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Comparative Assessment of Ecosystem and Biodiversity Conservation Measures in Indian Smart Cities: A City Biodiversity Index Approach

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Abstract

Biodiversity and ecosystem services are of great importance for maintaining the sustainability of a city. Singapore Index, also known as City Biodiversity Index (CBI) is a tool for monitoring and evaluating a city's performance and progress related to conserving and enhancing biodiversity and ecosystem services. We have utilized the CBI for three Indian smart cities, i.e., Pune, Faridabad and Raipur for assessing their biodiversity level and for ranking them based on CBI scores. A standard method of CBI scoring as mentioned in the 'User's Manual on the Singapore index on cities' biodiversity' has been followed. Though there was a severe lack of data availability for these Indian cities, still the CBI scores, based on the limited data, could identify the gaps in the biodiversity protection and related programs for these cities and also could point out the areas that should be taken care of for improving the situation. Thus this study would be a motivational tool and could provide incentives for local Governments to start making inventories and monitoring their programs on biodiversity and ecosystem protections which would be beneficial for the cities' long run sustainability. The uniqueness lies in the fact that, in this research, the CBI scoring approach has been implemented for three particular Indian smart cities, which was never done earlier for any other smart city in India.

Keywords: *Indian Smart Cities; City Biodiversity Index; Ecosystem; Urbanization*

1. Introduction

Rapid urbanization is the most common feature worldwide in recent years. During the next four decades, all of the world's population growth is expected to take place in urban areas. Statistics show that urbanization is spreading very rapidly. And this rapid urbanization is severely affecting ecosystems and natural resources. For example, in 2005, cities occupied two percent of Earth's surface, but the inhabitants used 75 percent of the planet's Natural resources. By 2050, the global population is expected to increase to 9.2 billion, of which 6.4 billion will be living in urban areas **[1]**. Consumption based on urban lifestyle requires a huge amount of natural resources and generates the level of waste that in turn severely increases pollution of air, water and soil. Also, with the rapid increase in population density, the environmental and ecological footprints of cities are increasing at an alarming pace. Urban expansion encroaching on forests, wetlands, agricultural lands and other ecosystems leads to degradation and fragmentation of the landscapes and extinction of species. Statistics shows that 8 percent of terrestrial vertebrate species have been labeled as endangered as a result of rapid urban development [2]. Therefore, now it is very important to capture the status and trends of biodiversity and ecosystem services in urban landscapes in order to understand whether the city development is sustainable or not. Valuations of ecosystems in both monetary and non-monetary terms are also important for mainstreaming ecological considerations into the management of a city. In fact, balancing and maintaining urban biodiversity and ecosystem is emerging as one of the toughest job to all local authorities and municipalities of the rapidly urbanizing cities in India. In the process, it has been learnt that to develop a tool to reflect and measure the city's biodiversity will help to manage the situation in a much sustainable way. Section 41 of the Biological diversity Act- 2002 provides the scopes to Municipal Corporations to perform all the activities relevant to its overall Biodiversity Management **[3].**

For a country like India, which is one of the 17 "mega diverse: countries in the world and enriched with different ecosystems like forests, grasslands, wetlands, coastal, marine and deserts [4]and presently where the current Government has taken an important social agenda like '100 smart cities in India', it is much relevant to do researches and prepare policies which could be incorporated to maintain ecosystem level in the smart city planning. Thus, for sustainable issues of smart city development, inclusion of index based ecosystem measurement tool of cities, popularly known as Biodiversity Index / Singapore Index is very important for the urban planners and policy makers.

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2. Objective of this study

In this context of biodiversity and ecosystem service measurement in the smart city planning, we implement the City Biodiversity Index for three Indian cities namely: Pune, Raipur and Faridabad in our study. These three cities were listed in the first '100 smart city' list published by the Government of India as future smart cities which should be developed by FY 2019-20.

The 'City Biodiversity Index (CBI)' also known as 'Singapore Index on Cities' Biodiversity (SI)', that has been utilized in this study is a tool for monitoring and evaluating city's performance and progress related to conserving and enhancing biodiversity and ecosystem services. The main objective for CBI scoring of the proposed smart cities is to take actions to conserve the biodiversity level which should be started with stock-taking and identifying the baselines. This should then be followed by regular monitoring and evaluation of the conservation initiatives [**1**]. Under this indexing method, 23 indicators have been taken up to measure native biodiversity in these cities, ecosystem services provided by the biodiversity, and governance and management of biodiversity. Each indicator is assigned a scoring range between zero and four points, with a total possible maximum score of 92 points.

Data has been collected for each indicator through secondary as well as primary sources. Through the data analysis, we tried to see the existing level of biodiversity and ecosystem of these three cities, the already existing Government policies for ecosystem protections and the level of implementation of the same. Based on this, we have scored the cities on different indicators.

Finally, policy recommendations were made for these three cities for the enhancement of their existing levels of biodiversity and ecosystem which in turn will help to enhance the sustainability of the smart city development plans and policies.

3. Literature review

Urban habitats depend on ecosystems and biological diversity both within and beyond the urban environment for a wide array of goods & services supporting their economic, environmental and social sustainability. Ecosystems have the potential in cities to regulate climate, protect against hazards, meet energy need, and offer opportunities for recreation and cultural inspiration.

We generally assume that urban habitats are devoid of flora and fauna – but the reality is that many cities are located in or near biodiversity hot spots; many have rich biological diversities irrespective of their climatic condition and geographical location. For example, the median distance from a protected area to a city in eastern Asia is predicted to fall from 43 kilometers. in 1995 to 23 kilometers by 2030. In reality, we see that the cities typically develop in places that are the most biologically diverse **[2].** Also, there are many evidences of increase in biodiversity level as well in or around a city which is also experiencing sharp human population increase and rapid urban expansion. The example of Mumbai city is remarkable in that the recovery of some mangrove forests has been noticed in Navi Mumbai corridor along the eastern side of Thane creek. This might be due to the decrease in the dependence of surrounding populations on fuel wood, as a result of a shift to alternative sources such as compressed natural gas and electricity. This is a good example of changes in human consumption pattern that can have consequences for ecosystem degradation as well as for restoration. Also, since the mid-1990s, Thane creek area near Mumbai city has become an important migrating ground for a sizeable population (10,000 to 15,000) of Greater Flamingoes during winter season. This shows unusual evidence of a native wildlife species migrating to a habitat right in the middle of a rapidly expanding megacity. Thus urbanization could become both a challenge and an opportunity to manage biological diversity and ecosystem services globally [5].

Also, as urban populations burgeon, effective land use and management of natural ecosystems in urban areas become beneficial to both residents and biodiversity in and around the city. The ecosystem services that urban biodiversity provides to the surrounding habitat areas are innumerable and often undervalued. Besides aesthetics, ecosystems and biodiversity regulate the quality and supply of water, soil and air as well as maintain the climatic temperatures. Urban water supply frequently comes from catchment areas within or beyond the city boundaries; which are sustained by natural ecosystems that purify and store the water. 'Urban greenery replenishes oxygen, sequesters carbon, absorbs solar radiation, reduces air pollution, maintains water balance and regulates surface temperature in urban landscapes through shading and evapotranspiration.' Parks and natural protected areas like reserved forests within or beyond city areas provide recreational and educational opportunities to urban dwellers and contribute towards the aesthetics and livability of a city [**1**].

Hence, city planning with biodiversity protection must be an integrated part of the sustainable solutions for city habitats and there should be public participation with local Government to materialize this goal. For example, in Bangalore, collaborations between municipal government and local communities have led to a growing movement towards the restoration of lakes. To make these efforts of biodiversity and ecosystem protection, city biodiversity indexing for a city is quite effective. Scoring the city based on the city biodiversity indexes is a very useful approach to maintain and protect the ecosystems and biodiversity in and around a city. Utilization of CBI can motivate and provide incentives for municipalities to start making inventories and monitoring their programs on

biodiversity. As per Pereira et al. 2013, in recent days, integrating remote sensing data and in situ observations to monitor several essential biodiversity variables such as habitat structure and phenology would be realistic and effective.

Hyderabad was the first Indian city which utilized City Biodiversity Index to assess its biological diversity aspects. In the document 'Greater Hyderabad City Biodiversity Index, 2012['**3**] published by Greater Hyderabad Municipal Corporation, Hyderabad, the city Hyderabad has been scored based on different biodiversity indices using the CBI methodology in the same way as we have done for our study in Raipur, Pune and Faridabad. It is recommended that subsequent applications of the Singapore Index take place every three years to allow sufficient time for changes to have taken effect or the results of biodiversity conservation efforts to materialize [**1**]. However, though not much publicized, another Indian city has also had CBI based scoring - a small town named Mira Bhainder in the state of Maharashtra in India.

However, now, CBI has become legally mandatory for many cities in different countries, and authors [6] have discussed about different evaluation of experiences with the CBI in different cities worldwide, namely, Yokohama, Kanazawa, Lisbon (Potugal), Helsinki (Finland), Edmonton (Canada), Mira Bhainder (India). For example, they mentioned in the, application of the 'CBI in Japan was brought under a new law, titled Basic Law on Biological Diversity (Seibutsu Tayousei Kihon-ho), that was introduced in 2008 as a parliamentary act. In Article 13 of the Law, municipalities (prefectures, cities and other local units) were called upon to develop their local biodiversity action plans. The Ministry of Environment has been leading the process with plans to develop a handbook for the municipalities including instructions on the usage of specific indicators to promote development of local biodiversity strategy and action plans.' Already the CBI has been applied in 15 Japanese cities.

In general, humans and nature are always an integrated part in Japanese traditional thinking and landscape management [7]. As mentioned in the UNU-IAS OUIK 2011, the Kanazawa CBI experience shows that the local versions of CBI could be developed with locally adapted forms of the indicators, reflecting the uniqueness and customized nature of individual cities in different geographical, ecological and cultural contexts.

However, though CBI is a very useful tool and nowadays becoming mandatory for the local municipalities by the Governments worldwide, this indexing technique has its own limitations as well. It is evident that the CBI has drawbacks in its methodology which need to be addressed: (1) lack of data and the scale and boundaries need careful consideration, (2) the scoring represents a challenge as the bio- geographical differences or the profile of the cities varies largely, (3) the number and scope of ecosystems captured are limited and a broader range of ecosystem services should be included, and (4) the integrated social-ecological dimension of cities needs further development [6].

4. Methodology

Biological diversity of a city largely depends on its geographical position and climatic conditions. To examine, how the differences affect the scoring, we have selected our case study cities, i.e., Pune, Faridabad and Raipur from different parts of India which comprises of different geographical and climatic zones. While providing scores to our three case study cities based on city biodiversity indexing, we simply followed the standard CBI or Singapore indexing method as described in 'User's Manual on the Singapore index on cities' biodiversity'[**1**].

The CBI is comprised of two parts: 1) The 'Profile of the City', and 2) 23 indicators that measure native biodiversity in the city, ecosystem services provided by the biodiversity, and governance and management of biodiversity. Each indicator is assigned a scoring range between zero and four points, with a total possible maximum score of 92 points [**1**]**.** All the 23 indicators come under three broad categories, e.g; 1) Native Biodiversity in the city (indicator-1 to indicator-10), 2) Ecosystem Services provided by biodiversity (indicator-11 to indicator-14), 3) Governance and Management of biodiversity (indicator-15 to indicator-23). These three broad categorization shows that the goal of these indicators are to measure the city's native biodiversity level, ecosystem services from the existing biodiversity and how the particular city's local Government and management protect the existing BDV and their level of seriousness and effectiveness about the same.

However, the following is the list of 23 indicators, which are specifically designed to meet the following three criteria: 1) to be a comprehensive tool for assessing not only biodiversity, but also ecosystem services, governance and management, 2) to be a self- assessment tool, and 3) to be a simple yet scientifically credible tool. In the following table, the description and explanation of each indicator are provided as well.

Box: 1 List of Indicators [1]

1) **Proportion of natural areas in the city:** Natural ecosystems harbour more species than disturbed or man-made landscapes, hence, the higher the percentage of natural areas compared to that of the total city area gives an indication of the amount of biodiversity there.
2) **Recreational and Educational services** through area of parks: Biodiversity provides invaluable recreational, spiritual, cultural and educational services. It is essential for physical and psychological health.
3) **Budget allocations for biodiversity:** This indicator evaluates the financial commitment of city government towards the maintenance and enhancement of biodiversity.

4) **Ecological Networks to counter habitat fragmentation**
5) Native Bird species biodiversity in built-up areas
6) Changes in number of native bird species
7) Changes in number of native butterflies species
8) Changes in number of native reptiles species
9) Changes in number of native fresh-water fish species
10) Extent of Protected areas: Protected or secured natural areas indicate the city's commitment to biodiversity conservation. Hence, the proportion of protected or secured natural areas is an important indicator.
11) Proportion of invasive Alien Species
12) Regulation of quantity of water: Climate change in many places is predicted to result in increased variability in precipitation which in urban landscapes may translates into high peaks in water flow and damage to construction, business and transport.
13) Climate Regulation: Carbon storage and cooling effect of vegetation: Climate regulation services are affected by many factors, including size of trees, different characteristics of tree species, and other variables.
14) Number of biodiversity projects implemented in the city per year: It measures the no. of biodiversity related projects and programmes that the city authorities are involved in, either as a main player or in partnership with the other entities where the city is a key collaborator.
15) Policy, Rules and Regulations: To ensure that there is good governance, sound policies must be formulated. To facilitate the implementation of biodiversity management policies, rules and regulations must be put in place. This section evaluates the existence of policies, rules and regulations relevant to biodiversity, in particular if they are aligned with the national agenda and CBD's initiatives, like the National Biodiversity Strategy and Action Plan (NBSAP) and/or the correspondent subnational strategies
16) Institutional capacity: Inter-agency cooperation
17) Institutional capacity: Essential biodiversity-related functions
18) Public consultation process
19) Institutional Partnership
20) Inclusion of Biodiversity awareness in the school curriculum: The incorporation of this indicator creates the opportunity for city officials to liaise with education officers so that biodiversity courses are taught at pre-school, primary, secondary and tertiary levels.
21) Number of outreach or Public awareness programs: The event should either be organized entirely by the city authorities, or there should be a heavy involvement of the authorities before the event can be considered for inclusion in the indicator.
22) Recreational and educational services through educational visits of children
23) Changes in number of native vascular plant species.

Each indicator is assigned a scoring range between zero and four points, with a total possible maximum score of 92 points. Data has been collected for each indicator through secondary data sources like Municipality websites, Government data sources, local NGOs websites, and newspaper and research papers on local biodiversities. Through the data analysis, we tried to see the existed level of biodiversity and ecosystem of these three cities, the already existing Government policies for ecosystem protections and the level of implementation of the same.

Finally, policy recommendations were made for these three cities for the maintenance of their existing levels of biodiversity and ecosystem and also implementation of the same which in turn will help to enhance the sustainability of the smart city development plans and policies.

4.1 City Biodiversity Index based scoring of three cities

As discussed earlier, biological diversity of a city largely depends on its geographical position and climatic conditions and our case study cities vary from each other in respect of their geographical location and climatic condition.

Pune City is situated in the transition zone between Deccan Plateau and moist mountains like the Western Ghats. Faridabad is bordered by the Yamuna to the East and the Aravalli Hills towards the West and Southwest. Raipur is located near the centre of a large plain and is covered by many rivers, e.g. Mahanadi to the east and with dense forests to the southern side. The Maikal Hills on the north west of Raipur; on the north the land rises and merges with the Chota Nagpur plateau. On the south, Raipur lies in the Deccan Plateau.

In terms of cities' biological diversity and conservation of ecosystems, Pune is in advanced condition compared to other cities. Main reasons could be existence of biodiversity hotspot within the Pune city. However, on one hand, Raipur have such hotspots away from the city region, whereas Faridabad City does not have any such hotspot though surrounded by Aravalli range of mountains.

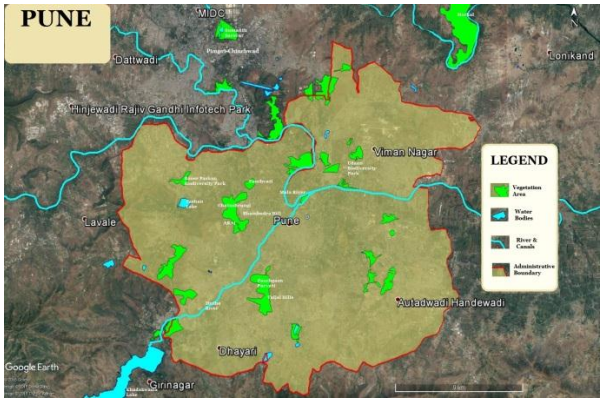

Figure 1 Map of Pune city showing the natural green areas

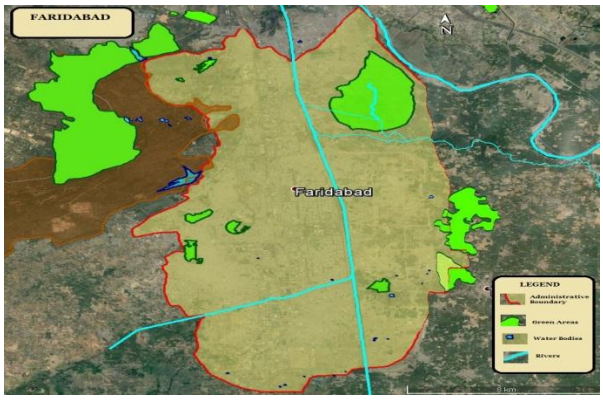

Figure 2 Map of Faridabad city showing the natural green areas

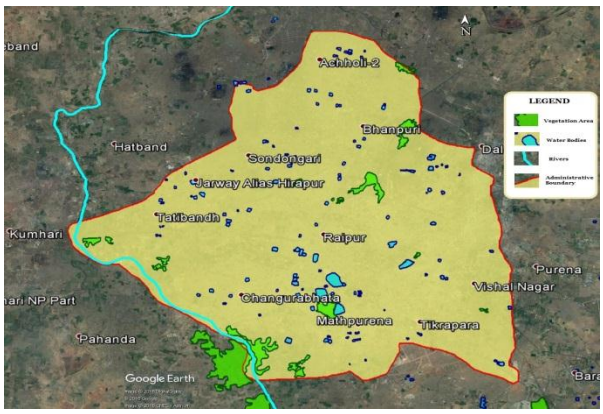

Figure 3 Map of Raipur city showing the natural green areas

Figure 1, 2 and 3 shows the map of our three case study cities Pune, Faridabad and Raipur respectively which consist of the proportion of natural green areas, water bodies and rivers.

4.2 Description of scoring mechanism and results

Based on the 23 standard indicators of the CBI, the case study cities has been scored. The following table shows the scorings of the three cities based on the 23 indicators. Also the table describes the formulas [1] those have been utilized for the calculations of the indicators. Also the calculated values of the indicators have been mentioned in the Table 1 below along with their explanations on how to scope the indicators, ranges of values and total scores.

While investigating the indicators' performances across the case study cities, we came across difficulties in terms of data and information. The major data deficiencies are observed for the indicators related to species number and ratio of alien to native species followed by the number of invasive species within the city area. Pune city has done some species identification related work especially for birds and butterfly but other cities are far behind that. Following the mechanism of the Singapore Index the total cumulative maximum score that a city can be allocated is 96. Here we evaluated the case study cities on 96 total score although we observed that more than one third of the indicators were not measureable in India due to lack of data. We envisaged low scoring of the cities indeed but it could also pave the path for future planning and development in this context of measuring ecological and biodiversity related performances of urban development.

Table 1 Detailed analysis of CBI scoring of the cities

No.	Indicators	How to measure	Scoring Range	Assessment of Indicator Performance			Scores		
				Pune	Faridabad	Raipur	Pune	Faridabad	Raipur
	I-1. Proportion of Natural Areas in the City	(Total area of natural, restored and naturalised areas) ÷ (Total area of city) × 100%	0 points: < 1.0% 1 point: 1.0% – 6.9% 2 points: 7.0% – 13.9% 3 points: 14.0% – 20.0% 4 points: > 20.0%	In Pune, 21% Natural area in compared to total City area. According to Environment and Forest (MoEF) guidelines, a city should have 33% green cover of its total area. Total area of Pune city is 243 sq.km. 85 sq. km i.e. 35% is under green cover which is more than the given guidelines. Green space in Pune covers hillocks (950 hectares), forest area (2380 hectares) and 115 gardens. Indicator Value : 21% [8][9][10]	15% of the Faridabad city comprise of Natural areas which includes Batkhal lake, Suraj kund lake, a portion of Asola Bhatti Wildlife Sanctuary, and portions of surrounding Aravalli hills. [26], [27], [28], [29] Indicator Value: 15%	Raipur city and surroundings (Raipur district) are consists of 21% of natural area which comprises of 44211 hectors of wetlands and 4412.7 km2 forest area.[44][45] [46] Indicator Value : 21%	4	3	4
Native Biodiversity in cities	I-2. Connectivity Measures or Ecological Networks to counter habitat fragmentation	X= 1/Atot (A12+A22+..... + An2) Where: · A total is the total area of all natural areas · A1 to An are areas that are distinct from each other (i.e. more than or equal to 100m apart) · n is the total number of connected natural areas	0 points: < 200 ha 1 point: 201 - 500 ha 2 points: 501 - 1000 ha 3 points: 1001 - 1500 ha 4 points: > 1500 ha	Here we have calculated the total natural area and also considered natural areas separately which are distinct from each other. But, natural patches which are less than 100m apart from each other have been considered connected. 5.02%. Indicator Value: 0 [11],[8]	Here we have calculated the total natural area and also considered natural areas separately which are distinct from each other. But, natural patches which are less than 100m apart from each other have been considered connected. [30] Indicator Value : 298 Ha	Indicator value : 0 [47]	0	1	0

I-3. Native Biodiversity in Built Up Areas (Bird Species)	Number of native bird species in 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.	0 points: < 19 bird species 1 point: 19 - 27 bird species 2 points: 28 - 46 bird species 3 points: 47 - 68 bird species 4 points: > 68 bird species	Comparing many other cities in India, there are good researches and studies on the bird species available in Pune. For example, Ecological Society of Pune have done some studies on these issues Data got from one of them. Indicator value : 85 [12],[13]	0 [12] Indicator value : 0 [12]	More than 68 including nocturnal birds. Bird Count India conducted two workshops in Raipur, Chhattisgarh on 6-7 November 2016. The workshops were organised by the Birds and Wildlife Group of Chhattisgarh and the Science College, Raipur. [12], [48], [49] Indicator value : 68	4	0	**3**
I-4. Change in Number of Vascular Plant Species		0 points: maintaining or a decrease in the number of species 1 point: 1 species increase 2 points: 2 species increase 3 points: 3 species increase 4 points: 4 species or more increase	N/A	N/A	N/A	N/A	N/A	N/A
I-5. Change in Number of Bird Species			N/A [13]	N/A	N/A [50]	N/A	N/A	N/A
I-6. Change in Number of Butterfly Species			N/A [14]	N/A	N/A	N/A	N/A	N/A
I-7. Changes in number of native reptiles species			N/A	N/A	N/A	N/A	N/A	N/A

	I-8. Changes in number of native fresh-water fish species			N/A	N/A [31]	N/A	N/A	N/A	N/A
	I-9. Proportion of Protected Natural Areas	(Area of protected or secured natural areas) ÷ (Total area of the city) × 100%	0 points: < 1.4% 1 point: 1.4% - 7.3% 2 points: 7.4% - 11.1% 3 points: 11.2% - 19.4% 4 points: > 19.4%	The major two protected areas in Pune city are Baner Pashan Biodiversity Park and Udaaan Biodiversity Park. Bhimashankar WLS & Mayureswar WLS are though nearby but outside Pune city area. Indicator value : 55.5% [8],[9],[10]	Natural Conservative Zone (NCZ) of Faridabad has shrunk by 26%.Only 1333.7 hectres of Faridabad Dist.(city and surroundings) are consisting of protected forest area. Indicator value : 3.9% [32], [33],[34], [35], [36]	Three protected forest or sanctuaries, namely Barnawapara Sanctuary, Sitanadi Sanctuary and Udanti Sanctuary-- all are outside Raipur city area (though within Raipur district) [51] Indicator value : 0%	4	1	**0**
	I-10. Proportion of Invasive Alien Species	(Number of invasive alien species) ÷ (Total number of species) × 100%	0 points: > 30.0% 1 point: 20.1% - 30.0% 2 points: 11.1% - 20.0% 3 points: 1.0% - 11.0% 4 points: < 1.0%	N/A [12]	N/A [32]	N/A	N/A	0	N/A
Ecosystem Services provided by Biodiversity	I-11. Regulation of Quantity of Water	(Total permeable area) ÷ (Total terrestrial area of the city) × 100%	0 points: < 33.1% 1 point: 33.1% - 39.7% 2 points: 39.8% - 64.2% 3 points: 64.3% - 75.0% 4 points: > 75.0%	Total area of Pune city is 243.84 sq.km. out of which 85 sq. km i.e. 35% is under natural green cover which has taken as the proportions of permeable area of Pune city. [9],[10] Indicator value : 35%	Total terrestrial area of Faridabad city is: 34368 ha [36], [37] Indicator value : 45%	N/A	1	2	**N/A**
	I-12. Climate Regulation: Carbon Storage and Cooling Effect of Vegetation	(Tree canopy cover) ÷ (Total terrestrial area of the city) × 100%	0 points: < 10.5% 1 point: 10.5% - 19.1% 2 points: 19.2% - 29.0% 3 points: 29.1% - 59.7% 4 points: > 59.7%	State average data of Maharashtra has been used here. [15] Indicator value : 3.11%	State average data of Haryana has been used here Indicator value : 3.09%	State average data of Chhattisgarh have used here. [15] Indicator value : 2.68%	0	0	**0**

	I-13. Recreation and Education: Area of Parks with Natural Areas	(Area of parks with natural areas and protected or secured natural areas)*/1000 persons *Some cities refer to this as accessible green spaces Area of natural areas = (194+221)ha=415ha	0 points: < 0.1 ha/1000 persons 1 point: 0.1 - 0.3 ha/1000 persons 2 points: 0.4 - 0.6 ha/1000 persons 3 points: 0.7 - 0.9 ha/1000 persons 4 points: > 0.9 ha/1000 persons	In Pune city, there are number of biodiversity parks, theme gardens and parks whose total areas cover around 415 ha. [16],[17] Indicator value : 0.42 ha/1000	In Faridabad city, total natural areas covered are 5341 ha which includes part of Asola Bhatti, and part of Aravalli range.[29] Indicator value : 5.3ha/1000	In Raipur, 2168 hectres of area comes under recreational use. [52], [48] Indicator value : 2.1 ha/1000	2	4		**4**
	I-14. Recreation and Education: Number of Formal Education Visits per Child Below 16 Years to Parks with Natural Areas per Year		0 points: 0 formal educational visit/year 1 point: 1 formal educational visit/year 2 points: 2 formal educational visits/year 3 points: 3 formal educational visits/year 4 points: > 3 formal educational visits/year	Private schools conduct more than 1 education Visits per Child below 16 Years to Parks with Natural Areas per Year while the Government schools conduct 0-1 such education Visits. So for this indicator, average value is 1. Indicator value : 1	Private schools conduct more than 1 education Visits per Child below 16 Years to Parks with Natural Areas per Year while the Government schools conduct 0-1 such education Visits. So for this indicator, average value is 1. Indicator value : 1	Private schools conduct more than 1 education Visits per Child below 16 Years to Parks with Natural Areas per Year while the Government schools conduct 0-1 such education Visits. So for this indicator, average value is 1. Indicator value : 1	1	1		**1**
Governance and Management of Biodiversity	I-15. Budget Allocated to Biodiversity	(Amount spent on biodiversity related administration) ÷ (Total budget of city) × 100%	0 points: < 0.4% 1 point: 0.4% - 2.2% 2 points: 2.3% - 2.7% 3 points: 2.8% - 3.7% 4 points: > 3.7%	Total budget of municipality of Pune is available but budget for biodiversityis not available. So state average biodiversity budget for Maharastra has been used. [18], [19], [20] Indicator value : 0.8%	Total budget of municipality of Faridabed is available but budget for biodiversityis not available. So state average biodiversity budget for Haryana has been used. [19] Indicator value : 0.2%	Total budget of municipality of Raipu is available but budget for biodiversityis not available. So state average biodiversity budget for Chattishgarh has been used. [19][53] Indicator value : 1%	1	0		**1**

I-16. Number of Biodiversity Projects Implemented by the City Annually	0 points: < 12 prog/projects 1 point: 12 - 21 prog/projects 2 points: 22 - 39 progs/projects 3 points: 40 - 71 prog/projects 4 points: > 71 prog/projects	Comparing many other Indian cities, Pune has number of active NGOs, Private companies and activists who conduct number of projects and programs for biodiversity protection throughout the years. [15] Indicator value : 2	There are very few such programs/ projects are listed in Faridabad City. Indicator value : 0	There are very few such programs/ projects are listed in Raipur city . [12], [48], [49] Indicator value : 0	2	0	**0**
I-17. Existence of Local Biodiversity Strategy and Action Plan (LBSAP)	0 points: No LBSAP* 1 point: LBSAP not aligned with NBSAP 2 points: LBSAP incorporates elements of NBSAP, but does not include any CBD initiatives** 3 points: LBSAP incorporates elements of NBSAP, and includes one to three CBD initiatives 4 points: LBSAP incorporates elements of NBSAP, and includes four or more CBD initiatives	Though municipality takes some kind of biodiversity measures and conducts programs for public awareness, but no formal LBSAP has been taken up [21]. Indicator value : None	Though municipality takes some kind of biodiversity measures and conducts programs for public awareness, but no formal LBSAP has been taken up.[38] Indicator value : None	Though municipality takes some kind of biodiversity measures and conducts programs for public awareness, but no formal LBSAP has been taken up. [54],[55], Indicator value : None	0	0	**0**
I-18. Institutional Capacity: Number of Biodiversity Related Functions	0 points: No functions 1 point: 1 function 2 points: 2 functions 3 points: 3 functions 4 points: > 3 functions	In Pune, there are more than 13-14 biodiversity park, theme garden etc. [22][9] Indicator value : >13	Part of Asola Bhatti Sanctuary, Delhi Bird Watching Society (old faridabad) and part of Aravalli ranges (which have been designated as Natural Conservation Zone in the plan) comes under this. [39] Indicator value : 3	Apart from parks,the district of Raipur 9surrounding Raipur city) possesses three wild life sanctuaries. Also four acre of wetland of Raipur gets a signal for development of bird park. [56] Indicator value : 4	4	3	**4**

I-19. Institutional Capacity: Number of City or Local Government Agencies Involved in Inter-agency Co-operation Pertaining to Biodiversity Matters	0 points: one or two agencies* cooperate on biodiversity matters 1 point: three agencies cooperate on biodiversity matters 2 points: four agencies cooperate on biodiversity matters 3 points: five agencies cooperate on biodiversity matters 4 points: More than five agencies cooperate on biodiversity matters	The Pune Municipal Corporation (PMC) website, there is mention of one biodiversity committee, but PMC is yet to officially communicate it to the State Biodiversity Board of India, (as of year 2014). But exact number of agencies cooperating on biodiversity matters are not available. [9] Indicator value : 1	Not much information available on these agencies in Faridabad city. [40], [41] Indicator value : 0	Not much information available on these agencies in Raipur city. Indicator value : 0	0	0	**0**
I-20. Participation and Partnership: Existence of Formal or Informal Public Consultation Process	0 points: No formal or informal partnerships 1 point: Formal or informal process being considered as part of the routine process 2 points: Formal or informal process being planned as part of the routine process 3 points: Formal or informal process in the process of being implemented as part of the routine process 4 points: Formal or informal process exists as part of the routine process	PMC has sub departments for environment and BDV related activities where there are cells like Indradhanush, Know your Officers, Animal Adoption scheme, Zoo Volunteer Scheme etc. for public awareness and involvement. So it could be considered as a formal public consultation process as apart of routine process. [9] Indicator value : 4	No such confirmed formal or informal public consultation process is existing yet. Thus we can assume, these kind of process are still in consideration process. Indicator value: 1	No such confirmed formal or informal public consultation process is existing yet. Thus we can assume, these kind of process are still in consideration process. [57] Indicator value: 1	4	1	**1**
I-21. Participation	0 points: No formal or informal	At least more than 10 Agencies/Private	One or two Agencies NGOs/Academic Institutions	One or two Agencies NGOs/Academic	2	1	**1**

and Partnership: Number of Agencies/Private Companies/NGOs/Academic Institutions/International Organisations with which the City is Partnering in Biodiversity Activities, Projects and Programmes	partnerships 1 point: City in partnership with 1-6 other national or subnational agencies/private companies/NGOs/academic institutions/international organisations 2 points: City in partnership with 7-12 other national or subnational agencies/private companies/NGOs/academic institutions/international organisations 3 points: City in partnership with 13-19 other national or subnational agencies/private companies/NGOs/academic institutions/international organisations 4 points: City in partnership with 20 or more other national/ subnational agencies/private companies/NGOs/academic institutions/international organisations	Companies/NGOs/Academic Institutions/International Organizations in Pune is Partnering in BDV activities, projects and programs. [22], [9] Indicator value : 2	in Faridabad is Partnering in BDV activities, projects and programs as per available confirmed data. Might be more than that are in existence, but information not publicly available. Indicator value : 1	Institutions in Faridabad is Partnering in BDV activities, projects and programs as per available confirmed data. Might be more than that are in existence, but information not publicly available. Indicator value : 1			
I-22. Education and Awareness: Is Biodiversity or Nature Awareness Included in the	0 points: Biodiversity or elements of it are not covered in the school curriculum 1 point: Biodiversity or elements of it are being considered for	Biodiversity or Nature Awareness is Included in the academic syllabus and School Curriculum as well in both Indian Government and private schools. [23]	Biodiversity or Nature Awareness is Included in the academic syllabus and School Curriculum as well in both Indian Government and private schools.[42], [43]	Biodiversity or Nature Awareness is Included in the academic syllabus and School Curriculum as well in both Indian Government and private schools.[58]	4	4	**4**

School Curriculum	inclusion in the school curriculum 2 points: Biodiversity or elements of it are being planned for inclusion in the school curriculum 3 points: Biodiversity or elements of it are in the process of being implemented in the school curriculum 4 points: Biodiversity or elements of it are included in the school curriculum	Indicator value : 4	Indicator value : 4	Indicator value : 4			
I-23. Education and Awareness: Number of Outreach or Public Awareness Events Held in the City per Year	0 points: 0 outreach events/year 1 point: 1 - 59 outreach events/year 2 points: 60 -149 outreach events/year 3 points: 150-300 outreach events/year 4 points: > 300 outreach events/year	Minimum 5-6 such formal events have been recorded in Pune.[24], [25] Indicator value : >5	1-2 NGOs (Like Navchetna Trust organized 'The Largest Plantation' drive in Faridabad) conducts such programs formally, as recorded. [40] Indicator value : >1	1-2 NGOs (for example Bird Count India conducted two workshops in Raipur, Chhattisgarh on 6-7 November 2016. The workshops were organised by the Birds and Wildlife Group of Chhattisgarh and the Science College, Raipur.) conducts such programs formally, as recorded.[59], [60] Indicator value :>1	1	1	**1**

Note: Cross referencing have been done for data validation for all the indicators mentioned in Table 1

4.3 Summary of findings and discussion

Table-1 above describes the fundamentals of all 23 indicators assessed under the CBI mechanism for three cities and their corresponding values and scores. It has been observed that the select three cities in general perform low compared to total score values i.e 96. Pune scored 34 followed by Raipur and Faridabad with 23 and 22 respectively. As a matter of fact, Pune city performed the best among the three case study smart cities that we have evaluated. Figure 4 below shows the cumulative total scores of three cities.

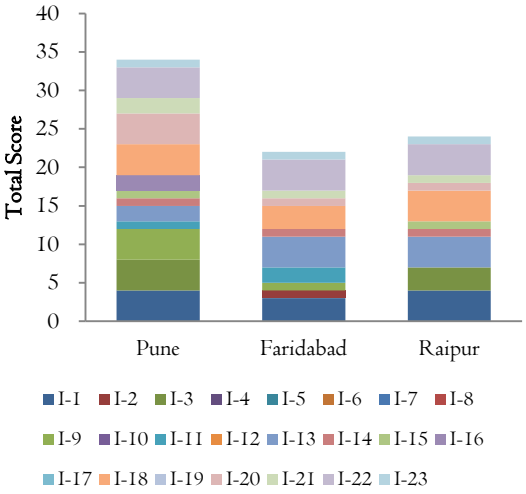

Figure 4 Cumulative score comparison of three cities
Note : I-1 to 23 are the indicators mentioned in Table 1

Nevertheless, cities' performances vary across the indicators as well. As we mentioned that there are three main categories of performance measurement in CBI, we have further decomposed the scores in three broad categories. The decomposition reveals that though Pune city topped the list in total scores it also performs lowest in the ecosystem services category compared to the top performer in this category of Faridabad. Pune is well ahead in biodiversity conservation and management category compared to Raipur and Faridabad. Figure 5 below shows the comparison of indicator wise performances of each city.

Figure 5 further demonstrates that Pune city needs to focus on utilizing cities existing ecosystem and biodiversity resources in a better way to get the services and values out of it. Compared to the performance on other indicators, Pune city needs to develop strategies on enhancing ecosystem services. Faridabad city needs to work out on all three indicators in a collective manner for overall performance improvement. Raipur city is also behind in performance in the area of ecosystem services and stock of biodiversity and ecosystem. Overall the result indicates that cities should have balanced performances in all categories of activities in terms of conservation of ecosystem and biodiversity for sustainable development.

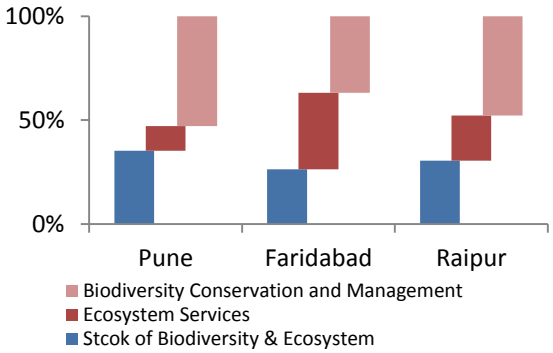

Figure 5 Comparison of indicators among the cities

4.4 How to use the tool for better urban planning

This indicator based tool can be used for multiple purposes of city development activities mentioned below which are exhaustive but not limited to the:

- Use for identification of weaker areas of policy intervention at city level for sustainable development
- Use for identification of the specific areas of SD to be encouraged, promoted and supported.
- Use for intercity comparison of sustainable development activities
- Use for LBAP implementation and monitoring and evaluation of indicator performances.

For example, in Pune city, urban ecosystem management is less addressed compared to others as well as to the benchmark level. Thus we can suggest that Pune city should work on the following areas:

a) More numbers of Ecological Corridors/ Green Corridors should be among different natural areas and forests.

b) To get better ecosystem services, PMC should take efforts to enhance the natural green cover of Pune City which is presently much less than required.

c) Also, total tree canopy covers in Pune City should be enhanced to mitigate the Climate change issues, e.g., to get the cooling effect of vegetations.

d) So to enhance the above mentioned services and management Budget Allocated to Biodiversity for PMC should be increased.

5. Limitations of this study

In India, the major concern for a biodiversity related study is to obtain reliable and useful data and information [61]. Thus, in this study, the biggest problem for scoring the cities based on CBI was unavailability of data. As discussed in other journal papers, Government reports and documents, we too

found many challenges while conducting this study, namely: (1) lack of data availability; (2) the differences in scoring which should be considered due to the vast bio-geographical differences among cities and (3) the scale, city boundaries and definitions of the indicators and so on.

However, though the lack of data was of great difficulty and challenge for this study, especially for a country like India, but we also found this as an opportunity to motivate different Government and private agencies for further data collection. Thus CBI can motivate and provide incentives for municipalities to start making inventories and monitoring their programs on biodiversity.

While conducting this study, we felt that the indicators on Species number have certain limitations. We didn't find any data for Indicators 4 to 8 for any of the cities. So we could not provide the scores based on these indicators. While doing literature review, I found that this was the case for another Indian city Mira Bhainder as well, as mentioned in Kohsaka et all.2013. But though data was not available for 3 rd Indicator, i.e., number of bird species in Built-up Areas for Mira Bhainder [6], we could gather data for Pune and Raipur for the same. For Indicator 10 (proportion of invasive alien species), no data available for Pune and Raipur, but for Faridabad we got the data from 'Singh & Mohammed 2015' [31].

It has been stressed by many applying the CBI that indicators capturing the flow of ecosystem services from more distant ecosystems beyond the city would be desirable to include, in order to assess the impact that cities and their inhabitants and policies have on ecosystems elsewhere [62][63].

Also, as we experience, the governance and management indicators are much in numbers and often difficult to specify. For example, like in Kohsaka et all.2013[6] (as per the Lisbon expert group), we too experienced that the city statistics and municipality reports 'do not always make the distinction between general public parks investment or other environmental activities and biodiversity-specific activities' [6].About other indicators, data availability condition is average. Data availability is better for Pune comparing Raipur and Faridabad. But we tried our best to calculate the indicators based on what is available. For some indicators, due to lack of municipality data, we have used respective state average data.

6. Conclusions and way forward

Though the unavailability of data was of great difficulty and challenges for this study, but we wanted this limitations to be seen as an opportunity to motivate different Governments and private agencies for further data collection. The city scores based on CBI reveals the lack in the BDV protection and related programs for that particular city. It also points out what areas should be taken care of to improve the situation which is very important for the sustainability for the city. Thus CBI scoring provides a measurement about the city's treasure of biodiversity and helps to evaluate city's performance to protect it. City's ranking based on CBI, provides a motivation for the municipalities local government to start making inventories and monitoring their programs on biodiversity.

Proper scoring of the cities based on CBI can suggest the city administration about the need for more detailed baseline biodiversity surveys. Motivating the city municipalities to conduct more biodiversity surveys would also help to mainstream biodiversity in the planning process, as well as to help raising awareness about biodiversity. For example, it is possible today to integrate remote sensing data and in situ observations to monitor several essential biodiversity variables such as habitat structure and phenology [64].

Private sector's role is also important for a city to maintain its level of biodiversity and ecosystems. Based on the CBI scoring, the local municipalities would be able to identify the areas they should work upon and can motivate and provide incentives to the private companies to include those area in forms of projects or programs in their CSR activities. It has been envisaged that unless the business and commercial activities mainstream biodiversity protection and conservation, it is difficult to achieve the targeted level of mitigation actions mainly due to lack of finance and technological innovation. [4]

An interesting initiative taken by Yokohama municipality is the incorporation of biodiversity into their environmental management system called ISO14001, thus aiming to minimize the impact of human activities. Through ISO14001, the issues of biodiversity are addressed in the agendas of each department and section in the city [6]. This kind of certifications must be implemented for the smart cities of India as well.

However, this study demonstrates the way forward for the city authorities in terms of developing a framework for sustainable ecosystem based urban development in India cities. Following India's national commitment and targets towards conservation of biological diversity (mentioned under the 5th Communication to CBD) it is important to develop such urban level framework of monitoring and evaluation which could strengthen the State Level Action Plan to the National Plan indeed. Also, the CBI may enable the local government to establish a formal system to address urban sustainability more generally, especially when indicators in CBI are linked to numerical targets in plans or strategies of the city. Besides, it's would be a motivation for the Municipalities of Indian cities to plan and activate Local Biodiversity Strategies and Action Plan (LBSAP).

The proposed framework (though adopted from the existing Singapore Index / CBI) can bring the benefits of not only identifying the strengths of the ecosystem and biodiversity conservation plan of

policies at city/urban level but also can identify the gaps of the activities which need to be strengthened. The study uniquely compared the performances of three smart cities in India in recent days but it can be used for other cities across the country and a national index ranking can be developed in the future. The biggest advantage would be that the cities can compare their performances by themselves and can get motivated for improvement.

However, as discussed earlier, developing CBI is a very important and integral part of sustainable development process of any city. And also, this CBI can support implementation of Sustainable Development Goals in India, as well as other countries.

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