



City Biodiversity Index of Lucknow City: A case study

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ABSTRACT

Biodiversity index of a city is a self-assessment tool which helps the city to evaluate the present condition of the urban biodiversity, what are the current conservation strategies, the strength and weaknesses of the existing plan and what policies we need to take in the future for improvement. The whole work is conducted by extensive field survey and data collection and by the implementation of a Geographical Information System (GIS). The indicators are calculated by collected data following the manual of the 'Singapore index of cities biodiversity'. This is the first application of the index to the city where we describe the profile of the city and baseline measurements were done as indicators. All indicators are assigned with a particular range of points i.e., 0-4, which helps us to determine the current condition of biodiversity in Lucknow City. The total score of the 12 indicators (excluding indicators 4-8) is 30 points and the maximum point is 92 i.e., 32.60% which is below average that means a new conservation strategy needs to be taken and need to improve the old ones. This index is not a tool to be used only once, it needs to apply at regular time intervals for better results and development.

Key words: Biodiversity Index; Conservation; Indicators; Natural area

1) INTRODUCTION

Generally, it is believed that the cities have a smaller number of flora and fauna but in reality the urban areas are also rich in biodiversity. The uncountable, priceless ecosystem services provided by the local biodiversity of that area are often underrated by the local bodies. To reach to a solution the former Minister of National Development of Singapore suggested the establishment of city biodiversity index also known as Singapore Index, to measure the quality and quantity of biodiversity in cities in the year 2008. The indicators are developed by the Convention on Biological Diversity (CBD) to reduce biodiversity loss. On the month of September 2009, the first City Biodiversity Index user's manual was released on the CBD website [3].

The Singapore Index is a revolutionary self-assessment tool aimed to develop the biodiversity of a city. It also focused on to improve the strategy and biodiversity conservation efforts over time. This tool does not design to compare or to oppose between the functions of different cities nor a tool used only once. Initially the city needs to make a baseline measurement, later by recognizing the policy priorities of their data, measurements need to be done at periodic intervals.

The index helps cities to achieve their targets by three interconnected mechanisms, which are crucial for positive strategy outcomes. First, this tool helps the cities to make

measurements of the existing biodiversity profile of the city and then observe and evaluate them over time. Secondly, it assists as a public domain upon which increasing exercises of biodiversity awareness can be launched. Finally, the index serves as a platform in various departments like the city governance, institutions, academics, NGO's and the public, inspiring for better communication, establishment of networks and more co-operation, via collecting the data, sharing and involving the mutual goals, which eventually help in better results [8]. Several countries all over the world already applied this index to the city for example Japan (Yokohama, Kanazawa, Sapporo, Sendai, Chiba, Tokyo wards, Kawasaki, Nagoya, Kyoto, Osaka, kobe, Hiroshima, Kita Kyusyu, Fukuoka cities), Portugal (Lisbon city), Finland (Helsinki city), Canada (Edmonton city, Alberta). In India the first city who implemented this index is Mira Bhander in Mumbai [3]. In this paper we have calculated and make a baseline measurement of the biodiversity index of Lucknow city following the manual of Singapore index on cities biodiversity.

Index focused on two major parts – first the profile of the city which provides the basic information about the city like location, climate, temperature, rainfall, size of the city, population density, physical features of the city, what kind of ecosystems are available and the species diversity of the

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Lucknow city. The second part comprises 23 indicators which measures three factors – one is native biodiversity of the city, second ecosystem services provided by biodiversity of that area and third is governance and management of biodiversity [7].

2) MATERIALS AND METHODS

The methodology included field survey, data collection, implementation with GIS and calculation.

Field Survey: An extensive field study was conducted between November 2019 to March 2020 covering the major area of Lucknow City specifically urban parks, undisturbed green area, roadside plantation and built-up areas. The detail of the study area is given in the profile of the city. The field survey includes the observation of the total number of vascular plant species i.e. angiosperms, gymnosperms and pteridophytes; total number of species of butterflies and birds in the city. The field study also included the observation of how many water bodies are present, nature of the water bodies, amount and types of green area in the city. The field survey was conducted whole day at different time interval for better result.

Data collection: Not only the field surveys, the secondary data also collected from different government and non-government bodies, academic and non-academic institutions working on biodiversity and from different research papers previously surveyed species diversity of Lucknow city and from data bases [12] [13]. The data collection also involved how many species are reintroduced in the city, how many awareness programs are conducted in the city per year, how many government or local bodies are involved in biodiversity conservation, how many visits of below 16 year child to a natural areas per year are conducted.

Implementation with GIS: From the sentinel 2A satellite data of Lucknow city through ArcGIS and Google earth, the cover area of Lucknow city, existing forests, Undisturbed green areas, city parks area, area of different types of water bodies and impermeable areas are calculated. Not only has the area, through the software the length of the Gomti River, major canals in the city and the major roads also been delineated (Figure 1).

Calculation: The index calculation is done by following the manual of 'Singapore Index of Cities Biodiversity' like proportion of natural area in the city, Connectivity measures or ecological networks to counter fragmentation, proportion of protected natural areas, proportion of invasive alien species, regulation of quantity of water and recreational services (Table 3).

Profile of the city

Location: Lucknow district is the capital of the state Uttar Pradesh. It comprises of five tehsils viz. Sadar, Sarojni Nagar, Bakshi Ka Talab, Malihabad, Mohanlalganj; eight blocks viz. Mall, Malihabad, Chinhat, Bakhshi Ka Talab, Kakori, Gosainganj, Sarojni Nagar, Mohanlalganj and 961 villages [11]. The study site for calculation of biodiversity index is only Lucknow City. Geographical coordinates (latitudes and longitudes) of the Lucknow city are 26°50'21.41"N and 88°55'23.27"E covering the area of 531.126647 km².

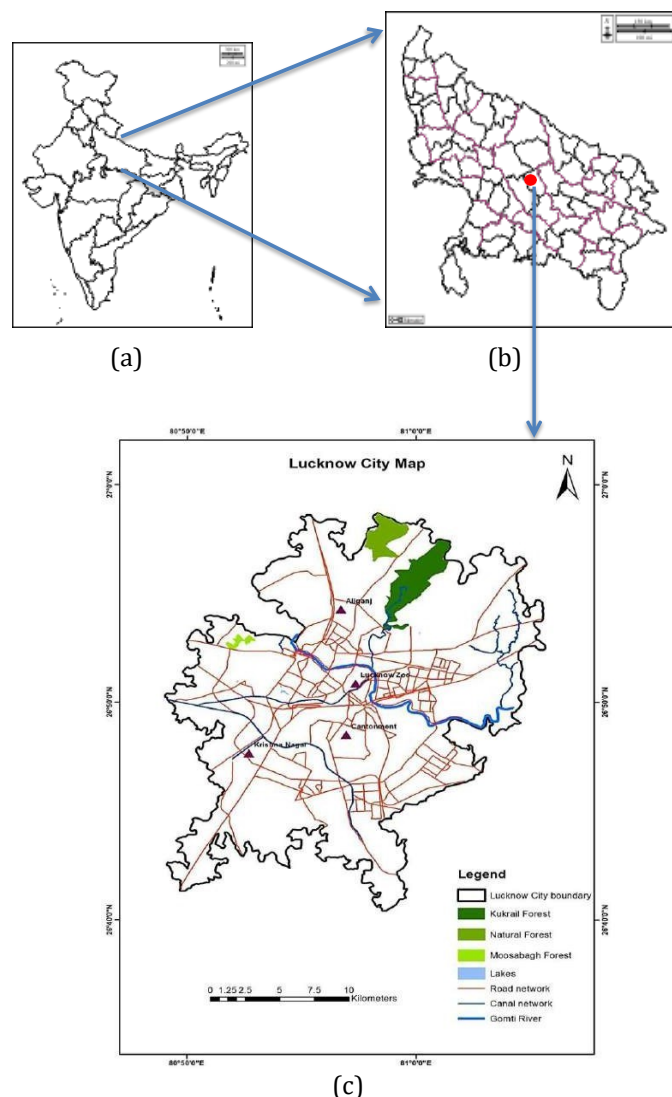


Figure 1: (a) India Map, (b) Uttar Pradesh map, (c) Study area: map of Lucknow City showing the existing ecosystems i.e., the forests, lakes and Gomti River with the major road network and canal network system.

Climate: Lucknow exhibit humid subtropical climate. It shows cool and dry winters extend from mid- November to February and summers are dry and hot with thunderstorms from late March to June. Fog is pretty common during winter season, from mid-December to late January. During winter season the average wind speed varies between 4-7.5 kmhr⁻¹ and in summer it varies between 9.9-11.7 kmhr⁻¹. The monsoon extends from July to September and gets its portion of rainfall from the southwest monsoon winds.

Population: According to the census in 2011 Lucknow city has a total population of 2,902,900 of which 1,460,970 are males and 1,356,235 are females approximately. Population density of the city is 1815 persons/km².

Physical features of the city: Geography – Gomti River enters the city after 240 km and flows through the Lucknow city dividing it into Trans - Gomti and Cis - Gomti regions (Table 2).

Lucknow city is situated in the middle of the Indus – Gangetic plain. Several rural towns and villages boarded the Lucknow city such as - Mohanlalganj, Itaunja, Malihabad, Gosainganj, Kakori and Chinhat. On its southern side lies

Raebareli, on the eastern side Barabanki, on the northern side Sitapur and Hardoi and to the west Unnao. Highest elevation of Lucknow city is 123.5 meter above sea level and lowest elevation is 110 meter above sea level [1].

Table 2: Showing the regions on the both side of the Gomti

Table 1: Month wise data of temperature, humidity and rainfall in mean \pm S.D. (Standard Deviation) of n=30, in the year 2019 [9][14].

Temperature range	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity	Rainfall (mm)
January	12.29 \pm 1.83	17.20 \pm 1.44	71.01 \pm 6.72	0.14 \pm 0.57
February	15.19 \pm 2.20	20.11 \pm 2.09	73.35 \pm 9.01	0.17 \pm 0.78
March	20.03 \pm 3.42	26.02 \pm 3.71	51.40 \pm 11.89	0.084 \pm 0.33
April	26.84 \pm 2.74	33.10 \pm 3.27	42.59 \pm 11.16	0.13 \pm 0.63
May	30.33 \pm 1.53	36.93 \pm 1.59	30.75 \pm 7.24	0.069 \pm 0.30
June	30.98 \pm 1.76	35.54 \pm 2.58	52.85 \pm 11.21	0.31 \pm 1.08
July	28.30 \pm 1.85	31.36 \pm 2.26	81.87 \pm 11.01	1.54 \pm 2.29
August	28.30 \pm 1.30	31.04 \pm 1.21	84 \pm 4.43	0.61 \pm 1.03
September	26.75 \pm 2.26	28.97 \pm 3.15	90.52 \pm 5.53	1.17 \pm 1.33
October	23.37 \pm 1.74	27.53 \pm 1.75	80.16 \pm 5.64	0.14 \pm 1.74
November	18.74 \pm 1.65	24.05 \pm 1.67	76.52 \pm 6.77	0.008 \pm 0.03
December	12.04 \pm 3.28	15.96 \pm 4.20	81.6 \pm 5.69	1.83 \pm 0.92

River [1]

Sl. No.	Cis - Gomti regions	Trans - Gomti regions
1.	Hazratganj	Nirala Nagar
2.	Aminabad	Aliganj
3.	Hussainganj	Daliganj
4.	Lalbagh	Old and new Hyderabad
5.	Gologanj	Mahanagar
6.	Wazirganj	Nishatganj
7.	Malviya Nagar	Indira Nagar
8.	Rajendra Nagar	Gomti Nagar
9.	Sarojni Nagar	Vikas Nagar
10.	Aishbagh	Jankipuram
11.	Rajajipuram	
12.	Saadatganj	
13.	Chowk	

The type of soil, found in the Lucknow City is alluvial soil which is formed mostly due to the silt deposited by Indo-Gangetic-Brahmaputra Rivers. Quaternary sediments can be divided into older and newer alluvium. The newer alluvium superimposes the older alluvium and comprises of light Khaki grey silt, clay and fine to medium and coarse-grained grey sand. The depth of the soil is above 300cm and the soil pH is ranging from 6.5 to 8.4.

The drainage of the Lucknow city is maintained by the river Gomti and its tributaries and by the Kukrail nala. During the entry point of the river, water is lifted from it for the city's water supply at the Aishbagh Water Works [1].

Biodiversity features and characteristics

Ecosystems found in the city: - Two types of ecosystems are found in the Lucknow city one is Forest ecosystem and other is Freshwater ecosystem. Three types of freshwater ecosystem are found in the city, those are river, lakes and ponds. Gomti River is the tributary of river Ganges. It is a

monsoon and ground water fed river flows through the middle of the Lucknow city with a length of 25.5570233 km. The lakes found in the Lucknow city are Moti jheel, Butler Lake, Rajajipuram Lake, Eldeco Udyan Lake and Jamuna jheel.

The Kukrail is an only reserve forest in Lucknow city covering an area of 20.105025 sqkm and located on the coordinates of 26°54'36.4"N and 80°59'15.7"E. The forest is a dry deciduous, subtropical type of ecosystem. Kukrail reserve forest is known for endangered Gharial breeding and conservation. Not only that this forest is a home of many native and endangered species of flora and fauna. U.P. State Biodiversity Board takes a great initiative along with other government bodies for the reintroduction of the native species *Indopiptadenia oudhensis* which is depleted from the Uttar Pradesh natural flora; Not only this species the government bodies of the city also reintroduced Sparrow with the help of local people by several activities and awareness programs.

Species found in the city: A huge diversity of species has been found in the city from microscopic to macroscopic. Among all of them few groups of species have been listed here. The major taxonomic groups include vascular plant species (angiosperms, gymnosperms and pteridophytes), Birds, Butterflies, freshwater fishes, invasive plant species and all of them the baseline data of the major taxonomic groups and few lower taxonomic groups has been listed here. The major taxonomic groups include vascular plant species (angiosperms, gymnosperms and pteridophytes), Birds, Butterflies, freshwater fishes, invasive plant species and the lower taxonomic groups contain Lichens, bryophytes and algae (*chlorophyceae*) (Figure 2, Table 3).

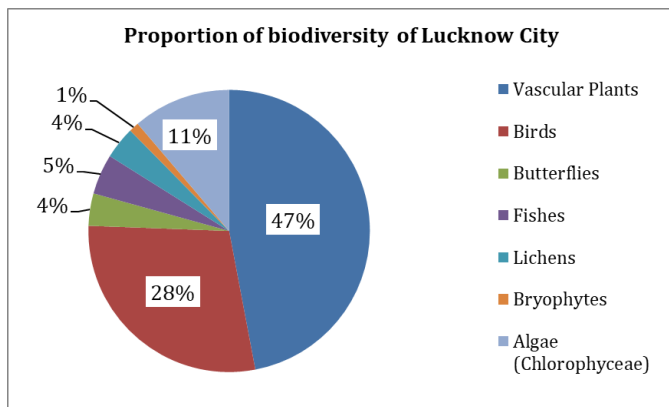


Figure 2: The percentage of biodiversity of major classes in the city (Table 3)

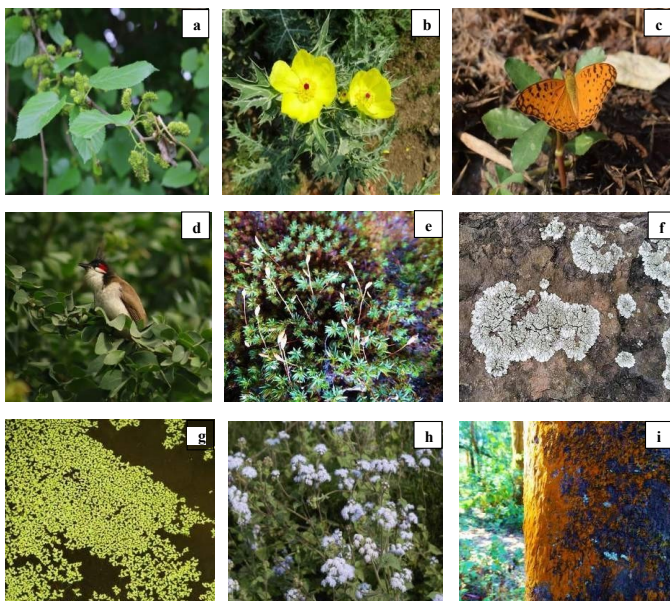


Figure 3: (a) *Morus alba*, (b) *Argemone maxicana*, (c) *Phalanta phalantha* (Common Leopard) (d) *Pycnonotus jocosus* (Red-whiskered Bulbul), (e) *Polytrichum* sp. (Bryophyte), (f) Crustose Lichen, (g) *Lemna purpusila* (Pteridophyte), (h) *Ageratum conyzoides* (invasive plant), (i) *Trentepohlia* sp. (Algae)

Administration of biodiversity

In Lucknow City there are several government and non-government departments and agencies, either directly or as a part associated with Biodiversity and its related works. List of some of the major departments are –

- a) Government bodies
 - Forest Department
 - U.P. State Biodiversity Board
 - Lucknow University
 - Nawab Wajid Ali Shah Zoological Garden
 - Babasaheb Bhimrao Ambedkar University
- b) Institutions
 - National Botanical Research Institute (NBRI)
 - National Bureau of Fish Genetic Resources (NBFGFR)
 - Birbal Sahni Institute of Paleosciences

3) RESULTS AND DISCUSSION

Here we describe the profile of the city and the indicators of the Lucknow city. Among the 23 indicators we can calculate only 16 indicators due to availability of the insufficient data. This is the first application of the index to the Lucknow city and all indicators presenting the baseline measurements. In case of indicators 4-8 with additional two parameters i.e. bryophytes and algae (Chlorophyceae), calculation of change in the native species, we cannot assign any score due to baseline data of the species. Each indicator has a score ranging from 0-4, where 0 indicates unsatisfactory, 1 is below average, 2 is average, 3 is satisfactory and the 4 indicates good condition. The maximum score of all the 23 indicators are 92 points and the calculated score of the 12 indicators (excluding indicator 4-8 and additional two parameters) is 30 points. It stands that the score of the Lucknow city Biodiversity Index is 30 points out of 92 points that is 32.60% representing below average percentile. The bar graph (Fig. 4) is showing indicator 3, 12, 14, 15 serving good in the biodiversity conservation and management; indicator 2 serve better, indicator 1, 10, 11, 13, 16 serve moderately and indicator 9 serve very poorly. According to these score now we can determine the present condition of biodiversity in Lucknow city and what conservation strategy should take by different stakeholders in the future to develop it. Through these indicators we also determine the weakness and strength of the city.

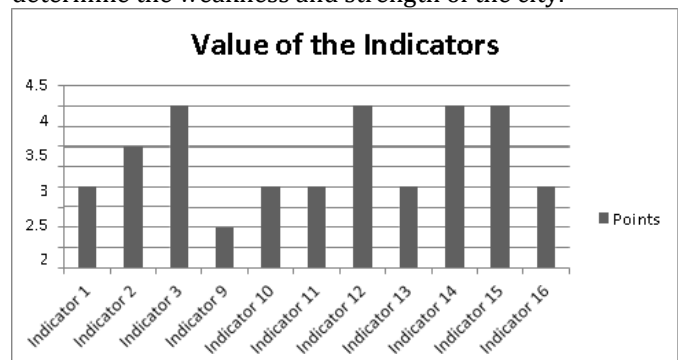


Figure 4: Indicators showing their proportion of serving in biodiversity conservation in one year.

Challenges

The major challenge of applying City Biodiversity Index successfully is lack of data to fulfill the criteria of the indicators. It has also been observed that some indicators need to be more precise as they are large in number and overlapping which make difficulty in calculation. Another problem is that a developing city is expanding in nature thus it is difficult to identify and measure proper geographical boundary of a city. The indicators comprise the number of species found in the city but it can be suggested that along with that if it consider the number of individual of each species, species abundance, density, frequency and the rate of species increase or depleted, ecosystem structure and degradation and how much impact it have on local people then it will provide more accurate framework of biodiversity.

Table 3: Indicators of Lucknow City Index

Core component	Indicators	Variables	Score
Native Biodiversity in the city	Indicator 1		
	Proportion of natural areas in the city	Formula: (Total area of natural restored and naturalized areas) / (Total area of city) * 100% Result: 12.3715196%	2 points: 7.0% - 13.90%
	Indicator 2		
	Connectivity measures or ecological networks to counter fragmentation	Formula: Indicator 2 = $\frac{1}{A_{max}} [(A1)^2 + (A2)^2 + (A3)^2 + \dots + (A_n)^2]$ Result: 1127.50212 ha	3 points: (1001-1500) ha
	Indicator 3		
	Native Biodiversity in built up areas (Bird species)	Formula: Number of native bird species in built up areas where built up areas include impermeable surfaces like buildings, roads, drainage, channels etc. and anthropogenic green spaces like roof gardens, roadside planting, golf courses, private gardens, cemeteries, lawns, urban parks etc. Areas that are counted as natural areas in Indicator 1 should not be included in this indicator. Result: Total number of bird species in built up areas are 70 – 80 approximately	4 point : > 68 bird species
	Indicator 4		
	Change in number of native species: Vascular plants	Baseline data of vascular plant species Result: Total no. of vascular plant species found in Lucknow city are 622. [Appendix 1]	Indicator 4 – 8 are the baseline data of the native species of Lucknow city during the first application of the index; there are no calculation of net change in native species and no points are applicable
	Indicator 5		
	Change in number of native species: Birds	Baseline data of native bird species Result: Total no. of birds species found in Lucknow city are 378 [Appendix 2]	----
	Indicator 6		
	Change in number of native species: Butterflies	Baseline data of butterflies Result: Total no. of butterflies species found in Lucknow city are 49 [Appendix 3]	----
	Indicator 7		
	Change in number of native species: Freshwater Fishes	Baseline data of native fish species Result: Total no. of freshwater fish species found in Lucknow city are 61 [Appendix 4]	----
	Indicator 8		
	Change in number of native species: Lichens	Baseline data of lichens Result: Total no. of lichen species found in Lucknow city are 49 [Appendix 6]	----

	Change in number of native species: Bryophytes	Baseline data of bryophytes Result: Total no. of bryophyte species found in Lucknow city are 15 [Appendix 5]	----
	Change in number of native species: Algae (Chlorophyceae)	Baseline data of algae (chlorophyceae) Result: Total no. of algal species are 149 [Appendix 7]	----
	Indicator 9		
	Proportion of protected natural areas	Formula: (Area of protected or secured natural areas) / (Total area of the city) * 100% Result: 3.98705848%	1 point: 1.4% - 7.3%
	Indicator 10		
	Proportion of invasive alien species	Formula: (Number of invasive alien species) / (Number of native species) * 100% Result: 16.5594855% [6]	2 points: 11.1% - 20.00%
Ecosystem services provided by Biodiversity	Indicator 11		
	Regulation of quantity of water	Formula: (Total permeable area) / (Total terrestrial area of the city) * 100% Result: 45.2813208%	2 point: 39.8% - 64.20%
	Indicator 12		
	Recreational services	Formula: (Area of parks with natural areas and protected or secured natural areas) / 1000 persons Result : 2.39455082 ha	4 points: > 0.9 ha/ 1000 persons
	Indicator 13		
	Educational services	Criteria: Average number of formal educational visits per child below 16 years to parks with natural areas or protected or secured natural areas per year Result: 1 to 2 formal educational visit take place	1 – 2 points : 1 point for one educational visit and 2 points for two educational visits
Governance and Management of Biodiversity	Indicator 14		
	Institutional capacity	Criteria: Number of essential biodiversity related functions that the city uses Result: There are 6 organizations which perform biodiversity related functions	4 points (4 point > 3 functions)
	Indicator 15		
	Education	Criteria: Is biodiversity or nature awareness included in the school curriculum (e.g. biology, geography, etc.)? Result: Yes	4 points: Biodiversity or elements of it are included in the school curriculum
	Indicator 16		
	Awareness	Criteria: Number of outreach or public awareness events held in the city per year Result: 77 events per year	2 points: 60 - 149 outreach events/ year
Total point			30 points

4) CONCLUSION

Though there are many challenges, but application of City Biodiversity Index has potential benefits. In future,

application of this index eventually helps in connecting many stakeholders more with biodiversity and its conservation. It will help to improve the data in the next implementation. It also benefits to recognize new bodies involved in biodiversity maintenance. Lucknow city has several local existing conservation strategies implemented by government bodies, different academic institutions and non-government bodies but this biodiversity index helps us to identify the gaps in local biodiversity management strategy. It also helps us to recognize the strengths and the weakness of the action plan, how many species of a particular taxonomic group is depleted or increased through time and how can we improve it. The city biodiversity index is not a tool to be used only once. After the first application, the city needs to apply this index in every three years to allow the city for taking place sufficient changes and to see either it is improving or not, or we need to take another strategy or action plan.

Author Contributions: Field survey, data collection, documentation, calculation and manuscript preparation were done by A. Ray. M. Mishra helped in the implementation of GIS and A. Kanaujia review the whole paper and data collection.

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Conflict of Interest: There is no conflict regarding the data provided in the manuscript. All are original data. Whichever data collected from other sources have authentic permission. I can assure that this is the first application of the city index in Lucknow City. No previous work has done before it on index on Lucknow. So, there is no potential conflict in publishing.

Supplementary Material: Appendix 1, Appendix 2, Appendix 3, Appendix 4, Appendix 5, Appendix 6, Appendix 7.

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