecological and social perspectives. The current metropolitan development plans include mandatory green spaces within their schemes. The urban greenery models can be modified to suit the context of the city of Kolkata, India, in planning patches and stretches of urban forestry keeping the balance between developmental needs and environmental concerns. Proposals have been there for establishing a separate section dealing with urban forestry within the designated forest regulating authority for better management.

But there has been a kind of lack of comprehensive planning for urban forestry in developing countries like India, and especially for Kolkata, there is lack of detailed urban forestry-related database and research which puts the city in a tight spot (Pataki et al. 2011). Besides, there is inadequate financial support, nominal budgetary allocation and bureaucratic red-tapeism for urban forestry programme which pose a problem for systematic expansion. If the ecological services provided by the urban forests can be tapped, then the promised economic return will augment the municipal investment in this green infrastructure (Sharma et al. 2009). There is lack of skilled researcher in the said field for which networking with seasoned academicians would help in streamlining the programmes of urban forestry.

Moreover, in a diverse megacity like Kolkata, it becomes fairly tough to find space for development of urban greens. Rapid urbanisation coupled with the increasing population is making the situation tough as green spaces are at the verge of extinction. The paper has been an attempt to assess the urban green space scenario of the city of Kolkata along with a treescape and person-park ratio. A skewed distribution from person-park ratio can be identified which might help planners increase the number of parks where the ratio is less favourable. The methodology also highlights the area where vegetation cover is showing a declining trend, thus indicating a risk zone. This might help the planners allocate the resources accordingly. The treescape is a tool that might help planners focus on green assets of the city and consequently plan the strategies. The ease of computation makes it advantageous for easily adopting this method by planners and policymakers for a sustainable development.

The urban environment is continuously developing and growing. Urban greening has become incredibly important for various reasons. Urban forests are fundamentally human dominated, and therefore, the role of human beings is critical. The level of education and environmental awareness of the urban residents play a major role in determining the composition, management and overall development of urban forest. Thus, urban greenery development not only relies on technology and investment but largely depends on the attitude and involvement of the residents. Registering and intermittent monitoring of urban trees besides expansion of green spaces, while formulating infrastructure-related policies, can improve the urban forestry status. Thus, nurturing community-based programmes might be beneficial. The perception study highlighted people's willingness to protect the green cover in the city. Strengthening the green cover from household to neighbourhood to the city level will lead to a stable environment.

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