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EXAMINING THE EFFICIENCY OF BIODIVERSITY FINANCE ACTION PLAN ACROSS THE INDIAN MEGACITIES

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Abstract

Human well-being is quite intrinsically linked to ecosystem services and biodiversity. There is a growing amount of literature attempting to understand the mechanisms of these interlinkages. Though there is considerable progress globally with respect to human well-being, challenges still remain in terms of access to resources. On the biodiversity front, anthropogenic interference continues to threaten species. Reviewing the Aichi Biodiversity Targets which were to be achieved in 2020 worldwide reveals that none could be attained fully. In India, city- level efforts in biodiversity conservation and integration with human well-being appear lacking. With the pressures of population growth and urbanisation, urban planners often leave less scope for open or green spaces in the city. The traditional trade-off between environment and economic development continues to play out in cities. This study reviews the biodiversity status of five highly populated Indian megacities – Bengaluru, Chennai, Delhi, Kolkata and Mumbai – using City Biodiversity Index framework. Subsequently, a set of indicators characterising the state of human well-being, environment, economy and urban development for 2019-20 is selected and used to create a composite score to facilitate comparison. Mumbai is the best performer overall and also in terms of urban biodiversity. Kolkata has the least score for urban biodiversity. Chennai ranks well in both quality of life and environment but scores low in urban planning. Delhi has the least overall score while Bengaluru tops the economic dimension. It is hoped that the comprehensive picture thus obtained would enable directing attention to required sectors. The spotlight is thus on extending the scope of the biodiversity index and maximising welfare through integrated policies at minimum cost.

Keywords: *Urban biodiversity, human well-being, urban planning, City Biodiversity Index, biodiversity finance, quality of life*
JEL Codes: *Q570, I310, Q560, R110*

Preface

Madras School of Economics (MSE) established the Centre for Public Finance (CPF), which started functioning from April 1, 2021. This Centre is financed by the Government of Tamil Nadu. Its activities are guided by an Advisory Council (headed by me). The Centre focuses on both theoretical and empirical issues of public finance covering the following areas: deficit financing and public debt, monetary and fiscal interactions, tax policy and reforms, public expenditure management, public investment appraisal and cost benefit analysis, public enterprises reform, intergovernmental transfers, local finances and environmental issues.

Apart from general research activities, the Centre is committed (i) to review the Tamil Nadu Economy and State Finances every year, (ii) to conduct an Annual Conference on topics related to public finance and policy and (iii) to conduct Training Programs on public finance. It will also undertake specific studies on public finance funded by Government of Tamil Nadu and other National and International agencies.

During the academic year 2021-22, the Centre organized "Virtual Meeting on Improving the Presentation of Tamil Nadu Budget Document" on April 29, 2021 and conducted the 5-day Training Programs on Public Finance for (270) 15 batches of Groups A and Group B officials of Government of Tamil Nadu through online mode (from August 31 ,2021 to December 31, 2021). It has also initiated about 10 research studies.

The study "Examining the Efficiency of Biodiversity Finance Action Plan across the Indian Megacities" by Dr. Zareena Begum Irfan is the fifth working paper of the Centre. This study reviews the biodiversity status of five highly populated Indian megacities – Bengaluru, Chennai, Delhi, Kolkata and Mumbai – using City Biodiversity Index framework. Subsequently, a set of indicators characterising the state of human well-being, environment, economy and urban development for 2019-20 is selected and used to create a composite score to facilitate comparison. Chennai ranks well in both quality of life and environment but scores low in urban planning. It is hoped that the comprehensive picture thus obtained would enable policy makers to take corrective actions where needed.

C.Rangarajan
Chairman

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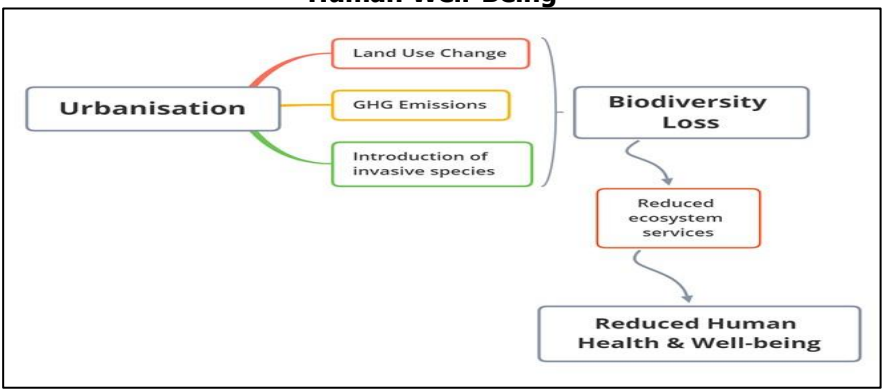
Zareena Begum Irfan

INTRODUCTION

The links between biodiversity and human health and well-being are now tangibly coming to the foreground as nations grapple with the far-reaching consequences of climate change, diseases, population expansion, and the race to attain economic growth. Recent researches do indicate positive correlation between biodiversity and human well-being; however, the depth and mechanisms of this linkage have not been explored much. Tools and guidelines such as Aichi Biodiversity Targets (ABT), National or Local Biodiversity Strategic Action Plans (NBSAP/LBSAP), City Biodiversity Index (CBI) and the various biodiversity protocols have tried to address the issue of biodiversity loss and push for conservation efforts globally. Integration of biodiversity into 'One Health' policies is slowly coming to the forefront, allowing and facilitating identification of common drivers of biodiversity loss and ill health.

Urbanisation is a major driver exacting pressure on nature, gobbling up ecosystems even and encroaching green spaces. In most cases, restoration efforts end up introducing invasive species which could negatively impact the little remaining proportion of native species. As the below flowchart shows, land use changes and other pressures brought by urbanisation can lead to reduced human health and well-being through biodiversity loss.

Figure 1: Linkages between Urbanisation, Biodiversity and Human Well-Being



Source: Author's representation

The cities do have a certain degree of ease of living attached but the well-being of the denizens has been impacted by increasing levels of pollution and lack of open spaces. More than 50 percent of the world's population resides in urban areas and there is every reason to believe this would only increase in the coming years. The goals of ensuring sustainable development, conserving biodiversity, restoring ecosystems and improving health and well-being thus become more pertinent than ever. Urban areas in India have been expanding without bounds with urban green spaces decreasing rapidly. Cities like Bengaluru have just 1 tree for every 7 persons as per a study by Ramachandra *et. al.* (2017), while the ideal ratio is the reverse – 7 trees per person. Impacts on health and well-being also highlight the linkages with environment, with the likelihood of contracting diseases increasing with levels of pollution or frequent interactions with wildlife. Cities like Delhi and Mumbai reported 54,000 and 25,000 avoidable deaths respectively due to air pollution in 2020 (Greenpeace India, 2021). Under these circumstances, making the most of the interlinkages between biodiversity and human well-being and framing city plans around them would be the more prudent approach considering time and financial constraints.

OBJECTIVES, SCOPE AND SIGNIFICANCE

Though India's NBSAP submitted to the Convention on Biological Diversity (CBD) reveals significant levels of each Aichi Target being achieved at a national level, a look at state and city records indicate there is a lot yet to be achieved. At a local level, only a little more than 18 percent of local bodies have a Biodiversity Management Committee despite the regulation being in place since 2002 (Tandon *et. al.*, 2017). Health infrastructure is certainly improving but recognition of the inherent linkages is slow with little research on the integrated aspects pertaining to Indian cities. The objectives for this study thus are:

(1) To select 5 highly populated Indian cities and review their status with respect to biodiversity using City Biodiversity Index.
(2) To select a set of indicators characterising the state of human well-being, environment and urban development and use them to make meaningful comparisons between the cities.
(3) To create a composite score based on all the selected indicators and rank cities.
(4) To recommend policy measures based on performance of the cities.

For this study, the cities of Bengaluru, Chennai, Delhi, Kolkata and Mumbai are selected since as urban agglomerations, their population is above 10 million as per the 16th Annual Demographia World Urban Areas Report of 2020. These five cities also are listed as India's megacities by United Nations considering the urban sprawl and population measure beyond its city limits. In India as such, only few cities in collaboration with different organisations have taken up the task of calculating the City Biodiversity Index (CBI) with Kochi and Gangtok being the most recent. Hence assessment and the role of

urban biodiversity is an area with comparatively less research focus in Indian context.

Through this study the various nuances in the links between biodiversity and human well-being would also be brought out. The environmental characteristics of each city would be different and hence there would be an interplay of multiple factors influencing these links. This would also help identify and locate gaps in order to formulate appropriate policies.

LITERATURE REVIEW

The review of extant literature reveals growing interest in studying interlinkages of biodiversity and human well-being especially in the light of the Covid-19 pandemic and the spread of zoonotic diseases. There are studies (Wolfe *et. al.*, 2005) which reveal that deforestation has directly or indirectly increased the incidence of vector-borne diseases and in some cases also led to emergence of novel zoonotic diseases. Keesing *et. al.* (2010) find evidence supporting the notion that preserving the ecosystem and endemic species would reduce the transmission of infectious diseases. A key point in biodiversity discussions however is that the loss or introduction of species could both buffer or amplify the transmission depending on the type of species. Prudent policy measures involving all stakeholders is thus essential.

Apart from disease regulation, researches on biodiversity linkages range from looking at cultural values, causes of loss and pressure to mental health and physical health. An extensive review by Sandifer *et. al.* (2014) showed strong evidence connecting biodiversity with ecosystem services and links between exposure to nature and human health.

Psychological well-being associated with urban green spaces has also been well-researched. A study in Europe by Methorst *et. al.* (2021) revealed that there is a positive association between bird species richness and human well-being as measured through life satisfaction. The research also noted that the impact of 10 percent increase in bird species richness on life satisfaction is similar to the impact of a 10 percent increase in income. The mechanisms are not very clearly known but the researchers believe a positive emotional response is certainly triggered due to sighting birds and exposure to green spaces.

While interlinkages and the value of green spaces have been the subject of many researches, urban 'blue spaces' (water bodies and aquatic environment within cities) need to be prioritised further, especially in the Indian context. Blue spaces in cities are emerging as the most preferred locations for relaxation and aid regulation of summertime temperatures and enhance water quality (Higgins *et. al.*, 2019). Smaller water bodies and the biodiversity they harbour often get overlooked in conservation policies and urban planning. Environmental and health benefits from urban freshwaters must be maximised.

The assessment report by Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services released in 2019 raised concerns over the impact of current negative trends in biodiversity and ecosystem services worldwide on the progress of Sustainable Development Goals (SDG) targets related to poverty, hunger, health, water, climate, cities, oceans and land. Despite the increased understanding of biodiversity over the last few decades, anthropogenic interference continues to threaten species. Only 6 targets out of the 20 Aichi Biodiversity Targets have been achieved globally, that too partially.

The CBI remains a popular tool to assess performance of cities with respect to biodiversity and has been applied globally since its conception, being endorsed by the Convention on Biological Diversity.

Also called the Singapore Index, it includes 23 indicators covering aspects of native biodiversity, ecosystem services and governance. It has links to the Aichi Targets with all except Target 18 (related to respecting and conserving traditional knowledge) being directly captured by the CBI indicators (Chan *et. al.*, 2014).

A multinational analysis by Pierce *et. al.* (2020) exposes the fact that there is little research on how cities actually plan for biodiversity. Their analysis of plans of 39 cities (none from India unfortunately) revealed that most cities do have plans in tandem with the CBI framework. However, for the post-2020 biodiversity framework, linking the CBI to a lot more factors such as socio-economic concerns and green infrastructure is necessary.

Brown and Grant (2005) believe that health is shaped by relationships between people and the natural resources, and that urban planning does play a role in managing ecosystems and thus has an impact on health. Examining literature, they further conclude that health benefits of urban greening arise from ecological services and experiential human interaction with nature. Increasing green cover improves air quality and can substantially reduce the health burden of respiratory diseases. Barton and Grant (2013) go a step further and characterise urban planning as a determinant of health. They highlight that given the way cities have been planning so far, unsustainability and pathogenicity are being built into the cities. A reassessment is required of the way human habitation, economy and environment impact and are impacted by health.

India has witnessed phenomenal growth and expansion in urban areas which has raised flags on the environmental degradation that often follows such rapid growth. Nagendra *et. al.* (2013) indicate that the projected trend of urbanisation for India would be along the coast lines which would put excessive pressure on water resources and the associated ecosystems. City planning and consumption patterns of

the denizens would definitely impact ecosystem services and hence quality of life. Analysing neighbourhood parks in Bengaluru, Swamy *et. al.* (2019) believe that there is a mismatch between the needs of the citizens, conservationists and the final product delivered by the municipality. Their survey on citizen perceptions suggests that density of parks is more important than the size when it comes to supporting biodiversity.

Acknowledging the linkages of biodiversity to well-being, a framework for National Mission on Biodiversity and Human Well-Being for India has been approved in 2018. The Mission is built around the idea that preservation and restoration of biodiversity is the least risky way to mitigate impacts of threats like climate change, low food security and high healthcare costs that plague the cities and villages alike, though in differing magnitudes (Bawa *et. al.*, 2021). As Indian cities are striving to develop as 'Smart Cities', the need to incorporate biodiversity conservation in city planning must not be ignored. This study thus assumes the interlinkages between urban biodiversity and well-being consistent with findings from the literature review and attempts to map the Indian city context. Integrated planning linking biodiversity and health and also quantifying the links are areas requiring more research and concerted efforts.

DATA, METHODOLOGY AND FRAMEWORK

The data for this review comes from publicly available sources and is secondary data for the period 2019-20. The prepared index score to rank the selected 5 cities involves the dimensions of biodiversity, health and well-being, environment and urban development. A summary of variables and indicators to be considered for preparing the score and comparing the cities is given in the following table.

Table 1: Summary of Variables Under Consideration

Sr. No.	Aspect	Component	Description
1	**Biodiversity**	Native Biodiversity in city	Calculated by author using the City Biodiversity Index framework
		Ecosystem services provided by Biodiversity	
		Governance and Management of Biodiversity	
2	**Health and Well-being**	Quality of Life	Data from MoHUA reports; includes health, sanitation, mobility, safety, housing and shelter and education
3	**Urban development**	Urban Planning	Data from MoHUA reports; includes plan preparation, enforcement and implementation
		Urban Governance	Data from MoHUA reports; includes effectiveness, participation, transparency and accountability
		Economic Ability	Data from MoHUA reports; includes Economic development and opportunities
4	**Environmental Status**	Environment	Data from MoHUA reports; includes air quality, water quality, hazardous waste generation, use of clean fuel and tree cover

organisations of the cities. It includes 23 indicators with 10 for native biodiversity, 4 for ecosystem services and 9 for governance and management. The scores are assigned from 0 to 4 for each indicator as per the mechanism in Table 2. For the purpose of the study, city boundaries are considered and not the urban agglomeration since municipal records are available for cities while there is ambiguity in reports on agglomerations.

Table 2: Scoring mechanism as per City Biodiversity Index framework

Component	Sr.No.	Indicator	Scoring
Native	1	Proportion of Natural Areas in the City	0: <1 percent 1: 1 percent - 6.9 percent 2: 7 percent - 13.9 percent 3: 14 percent - 20 percent 4: >20 percent
	2	Connectivity Measures or Ecological Networks to Counter Fragmentation	0: < 200 ha 1: 201 - 500 ha 2: 501 - 1000 ha 3: 1001 - 1500 ha 4: > 1500 ha
	3	Native Biodiversity in Built-up Areas – Birds	0: < 19 bird species 1: 19 - 27 2: 28 - 46 3: 47 – 68 4: > 68
Biodiversity	4-8	Change in Species	0: maintaining or decrease in number of species 1: 1 species increase 2: 2 species increase 3: 3 species increase 4: 4 species or more increase
	9	Proportion of Protected Natural Areas	0: < 1.4 percent 1: 1.4 percent - 7.3 percent 2: 7.4 percent - 11.1 percent 3: 11.2 percent - 19.4 percent 4: > 19.4 percent
	10	Proportion of Invasive Alien Species	0: > 30.0 percent 1: 20.1 percent - 30.0 percent 2: 11.1 percent - 20.0 percent 3: 1.0 percent - 11.0 percent 4: < 1.0 percent

Component	Sr.No.	Indicator	Scoring
Ecosystem Services	11	Regulation of Quantity of Water	0: < 33.1 percent 1: 33.1 percent - 39.7 percent 2: 39.8 percent - 64.2 percent 3: 64.3 percent - 75.0 percent 4: > 75.0 percent
	12	Climate Regulation: Carbon Storage and Cooling Effect of Vegetation	0: < 10.5 percent 1: 10.5 percent - 19.1 percent 2: 19.2 percent - 29.0 percent 3: 29.1 percent - 59.7 percent 4: > 59.7 percent
	13	Area of Parks with Natural Areas	0: < 0.1 ha/1000 persons 1: 0.1 - 0.3 ha/1000 2: 0.4 - 0.6 ha/1000 3: 0.7 - 0.9 ha/1000 4: > 0.9 ha/1000
	14	Number of Formal Educational Park Visits per Child below 16 Years per Year	0: 0 formal educational visit/year 1: 1 visit/year 2: 2 visits/year 3: 3 visits/year 4: > 3 visits/year
	15	Budget Allocated to Biodiversity	0: < 0.4 percent 1: 0.4 percent - 2.2 percent 2: 2.3 percent - 2.7 percent 3: 2.8 percent - 3.7 percent 4: > 3.7 percent
	16	Number of Biodiversity Projects Implemented by City Annually	0: < 12 projects 1: 12 - 21 2: 22 - 39 3: 40 - 71 4: > 71

Component	Sr.No.	Indicator	Scoring
Governance and Management	17	Existence of LBSAP	0: No LBSAP 1: LBSAP not aligned with NBSAP 2: LBSAP incorporates elements of NBSAP, but does not include any CBD initiatives 3: LBSAP incorporates elements of NBSAP, and includes one to three CBD initiatives 4: LBSAP incorporates elements of NBSAP, and includes four or more CBD initiatives
	18	Number of Biodiversity Related Functions	0: No functions 1: 1 function 2: 2 functions 3: 3 functions 4: > 3 functions
	19	Number of City Agencies Involved in Interagency Cooperation Pertaining to Biodiversity Matters	0: 1 or 2 agencies cooperate on biodiversity matters 1: 3 agencies cooperate 2: 4 agencies cooperate 3: 5 agencies cooperate 4: >5 agencies cooperate
	20	Existence of Formal or Informal Public Consultation Process	0: No routine formal or informal process 1: Formal or informal process being considered as part of the routine process 2: Formal or informal process being planned as part of the routine process 3: Formal or informal process in the process of being implemented as part of the routine process 4: Formal or informal process exists as part of the routine process

Component	Sr.No.	Indicator	Scoring
	21	Number of NGOs/Academic Institutions/Companies/ International Organisations with which City is Partnering in Biodiversity Activities, Projects and Programmes	0: No formal or informal partnerships 1: City in partnership with 1-6 other national or subnational agencies/private companies/NGOs/academic institutions/international organisations 2: With 7-12 agencies 3: With 13-19 agencies 4: With >19 agencies
Governance and Management	22	Biodiversity/Nature Awareness Included in School Curriculum	0: Biodiversity or elements of it are not covered in the school curriculum 1: Being considered for inclusion in curriculum 2: Being planned for inclusion 3: In the process of being implemented in curriculum 4: Included in the school curriculum
	23	Number of Outreach Events or Public Awareness Events Held in the city per Year	0: 0 outreach events/year 1: 1 - 59 events/year 2: 60 -149 3: 150-300 4: > 300
Maximum Score for CBI			92

Source: Adapted from Chan et. al. (2014)

The CBI doesn't claim to completely assess urban biodiversity but it is by far the most useful in aiding comparison and designing further action plans. It does not directly bring in the links with human well-being and health. Hence, this study uses a composite score comprising of different aspects known to be linked to biodiversity.

Data for indicators on connectivity measures, change in species and proportion of invasive species was unavailable. Hence, a total of 16 indicators are used for city comparisons. In the case of Indian cities, information on programs specific to biodiversity are less. Where applicable, environmental programs are also considered. The latest Master Plans of cities are referred for land use patterns. Due to unavailability of exact counts of bird species in recent years, the numbers recorded at bird races (excluding migratory birds) conducted in cities are used.

A comprehensive study by Brauman *et. al.* (2020) indicates the links of quality of life with biodiversity and environment via the health pathway. The global trends reveal a declining human quality of life with loss in species' habitats. The indicator used for health and well-being for this study is thus the quality of life. This indicator includes health, sanitation and other aspects as designed by the Ministry of Housing and Urban Affairs (MoHUA) as a part of their Ease of Living Index for cities. For Kolkata, the latest available figures are for 2017 from the data used for Smart Cities Index preparation. The environment dimension is included in the composite score to capture all angles in the interlinkages between biodiversity and wellbeing.

Uncontrolled urbanisation is taken to be the core driver of ecosystem loss in this study. The urban development indicator shows how each city has planned its expansion and its economic potential. Development is certainly essential but not at the cost of irreplaceable ecosystems. The indicator (as designed by MoHUA) includes sustainability components as well such as inclusion of incentivising green buildings in the city plan and penalties for plan violations.

Theoretical Framework: All indicator values are brought within the range of 0 to 100 by normalising or standardising as per requirement. A greater value implies a higher score. All data from MoHUA are already in comparable index units. For the final composite score, an

aggregation method of a simple average giving equal weightage to the values of each indicator is taken which would again be within 0 to 100. Values closer to 100 would imply comparatively better urban biodiversity status, environment, well-being and good practices. Comparing individual dimensions within each city and also between cities would give a comprehensive picture that would enable directing attention to required sectors.

CITY PROFILES

This section provides a snapshot of the status of environment and biodiversity in the 5 selected cities. The cities all have some common issues that come as a result of urbanisation; however, the extent and impact differ due to topography and characteristics of the region.

Bengaluru

Located in a semi-arid region, the 709 sq. km wide Bengaluru is prone to water scarcity problems which are only expected to intensify (Nagendra *et. al.*, 2013). The lakes in the city have seen high levels of encroachment. The frothing of lakes observed over the last couple of years was due to excessive chemical waste dumped into them. Similar instances were recorded of lakes 'burning' and catching fire (Bhasthi, 2017). Lack of action to resolve these issues has been attributed to too many agencies being involved in matters pertaining to water bodies in the city. Traces of diarrhoeagenic bacteria due to contamination have also been found in drinking water from the peri-urban areas of the city indicating moderate to high risk of diarrhoea (Sheeba *et. al.*, 2017).

The recently published Ease of Living Index for 2020 by MoHUA puts Bengaluru at the top making it the most liveable city overall. However, in terms of open spaces, green buildings and the state of environment, the city has significantly low scores compared to other million plus population cities. A study by Ramachandra *et. al.* (2017) shows how the built-up area has expanded in the city with almost no

vegetation cover estimated for 2020. The study in fact projects Bengaluru as a 'dead city' in the years to come if unplanned and 'unrealistic' urbanisation continues.

Chennai

Chennai, spanning 426 sq. km approximately, saw severe droughts and water crises in recent years raising concerns about water security in the city. With lakes, rivers, wetlands and marshes, Chennai still faces water shortage because these water bodies have been consistently used to dump sewage water without treating. Just 5.5 sq. km. is left of the Pallikaranai freshwater marsh which used to drain an area of 235 sq. km. (Kumar, 2017). Groundwater is also heavily exploited and sea water intrusion is a cause for concern. Cleaning up of the rivers, desilting and restoring the water bodies in the city have been initiated with the Chennai River Restoration Trust as the coordinating agency. Volunteer groups and citizen collectives have also been instrumental in restoring ponds, lakes, and temple tanks in Chennai.

Along with water woes, the city also has a peculiar pollution problem. Being a coastal city, sea breeze does affect the dispersion of pollutants. Though the levels of ambient pollution may not be as high as other megacities, there is high toxicity in the air (Centre for Science and Environment, 2013). The toxins have been found to be carcinogenic in nature and are likely from vehicular emissions, especially from those running on diesel. In 2020, there were economic losses of ₹10,910 crores and 11,000 deaths due to air pollution in Chennai (Greenpeace India, 2021).

Delhi

Being the national capital, Delhi has seen continuous influx of population and thus urban expansion. The city has come into limelight for excessive air pollution, coming from vehicle exhaust, industrial and construction activities combined with seasonal emissions from open field fires during harvest. This has resulted in exposure to

toxic smog for long periods of time giving rise to lung diseases and breathing troubles. The total Disability Adjusted Life Years (DALY) due to PM10 for Delhi increased from 0.34 million in 1995 to 0.75 million in 2015 (Maji *et. al.*, 2017). Due to the restrictions on account of the Covid-19 pandemic, concentrations have reduced in general across all cities, highlighting the impact of vehicular emissions on the environment.

Covering an area of 1483 sq. km, Delhi also has high built-up area temperatures, creating local hotspots. Coupled with loss in green cover, the urban heat island effect plays out which could increase heat-related mortality. The ridge in Delhi, an extension of the Aravalli hills, has been subjected to illegal quarrying. The ridge has often been called the 'lungs' or 'lifeline' of the city due to the greenery and biodiversity it harbours and hence needs to be protected.

The Odd-Even scheme of vehicle usage introduced in 2016 by the Delhi government, attempted to curb emissions in the city. A traffic rationing measure, the scheme allowed only those cars with registration numbers ending in odd digits to ply on odd numbered dates with the same rule for even dates. While in the introductory phases the scheme worked to reduce air pollution, subsequently a counter-intuitive trend was observed in the third and fourth phases where the levels rose again (Chatterji, 2020).

Kolkata

With an area of 206.1 sq. km, this is yet another city grappling air pollution, particularly from the use of kerosene-mixed diesel in the autorickshaws that ply so frequently on its roads (Nath, 2019). With current trends, it might soon become the most polluted city in the list. Known as the 'City of Joy', though Kolkata has maintained the level of quality of life, the increasing pollution and congestion in the city has led to several health issues. Among other megacities of India, Kolkata also experiences high noise pollution (Chowdhury, 2016).

Untreated effluents flowing down the rivers in Kolkata also have an impact on neighbouring areas as well as the Sundarbans and the wetlands of East Kolkata. The pollutants are changing the geochemistry of estuaries and altering the coastal environment (Rajashekariah, 2011). Due to continuous expansion with disregard to natural gradient, the frequency of floods has increased. Groundwater is also found to be contaminated with heavy metals such as lead and arsenic. Incidence of water-borne diseases especially diarrhoea has also been found to be high.

According to a special report in 2018 by Intergovernmental Panel on Climate Change (IPCC) on impacts of rising temperatures, Kolkata would be facing high-intensity heat waves under a 2°C warming with no adaptation. Currently, human activities have led to warming between approximately 0.8°C and1.2°C globally compared to pre-industrial levels. This brings urgency to the fore to act as a community with active governmental support. An action plan to curb pollution is being implemented by the government in Kolkata which has urged use of battery- operated buses and penalising open burning of garbage among others.

Mumbai

A coastal city spanning 603.4 sq. km, Mumbai's development was planned through extensive land reclamation projects. A study by Adhikari *et. al.* (2015) identified 'invasion hotspots' in India based on climate suitability and vulnerability, and found that these coincide with ecologically sensitive regions. Mumbai, being a port town, was found to be a hotspot with the invasive species probably being introduced through shipping routes.

According to a report by the National Crime Records Bureau in 2019, Mumbai topped the list of cities with highest number of environmental offences recorded under Environment (Protection) Act, 1986. In order to develop the Mumbai Metro, about 2141 trees in

Aarey Colony were felled in 2019 sparking severe agitations (Khelkar, 2019). The Metro Rail Corporation however has proposed to supplement existing green cover along the corridor and also achieve low energy consumption. The economic cost of air pollution in the city was estimated to be ₹26,912 crores in 2020 (Greenpeace India, 2021). Mumbai is also unable to control the rising prevalence of diseases, especially communicable ones. Praja, an organisation working towards accountable governance in Mumbai, estimated that 76 percent population did not have medical insurance.

The city also faces waste management issues just like other urban areas, generating 11,000 tonnes of solid waste per day in 2015-16 according to Central Pollution Control Board estimates. Dumping of debris along the Lokhandwala lake has been posing serious harm to the freshwater ecosystem and the biodiversity around it (Singh, 2019). A property tax rebate system was introduced by the municipal authorities in 2019 to incentivise waste segregation and proper disposal and composting of waste. The success of this incentive remains to be seen.

The mangrove patches along the coast of Mumbai are also dwindling and about 40 percent reduction in mangrove cover has occurred due to housing construction schemes, dumping waste and slum encroachment (Sarkar, 2017). Coastal Regulation Zone norms seek to protect mangroves and the Maharashtra Coastal Zone Management Authority has approved creation of bunds to protect mangrove forests in the Mumbai Metropolitan Region.

BIODIVERSITY INDEX FOR INDIAN CITIES

Since information on only 16 indicators was available, the maximum score achievable by a city is thus 64. The table below gives the final scores obtained by each city after an in-depth scrutiny of municipal records

available online and associated documents. For actual values and an outline of sources used for calculation per city, see appendix.

Table 3: Scores as per City Biodiversity Index framework

Component	S.N.	Indicator	Bengaluru	Chennai	Delhi	Kolkata	Mumbai
Native Biodiversity	1	Natural Area	1	2	2	2	4
	2	Connectivity Measures	-	-	-	-	-
	3	Birds	4	4	4	3	4
	4-8	Change in Species	-	-	-	-	-
	9	Protected Areas	0	1	1	1	3
	10	Invasive Species	-	-	-	-	-
Ecosystem Services	11	Regulation of Water	0	0	0	0	1
	12	Climate Regulation	0	0	2	0	2
	13	Parks	2	1	4	2	4
	14	Educational Park Visits	1	1	1	1	1
Governance and Management	15	Budget	4	1	0	0	2
	16	Biodiversity Projects	0	0	0	0	1
	17	LBSAP	0	0	0	0	0
	18	Biodiversity Functions	4	4	4	4	4
	19	Interagency cooperation	3	4	4	4	4
	20	Public Consultation	4	4	4	4	4
	21	Partnerships	2	2	4	2	1
	22	School Curriculum	4	4	4	4	4
	23	Outreach Events	1	1	1	1	1
Total			**30**	**29**	**35**	**28**	**40**

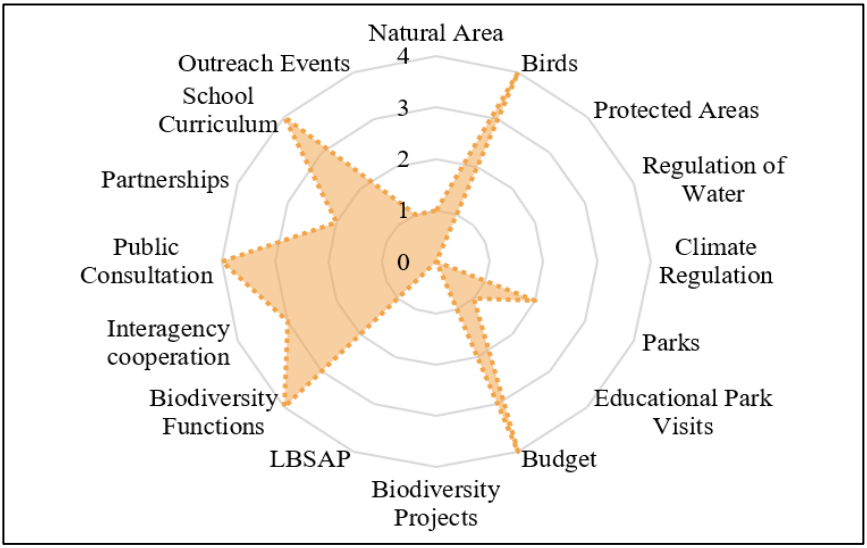
Source: Author's calculations

According to the scores, compared to the highest possible score of 64, Mumbai has a relatively better performance followed by Delhi.

Bengaluru, Chennai and Kolkata have a similar performance with respect to urban biodiversity. No city had initiated an LBSAP in the period 2019-20. With school curriculum inclusive of environmental science subjects and biodiversity issues, all cities have a complete score for this indicator. Most schools undertake excursions and at least one visit per class to nature parks and other nearby locations of natural beauty. All cities have incorporated biodiversity functions through a mix of biodiversity parks, herbariums, insectariums, botanical gardens and zoological parks. Public views on environment and biodiversity issues have been sought via different mechanisms. Online portals exist on the corporation websites where views and grievances of the denizens are addressed. For specific action plans and reports, focus group discussions take place along with representatives. There are some key aspects of the differences in the cities which are presented below by way of radar charts (Figure 2 to Figure 6).

Figure 2 clearly indicates that Bengaluru is performing well with respect to number of birds, budget allocation for biodiversity and other aspects in the governance dimension. There are many authorities but cooperation among them appears lacking as was observed in the case of lakes (see section 5.1). The Municipal Corporation has undertaken activities such as tree plantation, park management, improvements in lakes and canopy management. The authorities have also initiated preparation of the People's Biodiversity Register. The Karnataka Biodiversity Board also has been initiating discussions and proposals on bringing more biodiverse regions under protection. Organisations

Figure 2: Radar chart of CBI for Bengaluru



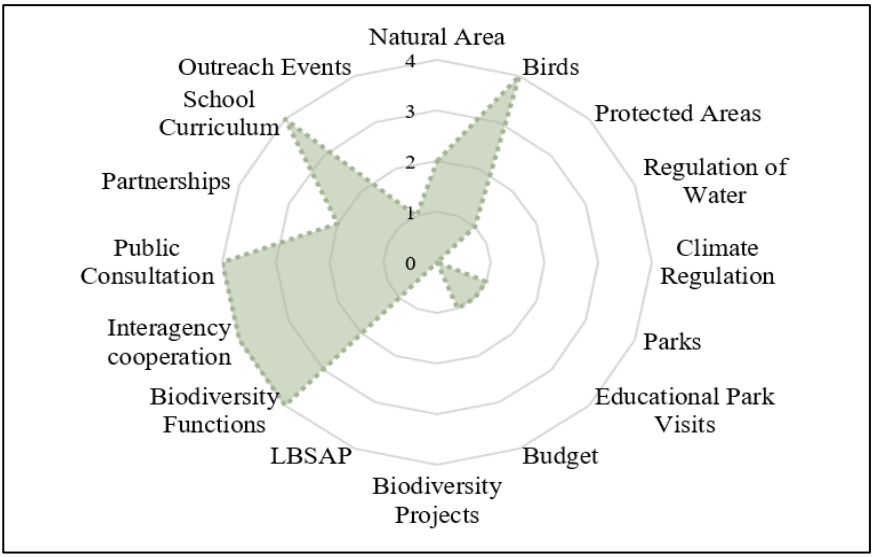
Source: Author's representation

and institutions like Eco-Watch, Environment Association of Bangalore, Environmental Management and Policy Research Institute, Ashoka Trust for Research in Ecology and Environment and Indian Institute of Science have been actively engaged in working towards preserving environment through campaigns and research.

Within the budget allocation for biodiversity and closely associated sectors, a majority share is for horticulture and environmental management followed by restoration of lakes. Urban forestry takes up the remaining share. Due to the enormity of funds required for restoration works, the number of biodiversity projects proportional to budget are less. Bengaluru's Revised Master Plan 2031 drafted by Bangalore Development Authority has been withdrawn due to concerns on uneven urbanisation and when opened to public review,

several objections were raised regarding green cover planning as well. The document has been used here only to extract figures on existing land use.

Figure 3: Radar chart of CBI for Chennai



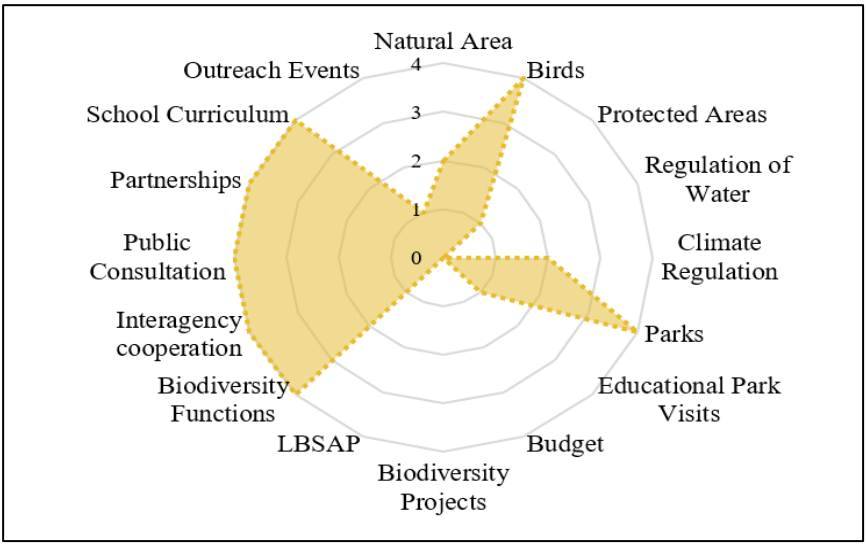
Source: Author's representation

Quite evidently Chennai is not performing well in terms of native biodiversity and ecosystem services dimensions. Budget allocation is also not quite adequate. Maximum allocation is for river restoration projects. Other projects involve vertical gardens, park retrofitting and tree planting. Zero-waste campaigns and plastic bans have also been initiated as a part of outreach events by the municipal authorities. The Greater Chennai Corporation does cooperate with other governmental agencies such as Tamil Nadu Infrastructure Development Board, Chennai Metro Water Supply and Sewage Board, and the Ministry of Environment, Forest and Climate Change in environmental matters.

The Guindy National Park of about 270.57 ha houses a variety of mammals, invertebrates, birds and is a protected area. Apart from this, Pallikaranai Reserve Forest and Nanmangalam Reserve also add to

the spots of greenery and harbour biodiversity. However, the area of parks and gardens with natural spaces is just 0.16 ha per 1000 people giving a low score for Indicator 13. With organisations like Care Earth Trust, MS Swaminathan Research Foundation, Environmentalist Foundation of India, and renowned academic institutions, the city is trying to bridge the gap between awareness and action.

Figure 4: Radar Chart of CBI for Delhi



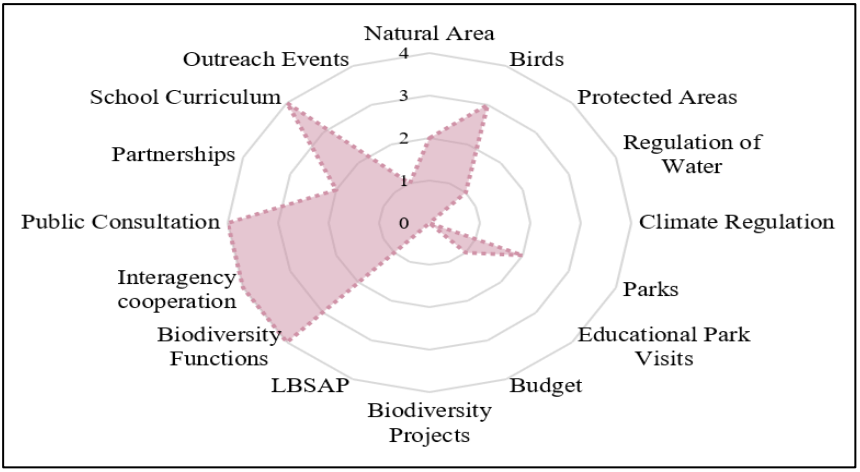
Source: Author's representation

Delhi, on the other hand, has several parks giving the city a high score on area of parks per 1000 persons. However, proportion of natural areas to total area of the city is approximately just 7 percent. As compared to other cities, it was easier to obtain information on the governance dimensions. Being the capital city, there are numerous institutions and organisations coordinating and functioning with the government agencies on biodiversity and environment matters, as expected. However, budget allocation is a mere 0.08 percent as per records.

Reserve and protected forests including Asola Bhatti Wildlife Sanctuary come under protected areas in the city. The municipal authorities have been actively commissioning projects such as tree planting to organisations for wider spread and ease of implementation. Attention has been drawn time and again to conservation of the ridge by environmentalists. Hopefully, the presence of so many organisations in the city can be leveraged further to spur action in the right direction.

Having the least score in this set of cities, Kolkata appears to have had a People's Biodiversity Register prepared; however, it is inaccessible to the public. The budget allocation reveals there is a considerable proportion coming through grants for projects like shore protection and Adi Ganga cleaning. There is allocation for solar lighting, air pollution monitors and for activities under the Parks, Squares and Urban Forestry division as well.

Figure 5: Radar chart of CBI for Kolkata

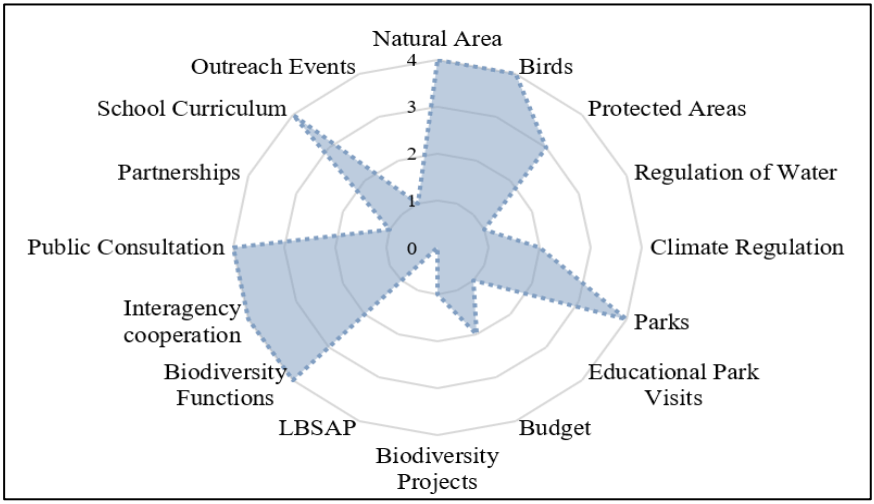


Source: Author's representation

With only few patches of parks, the Alipore zoo, the historically prominent Maidan, Rabindra Sarovar and some other water bodies,

the city needs to work towards preserving natural ecosystems. Outreach events and awareness campaigns have been organised by the city authorities on World Environment Day and World Wetland Day. 'No plastic' campaigns and ecotours for students have also been conducted. However, the translation to action appears lacking as can be seen in the minimal scores on native biodiversity and ecosystem services.

Figure 6: Radar chart of CBI for Mumbai



Source: Author's representation

Mumbai has scored decently on all parameters except number of biodiversity projects implemented, permeable surfaces, partnerships and outreach events. Among the cities considered here, Mumbai is the only city scoring 4 for proportion of natural areas. This is due to the massive 10,300 ha Sanjay Gandhi National Park in the heart of the city. For the native biodiversity and ecosystem services dimensions, the scores would significantly reduce if not for the National Park. However, the same area could have been distributed into smaller pockets of natural spaces across the city to facilitate accessibility. It would not give an accurate picture for an indicator like Indicator 13

which should be looking at accessible green spaces. One advantage of having unfragmented stretches is the fact that it reduces threat to sustainability of biodiversity. Hence, a balance would have to be worked out.

Mumbai also has maximum values with respect to proportion of protected areas, climate regulation and regulation of quantity of water (see appendix). City authorities of Mumbai have turned to Miyawaki technique to increase urban forest cover. Rejuvenation of rivers, beach cleaning, renovation of zoo, developing a wildlife conservation breeding centre are some projects initiated in the city. Mumbai does not have an LBSAP yet though the Maharashtra government has an action plan for biodiversity conservation.

COMPARATIVE ANALYSIS AND DISCUSSION

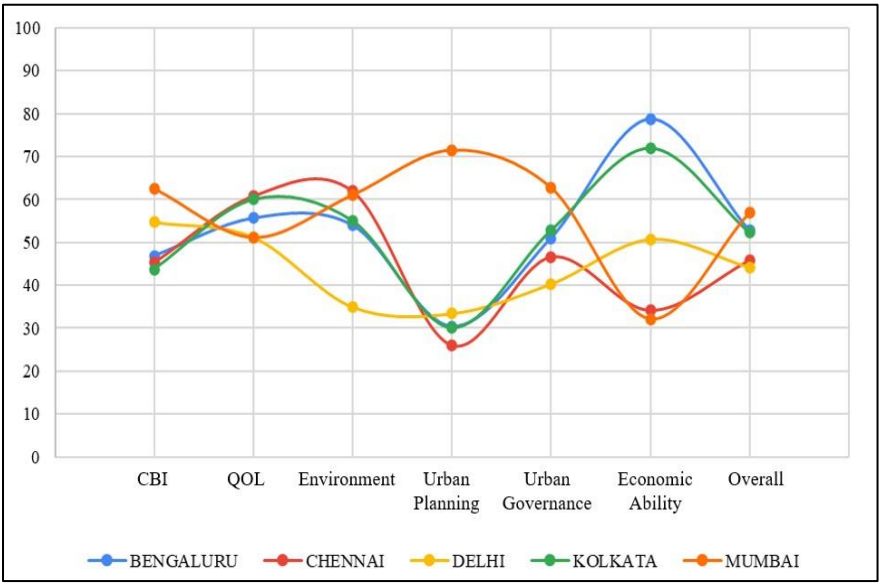
Comparing the biodiversity index (CBI) with other dimensions of quality of life (QOL), environment, urban planning, urban governance and economic ability yields interesting results. Table 4 shows the scores obtained in all dimensions and Figure 7 facilitates comparisons. The cell colours depict a red to green colour scale with red representing comparatively poor performance and green indicating relatively better performance. The overall score is a composite score arising from a simple average of all dimensions, as per methodology.

Table 4: Performance of cities across dimensions – 2019-20

Dimension	Bengaluru	Chennai	Delhi	Kolkata	Mumbai
CBI	46.875	45.3125	54.6875	43.75	62.5
QOL	55.67	60.84	51.22	60	51.12
Environment	54	62	35	55	61
Urban Planning	30.41	26.01	33.47	30	71.49
Urban Governance	51.01	46.63	40.33	52.75	62.74
Economic Ability	78.82	34.16	50.73	72	32.12
Overall	52.79	45.83	44.24	52.25	56.83

Source: Author's calculations

Figure 7: Performance Chart of Cities Across Dimensions – 2019-20



Source: Author's representation

Interestingly, when overall scores are considered, Delhi ranks lowest. From Figure 7 it is also observed that Bengaluru and Kolkata (blue and green lines respectively) follow a similar pattern, differing

largely only in quality of life and economic ability. Huge variations among the cities are seen for urban planning along with the economic ability dimension. Mumbai, which tops the list in urban planning, falls to the last position with economic ability. This could indicate that perhaps cities such as Mumbai and Chennai have become saturated with massive influx of job-seeking individuals over the years. Bengaluru has often been projected as a city brimming with opportunities especially in the IT sector and as expected tops the list in this dimension.

It is also a point to note that cities performing well in economic ability have relatively low scores in the biodiversity index, while the urban planning dimension follows a ranking similar to the index. Planning of the city affects urban biodiversity through the land use patterns determined by the planners. Land use changes affect native biodiversity and also hamper the provisioning of ecosystem services. None of the cities except Mumbai have a decent score in this dimension. A good plan would involve adequate proportions for open space and green cover. 'Healthy' urban planning would also recognise the links with the environment and natural spaces, ensure good water and air quality, encourage pedestrian movement and promote development of social capital along with other requirements of economic development (Barton and Grant, 2013). The environment dimension, which involves water quality, air quality, tree cover, hazardous waste generation and use of clean fuel, puts Chennai at the top with Mumbai following closely behind. Since data on the separate components was unavailable, based on the city profiles it could be presumed that air quality might have pulled down Delhi's performance, making it rank lowest. Coastal cities do have an advantage in air quality rankings. Testing water quality of state capitals by Bureau of Indian Standards in 2019 revealed that all samples from Mumbai passed the tests while Delhi samples failed in as many as 19 parameters.

There is relatively less variability in quality of life. Chennai has performed relatively well, while Mumbai and Delhi lag behind. This dimension involves health, education, WASH and SWM, recreation and other related aspects. As observed before (in section 5.5), waste management remains a challenge for Mumbai.

RECOMMENDATIONS

While economic and health related aspects are being looked after by the city authorities, sustainable cities would require more integrated actions. The spotlight is thus on extending the scope of the CBI and maximising welfare through integrated policies at minimum cost.

Extending the City Biodiversity Index

While the CBI remains an important tool for assessing urban biodiversity, it does not capture socio-economic measures which are equally important (Pierce *et. al.*, 2020). Since for all cities, municipal reports and information related to projects do not get disseminated on time, disclosure is essential to maintain the index and carry it forward. The index could be further finetuned with accessibility to data since this study could only use data available in online records.

CBI should be a regular exercise to determine the changing status of biodiversity. This will help plan urban forestry and demarcate areas where encroachment is strictly prohibited. This would also enable bringing more natural areas under conservation. Budget for biodiversity projects remains quite low on average. The cities could also seek external funding for this purpose.

The CBI accounts for the role of governance in planning and managing urban biodiversity; but that is not the only pathway by which biodiversity is maintained in a city. Many individuals and organisations have independently taken initiatives to improve green cover by using Miyawaki plantation techniques or creating vertical gardens. With

these cities having such a huge population, it could certainly be turned into an asset by directly and indirectly involving people and communities in the projects.

Policy Perspectives

(a) Focus Areas: While biodiversity is an area all cities need to focus on, looking at other dimensions, it is evident that Chennai, Kolkata and Bengaluru need better urban planning and implementation. Bengaluru also needs to improve quality of living. Delhi must focus on enhancing the environment, improving both air and water quality. Mumbai's economic ability could be improved by exploring a 'biodiversity economy', creating opportunities with respect to conservation, restoring ecological infrastructure and ecotourism.

(b) Using Green Nudges: The behavioural aspects of the population could be leveraged while making city-specific policies and plans. Green nudges could prove effective in increasing the ability and motivation of the residents to make more sustainable choices. In fact, biodiversity conservation could also be targeted using social comparisons and harnessing the competitive nature of humans.

A key element in the prospect theory in behavioural economics points to the tendency of loss aversion. A study by White *et. al.* (2020) revealed however that this may not necessarily apply to situations concerning biodiversity. While measuring people's reactions to biodiversity loss and gain via surveys, the researchers found that gains appeared to 'loom larger' than losses. Positive triggers or prompts to highlight gains in biodiversity might work better in prompting conservation.

Mumbai's longstanding issue of waste segregation could also be tackled using a nudge encouraging healthy social comparisons among students at universities or residents of a society. The current tax rebate system (see section 5.5) would certainly

incentivise segregation but there is a possibility that the behaviour may not sustain after the scheme expires. People might perceive segregation as a tedious task. However, coupling this with notifications to residents giving statistics on the how they compare with their peers or fellow society members would motivate them to perform better.

(c) Interlinking Urban Biodiversity and Human Wellbeing: The policies must also acknowledge the inherent linkages between urban biodiversity and human wellbeing in order to achieve multiple targets with a single integrated policy. This would make implementation cost-effective. As suggested by Barton and Grant (2013), urban planning should also promote interactions with nature while at the same time reduce human-wildlife conflicts. As the National Mission on Biodiversity and Human Well-Being pans out, focus on creating applicable LBSAPs should be prioritised as each city has different characteristics which an NBSAP/SBSAP may not be able to address effectively.

CONCLUSION

Urban biodiversity is a key factor affecting human well-being and as far as the Indian cities of Bengaluru, Chennai, Delhi, Kolkata and Mumbai are concerned, biodiversity needs to be conserved and preserved. Now more than ever, with the Covid-19 surge, recognising and incorporating the links of biodiversity and environment to human health and well-being is imperative. This study thus attempts to fill the literature gap in assessing biodiversity of Indian cities. As per the scores, Kolkata is the least performer with respect to the City Biodiversity Index, while Mumbai has relatively the highest score. Chennai tops both quality of living and environment dimensions but has the least score in urban planning. Economic ability is seen to be the highest in Bengaluru. Given the variations in data, Mumbai has the best all-round score while Delhi has the lowest.

These variations also indicate that each city has different characteristics and hence different focus areas with respect to planning and policymaking. Innovative tools such as green nudges could be explored to build in community actions in biodiversity conservation. Considering the time and data constraints of this study, further integrated research in expanding the scope and applicability of the City Biodiversity Index to Indian cities would certainly benefit policymakers.

India, being a megadiverse country, presents vast opportunities for research on different ecologies, species and their linkages to human well-being. With a growing population and continued demand for urbanisation, it is crucial to ensure that ecosystem services are not exploited. For continued functioning of the ecosystem and also improving human well-being as a positive externality, conserving biodiversity and sustainable using natural resources is essential.

REFERENCES

Adhikari, D., R. Tiwary and S. K. Barik (2015), 'Modelling Hotspots for Invasive Alien Plants in India', *PLoS ONE*, 10(7), DOI: https://doi.org/10.1371/journal.pone.0134665

Air Quality Monitoring and Research Laboratory (2019), 'Environment Status Report 2018- 2019', Municipal Corporation of Greater Mumbai, Available at: https://portal.mcgm.gov.in/irj/go/km/docs/documents /MCGM percent 20 Department percent 20 List/E nvironment/Docs /ESR percent20ENGLISH percent202018-2019.pdf

Bangalore Development Authority (2017), 'Revised Master Plan for Bengaluru – 2031 (Draft)', Available at: https://opencity.in/ documents /bda-revised-master-plan-2031-vision- document

Barton, H. and M. Grant (2013), 'Urban Planning for Healthy Cities', *Journal of Urban Health*, 90(1), pp. 129-141. DOI: https://dx.doi.org/10.1007 percent2Fs11524-011-9649-3

Bawa, K. S., A. Sengupta, V. Chavan, R. Chellam, R. Ganesan, J. Krishnaswamy, V. Mathur, N. Nawn, S. Olsson, N. Pandit, S. Quader, P. Rajagopal, U. Ramakrishnan, G. Ravikanth, M. Sankaran, D. Shankar, R. Seidler, U. R. Shaanker, A. T. Vanak, (2021), 'Securing Biodiversity, Securing Our Future: A National Mission on Biodiversity and Human Well-Being for India', *Biological Conservation*, 253, DOI: https://doi.org/10.1016/j.biocon.2020.108867

Bhasthi, D. (2017), 'City of Burning Lakes: Experts Fear Bangalore Will Be Uninhabitable by 2025', *The Guardian*, Available at: https://www.theguardian.com/cities/2017/mar/01/burning-lakes-experts-fear-bangalore- uninhabitable-2025.

Brauman, K. A., L. A. Garibaldi and S. Polasky (2020), 'Global Trends in Nature's Contributions to People', *PNAS*, 117(51), 32799-32805, DOI: https://doi.org/10.1073/pnas.2010473117

Brown, C. and M. Grant (2005), 'Biodiversity and Human Health: What Role For Nature in Healthy Urban Planning?', *Built Environment*, 31(4), 326-338, DOI: http://dx.doi.org/10.2148/benv.2005.31.4.326

Bruhat Bengaluru Mahanagara Palike (2019), 'Revised Budget Estimates for 2018-19 and Budget Estimates for 2019-2020', Available at:

https://bbmp.gov.in/departmentwebsites/Finance/Documents/Final percent20PDF percent202019- 20 percent20date percent204-6-2019.pdf

Centre for Science and Environment (2013), 'Chennai Faces a Unique Pollution Challenge – Pollution Levels That Appear to be Low Or Moderate, But Are Not So', *Press Releases*, Available at: https://www.cseindia.org/chennai-faces-a-unique-pollution-challenge-pollution-levels- that-appear-to-be-low-or-moderate-but-are-not-so-5078.

Chan, L., O. Hillel, T. Elmqvist, P. Werner, N. Homan, A. Mader, E. Calcaterra (2014), 'User's Manual on Singapore Index on Cities', Biodiversity (Also Known as the City Biodiversity Index)',

Chatterjee, B. (2020a), 'Lowest Species Count Ever at Mumbai Bird Race', *Hindustan Times.* Available at: https://www.hindustantimes.com/mumbai-news/lowest-species-count-ever- at-mumbai-birdrace/story-ZcY1ITvgnDa9pmPefNilHI.html

Chatterjee, B. (2020b), 'Thane Flamingo Sanctuary, SGNP are Best Managed Protected Areas in Maha: Centre Report', *Hindustan Times*, Available at: https://www.hindustantimes.com/cities/thane-flamingo-sanctuary-sgnp-are-best-managed-protected-areas-in-maha-centre-report/story-zvRMWNBiATorYAclcPntPI.html

Chatterji, A. (2020), 'Air Pollution in Delhi: Filling the Policy Gaps', *ORF Occasional Paper*, 291, Available at: https://www.orfonline.org/research/air-pollution-delhi-filling- policy-gaps/#_edn77

Chitnis, P. (2018), 'In charts: Land Mumbai has Found to Develop in the Next Two Decades', *Bloomberg Quint*, Available at: https://www.bloombergquint.com/business/in-charts-land-mumbai-has-found-to-develop-in-the-next-two-decades

Chowdhury, I. R. (2016), 'Scenario of Traffic Noise Pollution and Its Impact on Human Health: An Empirical Study on Kolkata City', *International Journal of Current Research*, 8(6), Available at: http://www.journalcra.com/sites/default/files/issue-pdf/15532.pdf

Demographia (2020), 'Demographia World Urban Areas (Built Up Urban Areas Or World Agglomerations) 16th Annual Edition', Available at: http://www.demographia.com/db- worldua.pdf

Finance Minister, Planning Department (2020), 'Budget Speech 2020-21', *Government of NCT of Delhi*. Available at: http://delhiplanning.nic.in/content/budget-delhi-2020-21

Forest Survey of India (2019), *India State of Forest Report 2019*, Volume 2, Ministry of Environment, Forest and Climate Change, Dehradun, Available at: https://fsi.nic.in/isfr- volume-ii?pgID=isfr-volume-ii

Gopalakrishnan, S. (2018), 'Inside Nanmangalam Reserve Forest, Chennai's Lesser-Known Natural Gem', *Citizen Matters*, https://chennai.citizenmatters.in/exploring-the- nanmangalam-reserve-forest-6486.

Government of NCT of Delhi; Institute for Human Development (n.d.), 'Vision Delhi 2030 Draft Report', Available at: http://des.delhigovt.nic.in/wps/wcm/connect/d92261804687c81fa5ccbf264798d198/Visio n+Delhi+2030.pdf?MOD=AJPERES and lmod=331890187 and CACHEID=d92261804687c81fa5ccbf264798d198

Greater Chennai Corporation (2019), 'Budget at a Glance', Available at: https://www.chennaicorporation.gov.in/budget/Budget_2019-20/Budget_at_glance.pdf

Greenpeace India (2021), '1800 Deaths Per Million Estimated Due to PM2.5 Air Pollution in Delhi, Reveals A New Finding by Greenpeace and IQAir', *Greenpeace Southeast Asia,* Available at: https://www.greenpeace.org/india/en/press/10991/1800-deaths-per-million- estimated-due-to-pm2-5-air-pollution-in-delhi-reveals-a-new-finding-by-greenpeace-and- iqair/

Higgins, S. L., F. Thomas, B. Goldsmith, S. J. Brooks, C. Hassall, J. Harlow, D. Stone, S. Volker and P. White (2019), 'Urban Freshwaters, Biodiversity, and Human Health and Well- Being: Setting An Interdisciplinary Research Agenda', *WIREs Water*, 6(2). DOI: https://doi.org/10.1002/wat2.1339

Hoegh-Guldberg, O., D. Jacob and M. Taylor *et. al.* (2018), 'Impacts of 1.5°C of Global Warming on Natural and Human Systems', *Global Warming of 1.5° C: An IPCC Special Report on the Impacts of Global Warming of 1.5° C Above Pre-Industrial Levels And Related Global Greenhouse Gas Emission Pathways in the Context Of Strengthening The Global Response To The Threat Of Climate Change, Sustainable Development, And Efforts To Eradicate Poverty,* Chapter 3, Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter3_Low_Res.pdf

HT Correspondent (2020), 'Count in, Bird Species Tally Up to 253 in Delhi-NCR', *Hindustan Times*. Available at: https://www.hindustantimes.com/delhi-news/count-in-bird-species-tally-up-to-253-in-delhi-ncr/story-EbwAXHz6PaVG79HPHdf4GJ.html https://www.indiatoday.in/india/story/aarey-milk-colony-tree-felling-supreme-court- mumbai-metro-construction-1607037-2019-10-07

IPBES (2019), 'Summary for Policymakers Of The Global Assessment Report On Biodiversity And Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services', *IPBES Secretariat*, Bonn, Germany.

Joseph, K. (2019), 'Birdwatchers Say Number of Birds in City Has Reduced', *Deccan Herald*. Available at: https:// www.deccanherald.com/metrolife/metrolife-cityscape/ birdwatchers-say-number-of-birds-in-city-has-reduced-764481.html

Kapoor, A., C. Yadav and M. Kapoor *et. al.* (2021a), 'Ease of Living Index 2020', *Ministry of Housing and Urban Affairs*. Available at: https://livabilitystore175634-prod.s3.amazonaws.com/public/docs/Ease_of_Living_Report.pdf

Kapoor, A., C. Yadav and M. Kapoor *et. al.* (2021b), 'Municipal Performance Index 2020', *Ministry of Housing and Urban Affairs*. Available at: https://livabilitystore175634-prod.s3.amazonaws.com/public/docs/MPI_Report.pdf

Keesing, F., L. Belden and P. Daszak *et. al.* (2010), 'Impacts of Biodiversity on the Emergence and Transmission of Infectious Diseases', *Nature*, 468, pp. 647–652. DOI: https://doi.org/10.1038/nature09575

Khelkar, P. (2019), 'Aarey Colony Dispute: 2141 Trees Already Cut, Mumbai Metro to Go Ahead With Construction', *India Today*, Available at:

Kumar, M. S. T. (2017), 'With Three Rivers and Five Wetlands, Why Is Chennai Staring at Ecological Collapse?', *Citizen Matters*, Available at: https://chennai.citizenmatters.in/chennai-rivers-wetlands-marsh-environment-heritage-1577.

Kumar, M. P. (2018), 'Bangalore has 11,000 Acres of Forest Area: Dipika Bajpai', *Citizen Matters*, Available at: https://bengaluru.citizenmatters.in/bangalore-has-11000-acres-of-reserved-forests-in-it-dipika-bajpai-25864

Lakshmi, K. (2019), 'The Vanishing Waterbodies of Chennai', *The Hindu*, Available at: https://www.thehindu.com/news/cities/chennai/the-vanishing-waterbodies-of- chennai/article23404437.ece

Maji, K. J., A.K. Dikshit and A. Deshpande (2017), 'Disability-Adjusted Life Years and Economic Cost Assessment of the Health Effects Related to PM2.5 and PM10 Pollution in Mumbai and Delhi, in India from 1991 to 2015', *Environmental Science and Pollution Research International*, 24(5). DOI: https://doi.org/10.1007/s11356-016-8164-1

Majumdar, M. (2020), 'When Chennai Raced To Count All Its Bird Species', *The Hindu*, Available at: https://www.thehindu.com/sci-tech/energy-and-environment/chennais-bird- species-are-counted-at-madras-bird-race-2020/article30674776.ece

Mayor, Central Municipal Office (2019), 'Budget Statement', *Kolkata Municipal Corporation*, Available at: https://www.kmcgov.in/KMCPortal/downloads/KMC_Budget_English_2019_2020.pdf

Methorst, J., K. Rehdanz, T. Mueller, B. Hansjurgens, A. Bonn and K. Bohning-Gaese (2021), 'The Importance of Species Diversity for Human Well-Being in Europe', Ecological Economics, 181, DOI: https://doi.org/10.1016/j.ecolecon.2020.106917

Municipal Commissioner, Brihanmumbai Mahanagarpalika (2020), 'Statement of Praveen Pardeshi While Presenting the Budget Estimates 'A' (fund Code - 11, 12, 60, 70), 'B' (Fund Code - 21, 22, 23) and 'G' (Fund Code - 40) For 2020 - 2021 to the Standing Committee on Tuesday, the 4 February 2020', *Municipal Corporation of Greater Mumbai*, Available at: https://portal.mcgm.gov.in/irj/go/km/docs/documents/MCGM percent20Department percent20List/C hief percent20Accountant percent20(Finance)/Budget/Budget percent20Estimates percent202020-21/1- percent20MC percent27s percent20Speech/BUDGET percent20A percent2C percent20B percent2CG/ENGLISH percent20SPEEC H.pdf

Nagendra, H., H.S. Sudhira, M. Katti and M. Schewenius (2013), 'Sub-Regional Assessment of India: Effects of Urbanisation On Land Use, Biodiversity And Ecosystem Services', *Urbanisation, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment*, Chapter 6, DOI: 10.1007/978-94-007-7088-1_6

Nath, S. (2019), 'Why Despite Fewer Vehicles and Industries, Kolkata is Chasing Delhi on Pollution', *News18*, Available at: https://www.news18.com/news/india/why-despite- fewer-vehicles-and-industries-kolkata-is-chasing-delhi-on-pollution-charts-2378547.html

National Biodiversity Authority, India; Ministry of Environment, Forest and Climate Change; German Agency for International Cooperation (n.d.), 'Access and Benefit Sharing Partnership Project – Indo-German Biodiversity Programme', *Activity Report 2016-20*, Available at: http://tnbb.tn.gov.in/images/pdf/ABS_Partnership_Project_Activity_report_2016- 2020.pdf

Paul, S. and S. Bardhan (2017), 'Biodiversity accounting of Cities: A Case Study of Kolkata, India', *WIT Transactions on Ecology and Environment*, 226, Sustainable Development and Planning IX, pp. 815-826. DOI: 10.2495/SDP170711

Pierce, J.R., M. A. Barton and M.M.J. Tan *et. al.* (2020), 'Actions, Indicators, And Outputs in Urban Biodiversity Plans: A Multinational Analysis of City Practice', *PLoS ONE*, 15(7), https://doi.org/10.1371/journal.pone.0235773

Praja Foundation (2018), 'The State of Health in Mumbai', *White Paper*, Available at: https://www.praja.org/praja_docs/praja_downloads/Report percent20on percent20The percent20STATE percent2 0of percent20HEALTH percent20in percent20MUMBAI.pdf

Punj Lloyd Institute of Infrastructure Management (2017), 'Smart Cities Index: A Tool For Evaluating Cities', *Indian School of Business*, Available at: https://shaktifoundation.in/wp-content/uploads/2017/11/Smart-Cities-Index.pdf

Rajashekariah, K. (2011), 'Impact of urbanisation on Biodiversity: Case Studies from India', *WWF Report*, Available at: https://d2391rlyg4hwoh.cloudfront.net/downloads/impact_of_urbanisation_on_biodiversity.pdf

Ramachandra, T.V., S. Vinay and B.H. Aithal (2017), 'Frequent Floods in Bangalore: Causes and Remedial Measures', *ENVIS Technical Report 123*, Environmental Information System, CES, Indian Institute of Science, Bangalore.

Ramachandra, T.V. B.H. Aithal, G. Kulkarni and S. Vinay (2017), 'Green Spaces in Bengaluru: Quantification Through Geospatial Techniques', *Indian Forester*, 143(4), 307-320, Available at: https://www.researchgate.net/publication/315670439_GREEN_SPACES_IN_BENGALURU_QUANTIFICATION_THROUGH_GEOSPATIAL_TECHNIQUES

Sandifer, P.A., A.E. Sutton-Grier, Ward (2014) 'Exploring Connections Among Nature, Ecosystem Services, and Human Health And Well-Being: Opportunities To Enhance Health And Biodiversity Conservation', *Ecosystem Services*, 12, 1-15, DOI: http://dx.doi.org/10.1016/j.ecoser.2014.12.007

Sarkar, L. H. (2017), 'Mangroves in Mumbai', *International Journal of Creative Research Thoughts*, 5(4), Available at: https://ijcrt.org/papers/IJCRT1704193.pdf

Sheeba, G. A. Jalagam and V. Venkatasubramanian (2017), 'Drinking Water Contamination from Peri-Urban Bengaluru, India', *Current Science*, 113(9), pp.1702-1709. DOI: https://www.jstor.org/stable/26493310

Singh, L. (2020), 'Mumbai to Get 1st Biodiversity Management Panel', *The Indian Express*, Available at: https://indianexpress.com/article/cities/mumbai/mumbai-to-get-1st-biodiversity-management-panel-7103750/

Singh, V.A. (2019), 'Mumbai: Debris Threaten Biodiversity Around Lokhandwala Lake', *DNA*, Available at: https://www.dnaindia.com/mumbai/report-mumbai-debris-threaten-biodiversity-around-lokhandwala-lake-2714517

Tamil Nadu Pollution Control Board, Government of Tamil Nadu (2019), 'District Environmental Plan–Chennai District', Available at: https://cdn.s3waas.gov.in/s313f3cf8c531952d72e5847c4183e6910/uploads/2019/12/2019 120999.pdf

Tandon, M. and R. Dutta (2017), 'Biodiversity Management Committees', Legal Initiative for Forest and Environment, Policy Paper Series – October, Available at: https://thelifeindia.org.in/upload/files/BMC percent20 percent20- percent20policy percent20paper percent20Final.pdf

Varshney, A. (2020), 'Bengaluru's Biodiversity Management Committee is Back in Action', *Mongabay*, Available at: https://india.mongabay.com/2020/09/bengalurus-biodiversity-management-committee-is-back-in-action/

White, M. P., G. N. Bratman, S. Pahl, G. Young, D. Cracknell and L. R. Elliott, (2020) 'Affective reactions to losses and gains in biodiversity: Testing a prospect theory approach', *Journal of*

Wolfe, N.D., P. Daszak, A.M. Kilpatrick and D.S. Burke (2005), 'Bushmeat Hunting, Deforestation, and Prediction of Zoonotic Disease', *Emerging Infectious Diseases*, 11(12), 1822-1827, DOI: https://dx.doi.org/10.3201 percent2Feid1112.040789

APPENDIX

Table A1: City-wise Sources for Biodiversity Index Calculations

Component	Sr. No.	Indicator	Bengaluru	Chennai	Delhi	Kolkata	Mumbai
Native Biodiversity	1	Natural Area	BDA Revised Master Plan 2031	Gopalakrishnan (2018); ISFR 2019; Lakshmi (2019)	DDA*; ISFR 2019	KMC*; ISFR 2019	Chitnis (2018); ISFR 2019
	2	Connectivity Measures	-	-	-	-	-
	3	Birds	Joseph (2019); eBird*; Swamy *et. al.* (2019)	Majumdar (2020); eBird*	HT Correspondent (2020); eBird*	Paul and Bardhan (2017)	Chatterje e (2020a)
	4-8	Change in Species	-	-	-	-	-
	9	Protected Areas	BDA Revised Master Plan 2031	Gopalakrishnan (2018); ISFR 2019	ISFR 2019; DDA*	KMC*; ISFR 2019	ISFR 2019; Chatterje e (2020b)
	10	Invasive Species	-	-	-	-	-
Ecosyste m Services	11	Regulation of Water	BDA Revised Master Plan 2031; ISFR 2019; BBMP*; Ramachandra *et. al.* (2017)	Gopalakrishnan (2018); ISFR 2019; Lakshmi (2019); GCC*	Budget Speech 2020-21; ISFR 2019	KMC*; ISFR 2019; KMC Budget 2019-20	ISFR 2019; BMC*
	12	Climate Regulation	Kumar (2018); ISFR 2019	Gopalakrishnan (2018); ISFR 2019; Lakshmi (2019)	DDA*; ISFR 2019	KMC*; ISFR 2019	BMC*; ISFR 2019
	13	Parks	BBMP List of Parks*	GCC List of Parks*	DDA List of Parks*	KMC List of Parks*	BMC List of Parks*
	14	Educational Park Visits	Compiled from school websites	Compiled from school websites	Compiled from school websites	Compile d from school websites	Compiled from school websites
Governan	15	Budget	BBMP Budget 2019-20	GCC Budget 2019-20	Budget Speech 2020-21	KMC Budget 2019-20	BMC Budget 2020-21

Component	Sr. No.	Indicator	Bengaluru	Chennai	Delhi	Kolkata	Mumbai
ce and Management	16	Biodiversity Projects	BBMP Budget 2019-20; Agency websites	GCC Budget 2019-20; CRRT*	Budget Speech 2020-21; Agency websites	KMC Budget 2019-20	BMC Budget 2020-21; ESR 2018-19
Governance and Management	17	LBSAP	No record found; Varshney (2020)	No record found; TNBB*	No record found; Vision Delhi 2030 Draft Report	No record found; Paul and Bardhan (2017)	No record found; Singh (2020)
	18	Biodiversity Functions	BBMP*; Google Earth	GCC*; Google Earth	DDA*; Google Earth	KMC*; Google Earth	BMC*; Google Earth
	19	Interagency cooperation	BBMP*; BDA*; Agency websites; Budget 2019-20	CRRT*; Chennai District Environmental Plan 2019	Department of Environment, Govt. of Delhi; DDA*; Budget Speech 2020-21	KMC Budget 2019-20	BMC Budget 2020-21; ESR 2018-19
	20	Public Consultation	BBMP*; BDA*	GCC*; CRRT*	Department of Environment, Govt. of Delhi	KEIIP 2019	BMC*; ESR 2018-19
	21	Partnerships	BBMP*; Agency websites; Budget 2019-20	GCC*; TNBB*; Agency websites	Department of Environment, Govt. of Delhi; Budget Speech 2020-21	KMC Budget 2019-20; KEIIP 2019	BMC; ESR 2018-19
	22	School Curriculum	CBSE syllabus; KSEEB syllabus	CBSE syllabus; TNBSE syllabus	CBSE syllabus; DBSSE syllabus	CBSE syllabus; WBBSE syllabus	CBSE syllabus; MSBSHSE syllabus
	23	Outreach Events	BBMP*	GCC*	Department of Environment, Govt. of Delhi	KMC*	BMC*; ESR 2018-19

*: Refers to websites and webpages of that agency accessed over the period of January, 2021 to March, 2021.

Source: Author's compilation

Table A2: City-wise Values of Indicators for Biodiversity Index

Component	Sr. No.	Indicator	Bengaluru	Chennai	Delhi	Kolkata	Mumbai
Native Biodiversity	1	Natural Area	3.6 percent	12.03 percent	7.07 percent	7.13 percent	38.42 percent
	2	Connectivity Measures	-	-	-	-	-
	3	Birds	Around 150	Around 171	Around 247	Around 64	Around 192
	4-8	Change in Species	-	-	-	-	-
	9	Protected Areas	0.6 percent	2.13 percent	6.87 percent	2.20 percent	17.06 percent
	10	Invasive Species	-	-	-	-	-
Ecosystem Services	11	Regulation of Water	8.02 percent	25.64 percent	27.27 percent	7.30 percent	39.28 percent
	12	Climate Regulation	0.045 percent	9.03 percent	21.87 percent	0.86 percent	23.67 percent
	13	Parks	0.391	0.16	18.44	0.461	10.82
	14	Educational Park Visits	1	1	1	1	1
Governance and Management	15	Budget	4.3 percent	0.93 percent	0.08 percent	0.36 percent	2.5 percent
	16	Biodiversity Projects	<12	<12	<12	<12	12-15
	17	LBSAP	Doesn't exist	Doesn't exist	Doesn't exist	Doesn't exist	Doesn't exist
	18	Biodiversity Functions	At least 4	At least 4	At least 4	At least 4	At least 4
	19	Interagency cooperation	At least 5	>5	At least 12	At least 7	>5
	20	Public Consultation	Process exists	Process exists	Process exists	Process exists	Process exists
	21	Partnerships	7 to 12	At least 7	Around 19 - 22	7 to 12	Around 6
	22	School Curriculum	Included	Included	Included	Included	Included
	23	Outreach Events	1-59	1-59	1-59	1-59	1-59
Total			30	29	35	28	40

Source: Author's compilation

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