Research Paper

"To develop an urban green Index to measure the inequality in urban green space in Indian cities"

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Abstract

The environmental benefits offered by urban green space (UGS) not only contribute to the ecological functions of cities but also safeguards the health of urban people. The extent of migration, urban growth, and the effects of urban transformation have reduced the availability and accessibility of UGS in recent decades. This study aims to analyse the change in urban green space in Indian cities and to develop an urban green index (UGI) to measure inequality of UGS distribution to the urban population. The Normalized Difference Vegetation Index (NDVI) is used from Remote sensing satellites. A spatial geographic information system (GIS) is used to map spatial patterns of inequalities in terms of greenery and public green space. The proposed index provides a method for evaluating, quantifying, and comparing the volume and distribution of green areas in distinct locations. The UGI indicates the significance of green space distribution at various urban scales. It also considers the peculiarities of urban vegetation and the architectural environment. The generated index serves as an input to the model and aids in evaluating the future scenarios of various cities in terms of sustainability, liveability, and resilience. The suggested methodology can assist in identifying the critical area or region, which can then be used to identify action areas for enhancing green quality. This index can be applied by researchers, planners, and policymakers to facilitate a variety of urban greening initiatives and will serve as valuable input for urban planning systems.

Keywords

Urban green space, urban green Index, Public green, Physical activity, Urban Health

1. Introduction

1.1. Background

By 2050, the global urban population is projected to reach 68 %. (Nations *et al.*, 2018) The negative effects of urbanisation include environmental pollution, accidents, heat island effects, and climate change. Urbanisation has undeniable effects on health; however, few studies have demonstrated the health advantages of green places such as parks and playing fields. (Talebmorad *et al.*, 2020)(Ostad-Ali-Askari *et al.*, 2019)Through their alleged impact on physical exercise, green areas have been connected to health and psychological advantages. (Ige *et al.*, 2019)(Christie *et al.*, 2021) Physical activity has been shown to have a variety of positive health consequences, including reductions in the risk of depression, osteoporosis, cardiovascular disease, and injuries caused by falls. (Hamanaka and Mutlu, 2018)(Huang, Leung and Schooling, 2019)(Moore *et al.*, 2018)(Ezejimofor *et al.*, 2018)(Salvo *et al.*, 2018) Green spaces and other nature-based solutions provide new techniques to improve the quality of urban environments, strengthen local resilience, encourage sustainable lifestyles, and boost the health and social well-being of citizens.(Li *et al.*, 2021)(Beard, Wentz and Scotch, 2018) Urban green spaces (UGS) include various natural and semi-natural vegetated regions in urban environments, regardless of their size, control, or function. The most common types are forests, public parks and gardens, institutional green spaces, playgrounds, sports fields, street trees, nature conservation zones, garden walls, and cemeteries. Street trees provide shade and absorb air pollution and vehicle noise but are less ideal for recreation. Grassy green spaces reduce the urban heat island effect less effectively than trees and shrubs. Studies have shown that green spaces purify urban air, improve the local ecosystem and temperature, reduce surface runoff, reduce urban pollutants, and boost carbon sinks. (Gascon *et al.*, 2015)(Lorenc *et al.*, 2013)(Nieuwenhuijsen, 2016) Moreover, Public urban green space (PUGS) provides numerous social benefits, including cultural, educational, and aesthetic**.** The associations between urban green space and happiness are influenced by social support, and the GDP acts as a moderating factor. (Kwon *et al.*, 2021) It is the goal of city planners to create green spaces that can provide a variety of complicated ecosystem services. Researchers, urban planners, and decision-makers recognise the relevance of UGS.

An increasing number of studies examine whether urban green is allocated equally based on individuals' socioeconomic position. Thus, urban green is increasingly recognised as an environmental justice issue, necessitating methodological development. (Li and Liu, 2016)(Li, Huang and Ma, 2021) Cities in Africa, Asia, and Latin America all have higher UGS inequities than the global average. Global South cities may experience similar inequalities in UGS quantity and quality as Global North cities, but they also face disparities in UGS proximity.(Rigolon et al., 2018)Several ways exist to measure urban green accessibility. One of the most prevalent accessibility models uses a set distance from presumed sources to count destinations. The most common measure of UGS is the green index which accounts for overall green space in the city(Liang, Chen and Zhang, 2016)(Chen *et al.*, 2019)(Gupta *et al.*, 2012). Additionally, recent research indicates that the green index may underrate UGS quality. (Duong and Kshama, 2015)create a Weighted Urban Green Space Index (WUGSI) for assessing city-wide UGS based on a multi-criteria analysis that includes parameters such as the percentage of green, the type of green, and proximity to green to measure urban green. Table 1 shows the Characteristics of existing and proposed master plans of various Indian cities.

Table 1 Characteristics of existing and proposed master plans of various Indian cities

SL No.	Master Plan	The existing scenario of Recreational/Open space					The proposed scenario of Recreational/Open space				
		Land use year	Population	Total(ha)	Recreational/Open space	Open space sq./capita	Proposed Land use year	Population	Total (Ha)	Recreational/Open space	Open space sq./capita
1	Second Master Plan for Chennai Metropolitan Area only Chennai City	2006	4509210	17553	366	0.81	2026	12582000	17617.7	1000.6	0.8
2	Master Plan Varanasi	1999	1091918	14494.4	2705.8	24.78	2011	1201815	17927.2	984.5	8.19
3	Draft Master Development Plan Jaipur Region	2011	3073350	30830	3461	11.26	2025	6495000	19800	5745	8.85
4	Master Plan for Ghaziabad			8445	399.5		2021	2300000	15554	2484	10.8
5	Master Plan for Bhopal	2005	1571182	17500	2925	18.62	2028	352000	15572.1	646.46	18.37
6	Draft Master Plan for Port Blair Planning Area	2001	99984	1774	101.25	10.13	2021	4500000	41360	8400	18.67
7	Master Plan for Lucknow	2004	2358393	16270	2455	10.41	2021	1270000	21570	5000	39.37
8	Master Plan for Greater Noida	2011	107676	13570	3000	278.61	2031	149256	1500	240	15.08
9	Master Plan Tarn Taran LPA	2010	72337	569	63.7	8.81	2031	149256	1500	240	16.08

10	Master Plan Srinagar Metropolitan Area	2000	120000	11527	481.31	4.01	2021	2350000	23853.9	2853	12.14
11	Master Plan Allahabad	2001	1081622	21689.1	2602.7	24.06	2021	2043735	30917.4	4953	24.24
12	Master Plan Ludhiana	2007	1524081	127122	300	1.97	2021	4800000	127122	7416	15.45
13	Master Plan Batla	2010	190418	1474.2	11.9	0.62	2031	346651	3467	346.7	10
14	Noida Master Plan	2010	1068228	9210.8	1762	16.49	2031	2500000	15279	2432.82	9.73
15	Master Plan Amritsar	2010	1976050	139419.5	186.8	0.95	2031	3017936	16594	2489.1	8.25
16	Bangalore Master Plan	2003	6501343	42141	1310	2.01	2011	8015000	56463	7788	9.72
17	Mysore Nanjagund LPA-Mysore city	2009	7786510	27864.32	766.31	0.98	2031	2100000	27863.8	1584.2	7.54
18	Master Plan Dehradun	2004	753420	9699	222.8	2.96	2025	1530000	35867.2	928.17	6.07
19	Master Plan for Kanpur city	2001	2551000	89131	959.1	3.76	2021	4000000	33704	3221	8.05
20	Master Plan Trivandrum	2012	989099	21586	54	0.55	2031	1032292	21586	101.64	0.98
21	Master Plan Aizawl						2030	820000	15280	244	2.98
22	Chandigarh Master Plan	2011	1054686	6648.2	1838.26	17.43	2031	1600000	11400	3152.9	19.71

Source: Urban green guideline, 2014

1.2. Aim

The aim of this study is to develop an index to measure UGS inequalities in Indian cities. The above literature has highlighted the significance of different types of green spaces which provide various health and well-being to city and its citizen.

1.3. Objective

The primary objective is to propose an index which can measure inequalities in urban green spaces i.e., assessment of overall green space and public green spaces.

1.4. Scope

The proposed index is a structured method for building an index and it acts as a tool to monitor the distribution of UGS at various scale of the city. Also, this will help policy makers to identify the criteria for UGS planning during land use classification focusing on public health.

1.5. Limitations

This study uses GIS as tool to calculate NDVI and there might be seasonal variation in satellite image analysis which can impact data precision and accuracy. This study considers urban parks and playgrounds as an active green space as it promotes physical activity and other health related benefits. The institutional and private green spaces have not been incorporated in analysis.

2. Method

2.1. Study Area

The state capital of Madhya Pradesh, Bhopal is selected for the study as it is famous for its flora and fauna and often known as city of lakes. The Bhopal Municipal Corporation is the Urban Local Body that is in charge of regulating the city of Bhopal. The administrative area of the city is distributed into a total of 85 wards, which constitute the smallest possible administration. Table 2 shows the Characteristics of the Bhopal city.

Table 2 Characteristics of the Bhopal city

Demographic profile	
City	Bhopal
Population	17,98,218
Municipal Area (in sq. Km)	463
Governing Body	Bhopal Municipal Corporation (1907)
The density of population (person per sq. km)*	6290
Literacy Rate (%)	83.47
Youth, 15 - 24 years (%)	21.3
Slum Population (%)	26.68
Working Age Group, 15-59 years (%)	65.22

Source: Census of India 2011, * District Census Handbook, Census of India, 2011

2.2 Study Design

Classification of data sources, delineation of the study area and the ward boundaries are prepared on ARC GIS software, then preparation of NDVI imagery using sentinel 2 satellite is done. The study design uses NDVI imagery for measuring urban greenness in the city and measures the distribution of public green spaces. Figure 1 Represents the steps involved in the development of IUGI.

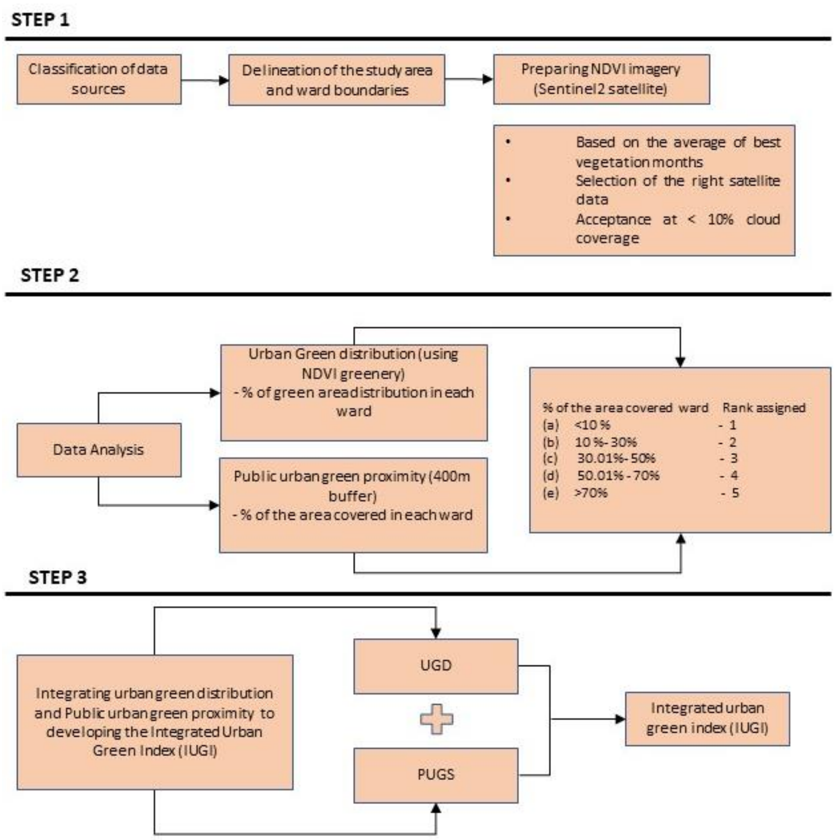

Figure 2 Representation of steps involved in the development of IUGI. Source: Author.

2.3 Data collection

To generate NDVI imagery, sentinel satellite images are used based on best vegetation months(Lange *et al.*, 2017)(Zhang *et al.*, 2018). The average of 6 satellite images between months of february and october is selected for analysis. The smallest urban administration area in India is ward level which is selected for a unit of analysis of urban green space distribution within city. The urban municipal boundary is marked along with ward boundaries in ArcGIS software. In this study UGS is divided into 4 Categories, (a) Urban parks (b) Urban playground (c) Institutional green (d) others (forest cover, vacant land, etc.). These spaces are marked in ArcGIS for the analysis.

2.4 Data Analysis

To get best NDVI image, data of 6 staellite images have been overlapped. The generated NDVI is categories as (a) Water bodies (b) Built-up area (c) Green (D) Dense green as shown in Figure 2. NDVI is commonly used to measure greeness of an area(Liu, 2017). NDVI data generated is then intersected with ward boundaries to measure distribution of greeness in each ward.

Figure 3 Represents the Urban Green Space UGS with in ward boundaries. To analyse the proximity of active urban green, only urban park and playground are selected as insitutional green is restricted for public and other green area have forest cover or vacant land. The buffer analysis is used to create proxomity of 400m i.e. within 5 minutes of walkable distance. The buffer created is then intersected to measure the area of proximity coverage within each ward, as shown in Figure 4 Map representing Buffer Analysis of Public Green Spaces with in ward boundaries.

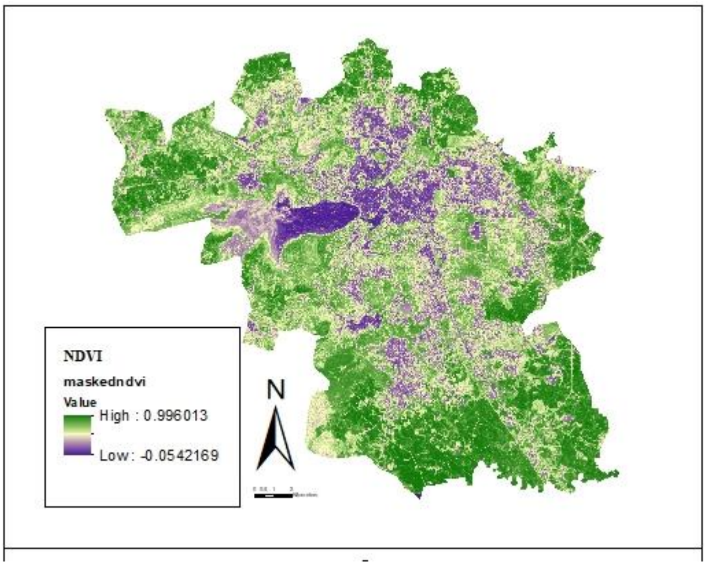

Figure 2 Map representing NDVI imagery of Bhopal. Source: Author.

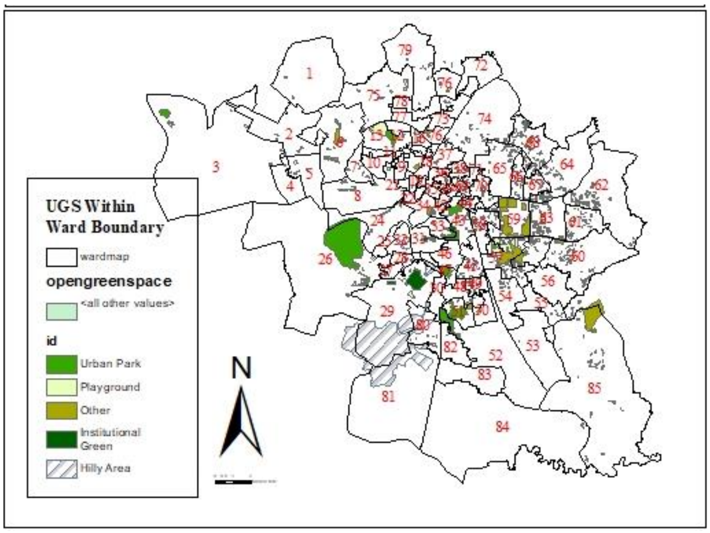

Figure 3 Map representing Urban Green Space UGS with in ward boundaries. Source: Author.

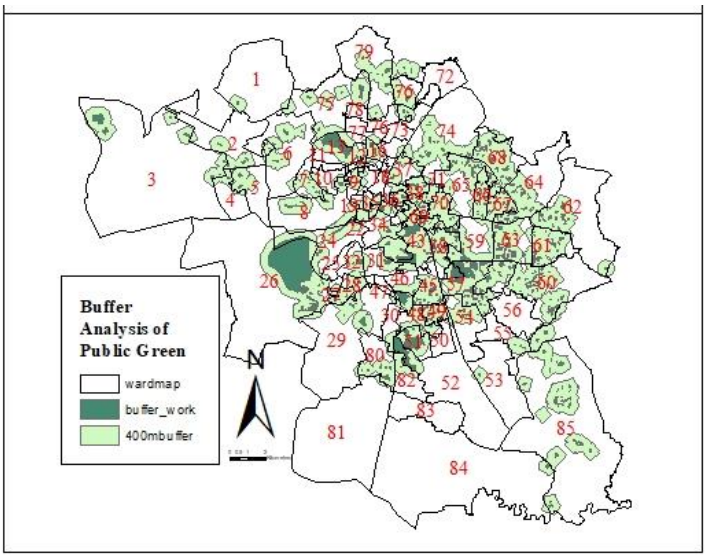

Figure 4 Map representing Buffer Analysis of Public Green Spaces with in ward boundaries. Source: Author.

To measure the percentage of greenness area distribution in each ward in this study rank is assigned as follows:

Area distribution	Rank assigned
(a) <10%	1
(b) 10-30%	2
(c) 30.01-50%	3
(d) 50.01-70%	4
(e) >70%	5

In measuring the distribution of the green space at ward level, the study calculated the percentage of areas whcih falls under respected wards. This study assign the rank based on the above criteria for both greeness distribution as well as parks and playground distribution within city.

The developed index gives 50% weightage to both, greeness as it has health benefits like purifying polluted air and parks and play ground for active living.

3. Results

The current assessment of ward level distribution of green space reflects the fair amount of public green space in most of the wards as per the Figure 5, and Table 3 shows the highest and the lowest ranks.

Table 3 Distribution of greenery, urban parks and playground and Interagted Urban green Index IUGI

Highest rank			
Ranks	IUGI (ward no.)	Greeness GR (ward no.)	Public parks & playground PPP (ward no.)
1	13	3	68
2	60	26	57
3	57	85	63
4	63	84	61
5	61	81	13
Lowest Rank			
80	18	20	83
81	17	41	78
82	11	21	50
83	21	40	73
84	73	23	25
85	14	14	11

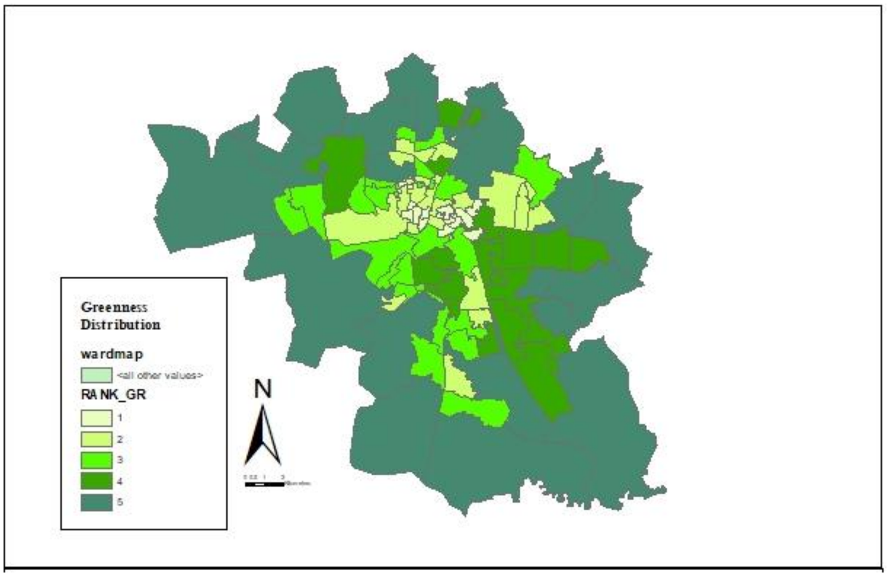

Figure 5 Map representing Urban Green Distribution with in ward boundaries

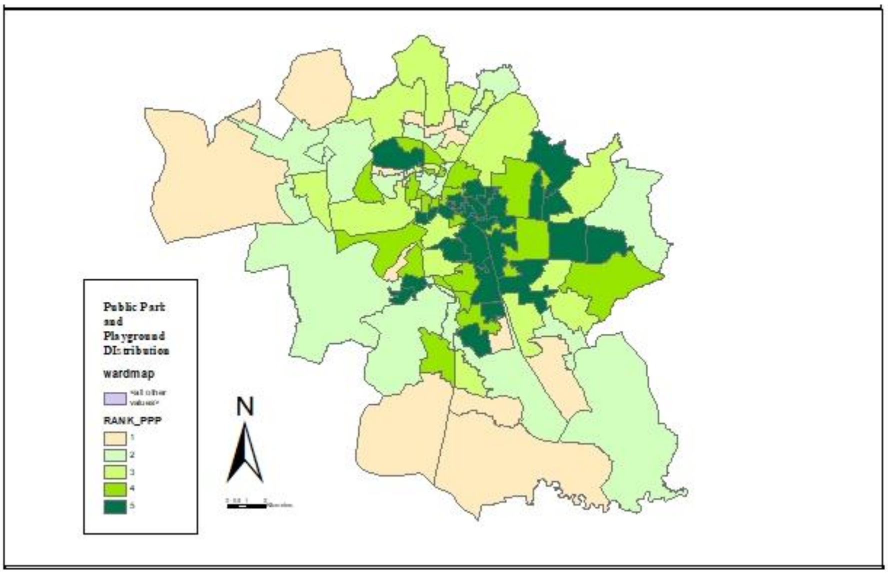

Figure 6 Map representing Public Park and Playground distribution with in ward boundaries. Source: Author.

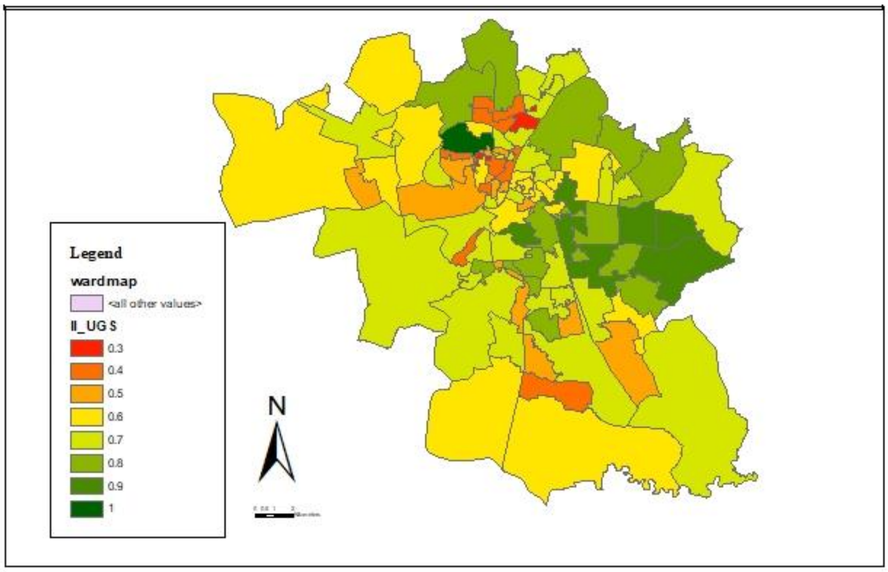

Figure 7 Map representing Integerated Urban Green Index. Source: Author.

4. Discussion

Urban greenery contributes to sustainable quality of life and development. The study addresses the distribution of urban green space, including parks and play grounds, which help in regulating psychological and physical health(Dzhambov *et al.*, 2020)(Li *et al.*, 2021), enhancing social relationships(Houghton and Castillo-Salgado, 2017), and giving educational possibilities. Future research could examine how urban dwellers experience and interact with parks and green space and their health implications. Is park provision enough, or is a certain quantity of nature needed? All types of green and open space can be utilized during disasters, rather they are needed for immediate relief from few disasters like earthquake, fire outbreak.(Kamat, 2015) (Kamat, 2019) Greenery and aesthetics motivates people to participate in physical activity found in few researches.(Verma and Tiwari, 2020) (Knowles, Ferbrache and Papa, 2019). In longitudinal research, increasing residential greenness reduces all-cause mortality. Expanding urban park infrastructure and activities may produce new urban livelihoods. Even if parks don't directly contribute to financial well-being, they're a common feature of rich metropolitan populations with plenty of economic prospects. In India ward level is best way to manage the green infrastructure and supporting facilities. As urban population is rising due to rural urban migration for better quality of life and earning opportunities. There is urban expansion in most of the Indian cities and reducing green space would negatively impact the well-being of the citizens.

5. Conclusion

This study proposes IUGI way to measure UGS which integrates both greenness as well as distribution of active green spaces like parks and playground. Mostly parks and playground is essential for growth of children. These spaces allow social interaction for old age people. India has the youngest population in the world and should plan its green spaces to eclectic benefits. This study adds new method to assess green space. This study lacks the perceived measure of urban green which can improve the infrastructure issue. In India there is still huge gap in pedestrian and cycling infrastructure. Unsafe road and safety is one of the prominent issues which need to be addressed. To strengthen this study future research can be on socioeconomic groups and other health related data to explore the relationship of current green space with other variables.

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