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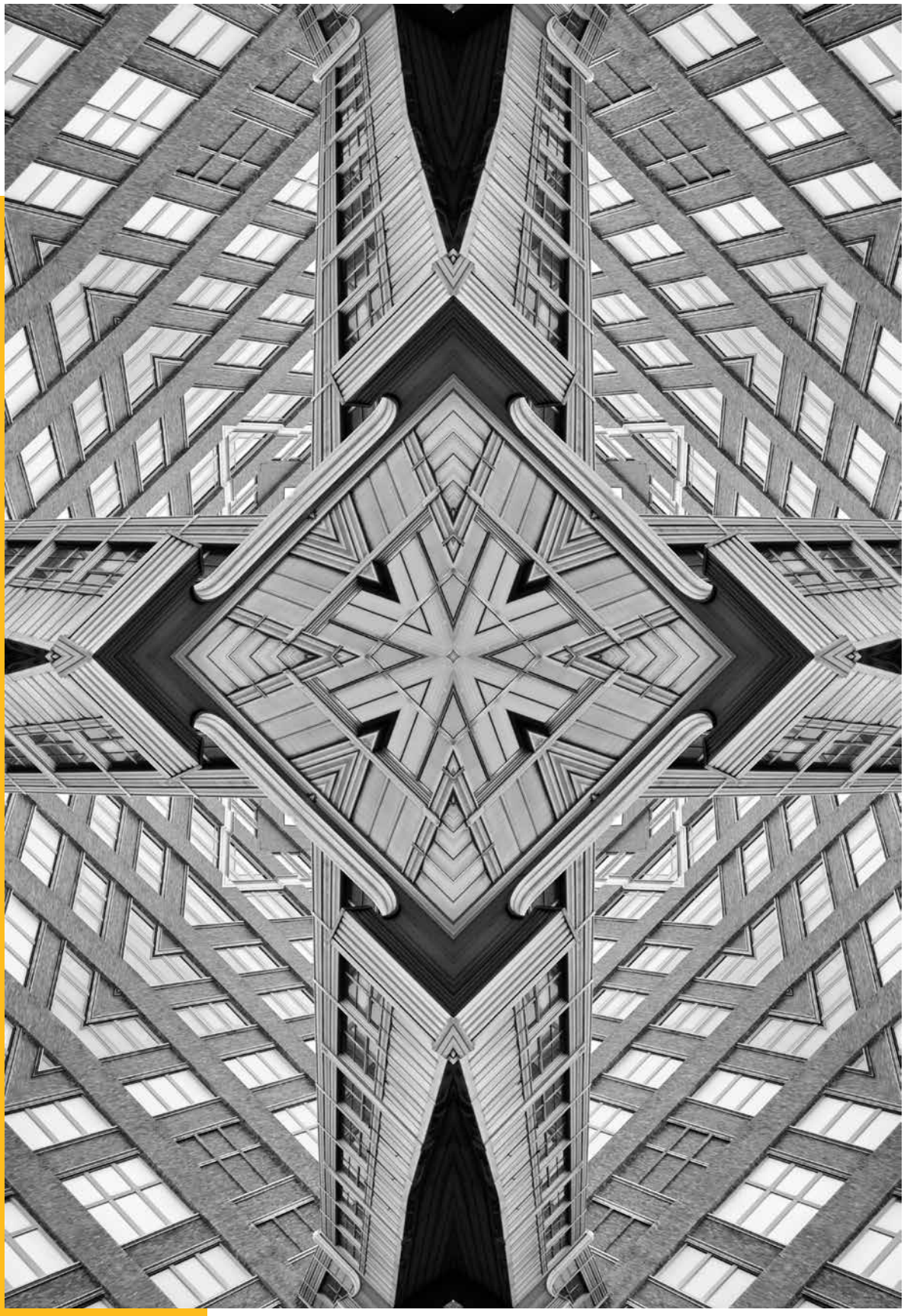

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Blue-Green Infrastructure: An Opportunity for Indian Cities

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Abstract

As the threat from climate hazards rise, several global cities have altered their urban planning and design approaches to incorporate nature-driven solutions as a counter to conventional infrastructure practices by harnessing blue elements (for instance, seas, rivers, lakes, wetlands, and water utilities) alongside the green (such as trees, parks, gardens, playgrounds and forests). This paper explores the emerging concept of blue-green infrastructure, and analyses existing plans and projects in India and globally. It also identifies opportunities in the blue-green space to help India's cities respond to climate hazards, promote equity and resilience, and catalyse economic transitions for sustainable urban futures.

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Introduction

As countries around the world embark on economic recovery plans in the wake of the COVID-19 pandemic there is widespread acknowledgement of the need for sustainable revival focussed on adapting to and mitigating climate change.[1] For India, which aims to grow into a US$5 trillion (INR 364 trillion) economy by 2024,[2] climate-proofing the economy and building resilient development sectors is a priority. This necessitates a policy and investment response addressing the three linked aspects of sustainable development: economic, social and environmental.[3]

Urban areas are facing increasing climate risks and threats to human comfort and environmental justice. Of the four major global risks projected to have a negative decadal consequence on countries through temperature increases, three are primarily environmental—natural disaster, extreme weather and biodiversity loss, with climate action failure as the fourth.[4] In attempts to address these challenges, growing attention is being paid to the potential role of green (such as trees, parks, gardens, playgrounds and forests) and blue (seas, rivers, lakes, wetlands, and water utilities) spaces, often approached through the concept of green and blue infrastructure.[5]

According to the Intergovernmental Panel on Climate Change, global CO_2 emissions will need to decline by about 45 percent below 2010 levels by 2030 and reach net zero by 2050 to keep the overall temperature increase within the 1.5°C-limit by the end of the century.[6] In India, average temperatures increased by 0.7°C between 1901 and 2018 due to excessive greenhouse gas emissions. Even at the most optimum rate of immediate emissions mitigation, India's temperature will still rise by 2.7°C by 2099; in the worst scenario, it will rise by 4.4°C by the end of the century.[7]

> "Green and blue spaces will have a key role to play in addressing climate-related threats."

Introduction

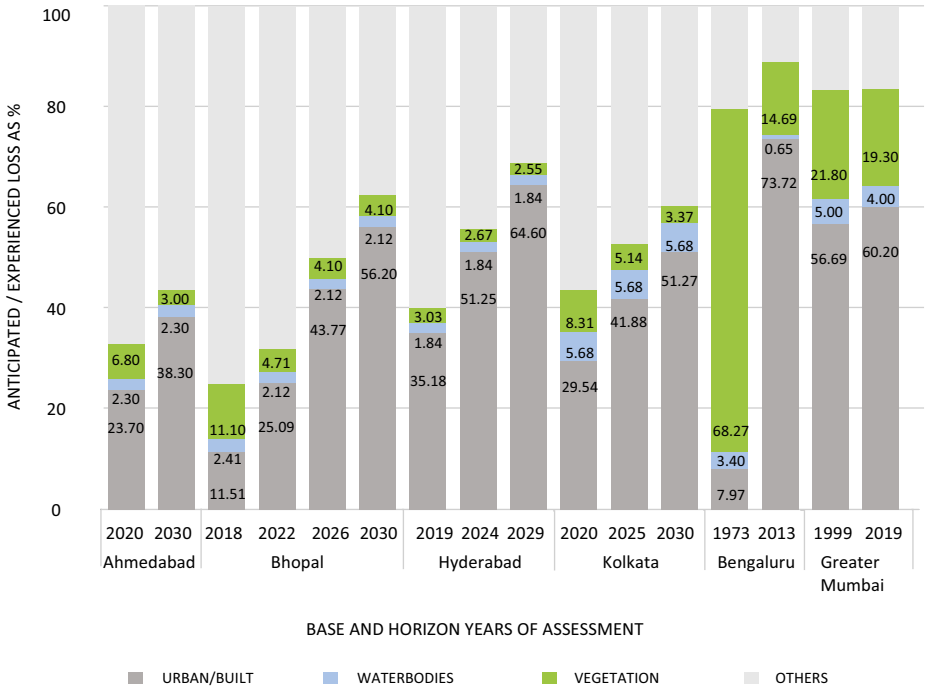
Cities are a key contributor to climate change. Despite accounting for less than 2 percent of the Earth's surface, cities consume 78 percent of the world's energy and produce over 60 percent of all greenhouse gas emissions.[8] By 2050, about 68 percent of the global population is expected to reside in urban agglomerations.[9] One in every two Indians is expected to live in cities by that year.[10]

The unprecedented surge of extreme weather events in India—such as drought, cyclones, forest fires, heatwaves and floods—have been directly linked to climate change, induced by greenhouse gas emissions through the use of fossil fuels and aerosols, and changes in land use and land cover.[11] Existing urban infrastructure[a] will need to be reinforced and made resilient to the anticipated population growth and withstand future shocks and calamities expected as outcomes of climate change. Sustainable water management through blue interventions and investment in green infrastructure can help build climate resilience.[12]

Several Indian cities have seen a decline in green and blue features due to rapid urbanisation, with studies on land-use transitions indicating environmental losses (see Figure 1). Bengaluru, for instance, has seen a 925-percent increase in built-up area[13] between 1973 and 2013, with green features decreasing from 68 percent to 14 percent, and blue features from 3 percent to less than 1 percent. Similarly, from 1977 to 2017, Mumbai witnessed a 60-percent loss in vegetation and 65-percent decrease in waterbodies.[14] A technical land-use land cover assessment for Greater Mumbai released in 2020 further indicates up to a 2.5 percent loss in vegetation and a 1.4 percent loss in waterbodies over the 1999-2019 period.[15] And Ahmedabad is projected to see an approximate 50-percent loss in vegetation between 2010 and 2030.[16] An inability to effectively streamline, regulate and monitor urbanisation processes is inadvertently responsible for this vast environmental loss.

a The basic physical and organisational structures and facilities that are needed for a city's functioning, such as buildings, roads and power supply.

Figure 1:
Loss in Blue-Green Areas and Rise in Built-Up Areas in Major Indian Cities



Source: Prepared by authors based on data from Ramachandra et. al. (2016),[17] (2017),[18] and Shantaram et. al. (2020)[19]

Where the responsibility of compensating for natural losses lay with statutory development norms and the regulations of each Indian state and their cities, early approaches involved creating 'grey' infrastructure—artificially engineered solutions adapted to deal with climate emergencies related to water, such as wastewater treatment plants, water pumping stations in flood prone zones, pipelines, dams and reservoirs. Since these works involved the construction of hard surfaces and the usage of concrete, asphalt and steel, there are more capable solutions that could provide the climate resiliency required in the twenty-first century.[20] Infrastructure planning must become more sensitive to ecological considerations by developing and adapting nature-based solutions to meet climate and sustainability goals, a purpose served by blue-green infrastructure.

Blue-Green Infrastructure: Defining the Concept

While there is no established definition of the concept of blue-green infrastructure, a literature review of most terminologies and output can be categorically adjusted under the umbrella of nature-based solutions,[21] with a focus on three pillars—climate change, health and urban resilience (see Figure 2).

Figure 2: The Umbrella of Nature-Based Solutions and Benefit Categories

Source: Interpreted by the authors from Seddon N. et. al. (2020)[22] and Fargione et. al.[23]

Western definitions of 'green infrastructure' and blue-green infrastructure tend to be synonymous for the most part. Blue features have been included in most definitions specifically pertaining to green infrastructure, and thus cannot simply be categorised as 'green' but must be called 'blue and green' definitions. The European Commission defines green infrastructure as "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities and enhances biodiversity".[24]

Introduction

The Australian public sector approach expanded the scope of dormant opportunities in blue-green infrastructure (in reference to integrating water management and planning with urban landscape and greening outcomes) by recognising the inherent multifunctionality of the individual blue and green components.[25] Deploying blue-green infrastructure in sectors such as transportation, water and housing[26] can result in various provisioning, regulating, supporting and cultural ecosystem services,[27] which in turn lead to health and environmental improvements alongside financial savings.

The blue-green infrastructure concept is still new in India, and as such will be defined as per its inclusion in policies at the central, state and sub-regional levels. For instance, the Delhi Development Authority, which is creating a blue-green masterplan for the city, defines blue and green infrastructure separately, and restricts both to the field of urban planning: "'Blue' infrastructure refers to water bodies like rivers, canals, ponds, wetlands, floodplains, and water treatment facilities; while 'Green' stands for trees, lawns, hedgerows, parks, fields, and forests. The concept refers to urban planning where water bodies and land are inter-dependent and grow with the help of each other while offering environmental and social benefits".[28]

> "Blue-green infrastructure can be defined as an umbrella of nature-based solutions that have a direct impact on climate change, urban resilience, and health and wellness."

Existing Global Blue-Green Practices

Global instances of blue-green interventions over the past two decades have been introduced to address various kinds of urban issues. For instance, the German city of Leipzig overcame population and economy declines in the post-reunification period through comprehensive green infrastructure planning at the city and regional levels. By making way for detached housing in previously developed green sites, proposing pocket parks, and chaining green spaces near high density housing, the liveability and valuation of Leipzig's urban areas improved substantially.[29]

Although existing global blue-green interventions may differ in terms of density, size or the nature of the problem and the goal, learnings from these initiatives will be useful to Indian cities and others in creating blue-green infrastructure frameworks to address local problems and challenges.

Blue-Green Cities Research Project, UK

A three-year project (starting February 2013) at the University of Nottingham, UK, to create an integrated blue-green infrastructure plan to popularise the concept of blue-green cities. The University of Nottingham partnered with eight other UK universities[b] and the government, citizens and industry in Newcastle to create and deliver multiple flood risk benefits through blue-green infrastructure.

The strategy adopted was for the stakeholders to be the central focus of the project, remodel the drainage systems and minimise risks by studying gaps in the urban drain networks, creating adaptive strategies with the communities, establishing a flood footprint to calculate economic costs, identifying barriers to flood prevention, and setting-up blue-green infrastructure.[30]

b Cranfield University, De Montfort University, Leeds University, London School of Economics, Newcastle University, University of University of East Anglia, University of Nottingham Ningbo, and University of the West of England

The 'flood footprint', a framework to measure the direct and indirect socioeconomic impact of the damage caused by floods in absolute numbers, was a key outcome.[31] Typically, flood impacts are measured only in terms of the direct damage caused to physical assets. Its ripple effects on other indicators beyond physical assets are generally ignored. The flood footprint helped identify the gaps and blind spots in critical infrastructure through a sectoral analysis. It found that Newcastle suffered a direct economic damage of £44 million (INR 4.54 billion) during the 2012 summer floods. The indirect damage caused by the floods was 27 percent larger than the direct damage.[32]

Learnings from this initiative are pertinent to flood-prone Indian cities like Mumbai and Hyderabad, which have been unable to address urban flooding by not accounting for hazard levels during major infrastructure development. Mumbai, for instance, lost INR 14,000 crore over a decade (2005-2015) to flooding.[33]

Rain City Strategy, Vancouver, Canada

Approved in 2019 and formulated by the Vancouver Board of Parks and Recreation, the 'Rain City Strategy' aimed to protect and improve urban water quality, increase urban resilience through sustainable water management, and enhance liveability by improving natural and urban ecosystems,[34] with a total investment of US$70 million (INR 5.13 billion). This was done by outlining specific objectives, such as air and water pollutant removal, increasing managed impermeable areas and green areas that treat runoffs, and mitigating urban heat island effect. The goal of capturing and cleaning 90 percent of received rainwater was met through a series of action plans involving streets and public spaces, buildings, parks and beaches. The Rain City Strategy identified numerous components, such as bioswales, rain gardens, green roofs, permeable pavements, engineered wetlands, modular systems and absorbent landscapes, to achieve the goals of water management and conservation.[35]

As a result of the project, Vancouver became water sensitive, was able to protect the health and vitality of water bodies and help communities and ecosystems thrive by revitalising watersheds. The project also sought to broadly address equity reforms, and presented further opportunities with respect to innovation, education and culture.

A similar strategy will be apt for those Indian cities where most of the land has been developed and can be appropriately retrofitted based on the Development Control Regulations,[c] such as Bengaluru, Mumbai and Hyderabad.

Active, Beautiful, Clean Waters Programme, Singapore

In 2006, Singapore's Public Utilities Department under the Ministry of Environment and Water Resources launched the Active, Beautiful, Clean (ABC) Waters Programme to realise the full potential of a progressively developed drainage network of 17 reservoirs and 8,000 km of drains, canals and rivers. Since two-thirds of Singapore comprises catchment areas, holistic and sustainable stormwater management was initiated through onsite detention and retention methods, even as the need to increase community involvement was recognised.[36]

The ABC programme sought to holistically integrate canals, drains and reservoirs with the surrounding environment to improve the quality and aesthetic value of streams, rivers and lakes. The elements involved at the ground level were categorically subdivided in alignment with the intent to collect, treat and store stormwater—catchment on roads, pedestrian walkways, bicycle paths, waterbodies, open fields, urban plazas, building features; treatment through constructed wetlands, sedimentation basins, vegetated swales, bioretention swales and basins; and conveyance and storage through water bodies and waterways.[37]

The programme was executed through a master plan, water design guidelines (2009) and a rating certification (2010). The guidelines encouraged the public and private sectors to arrive at unique ways to implement ABC water design features and integrate waterways within developments. Entities opting for certification incurred no assessment fees and could display the ABC programme logo to promote the project.[38]

c A set of land use rules to ensure the proper planning and effective development of a city. It is revised and updated whenever a new development plan is introduced.

For India, aligning short-term and long-term objectives for water in urban settings is key to the successful implementation of standalone plans. Project intentions and monetary commitments must be complimented with climate action plans and reflect in periodic development strategies for each city.

Hoeksche Waard and Room for the River, The Netherlands

About one-third of the Netherlands is located below sea level and, as a result, nearly 50 percent of the country is protected by embankments. Anticipating that past land-use patterns may exacerbate the challenges posed by climate change, the Netherlands sought to integrate biodiversity adaptation through blue-green infrastructure for more efficient resource management and to encourage greater multifunctional value in land use.[39]

In 2010, the government investigated the potential of blue-green infrastructure additions in farmlands in Hoeksche Waard as a chemical pesticide reduction measure to ensure ample resource availability to species that suppressed prevalent pests. Physical measures were introduced through spatial norms and blue-green network design rules (minimal standards), with a cost-benefit analysis revealing the monetary valuation of benefits availed far exceeding those of input investment.[40]

The Delta Works programme (a series of construction projects consisting of dams, locks and storm surge barriers) was initiated in response to the 1953 North Sea flood. Major blue infrastructure components like flood barriers were recognised as national monuments and had positive impacts on water quality, tourism and leisure activities by helping create nature reserves and other greenspaces.[41] Additionally, strategies like the 'Room for River' (also under the Delta Works programme) sought to restore floodplains in 30 locations to minimise potential flooding risks.[42]

The Hoeksche Waard case illustrates the importance of blue-green infrastructure in protecting farmers' interests and should be explored in the Indian context given that large swathes of land in the country are agricultural. This also presents an opportunity to develop towns that have an abundance of agricultural land. Agricultural land must be added to the objectives of the central government scheme to develop

small and medium towns.[d] Funding the integration of stormwater channels, gardens, parks and playgrounds, which are blue-green infrastructure components, with agricultural land will be beneficial, with stormwater and treated wastewater potentially acting as a periodic replacement to overexploited groundwater for cultivation and ecological benefits. To ensure resilience, it is critical that such systems be included at the earliest stages of urban planning. Additionally, the Delta Works programme shows that river and floodplain restoration are sound and sustainable solutions.

Grey to Green Initiative, Portland, US

The five-year 'Grey to Green' initiative facilitated the implementation of the Portland Watershed Management Plan (2005), with larger goals of protecting natural resources, restoring critical ecosystems, and implementing stormwater solutions integrating urban areas with the natural environment.[43] The project identified elements such as planting street and yard trees, green streets, eco-roofs,[44] and key methods like invasive species removal and revegetation, culvert removal, planting, and acquisition of sensitive land parcels to achieve these goals. Potential benefits were split into three categories—health; energy and carbon sequestration; and community liveability—with individual metrics to evaluate best management practices, and the certainty level of the benefit was represented through a colour scale.[45]

The project resulted in the planting of over 30,000 street and yard trees capable of capturing 18 million gallons of stormwater annually; the addition of 867 new street planters; the treatment of 7,400 acres of land for invasive plant species; the replacement of five culverts; the addition of 398 eco-roofs covering an area greater than 11 acres; the acquisition of 406 acres of natural land parcels; and the restoration of indigenous vegetation on about 4,100 acres of land in consultation with private and public property owners.[46]

The Portland initiative represents the value of focused retrofitting and the resultant sustainable benefits. In this regard, an extensive inventorisation of blue-green infrastructure elements may prove valuable in the context of urban India and can be segregated climatically to ensure maximum feasibility and reduce operation and maintenance expenditures.

d The Urban Infrastructure Development Scheme for Small & Medium Towns aims to improve urban infrastructure in towns and cities in a planned manner, and includes provisions on public-private partnerships.

Sponge City Programme, Wuhan, China

Wuhan, a low-lying area in China's Hubei province, was once referred to as the 'city of a hundred lakes,' but not many lakes have survived the city's rapid urbanisation. Instances of intense flooding have compromised transport infrastructure (in 2012) and led to drainage system collapses (in 2016), which saw CNY 2.3 billion (INR 26.1 billion) in losses to life and property.[47]

In 2013, the national government initiated the 'Sponge City' programme in 16 pilot cities, expanded to 30 cities in 2016, to add absorptive capabilities to existing urban infrastructure, with an initial budgetary allocation of CNY 20.7 billion (INR 236 billion) for the 2015-2017 period. The cities had to provide 20 percent land with sponge features (to absorb and utilise up to 70 percent rainfall) by 2020, increasing to about 80 percent land by 2030.[48]

As part of the programme, Wuhan set technical targets related to annual rainwater absorption, building capacity to withstand a 50-year storm,[e] and pre-zoning sponge regions. This implied that up to 170 sq. km. area had to be infused with sponge features, such as rain gardens, green roofs, grass swales, bioretention basins and permeable pavements. Wuhan undertook 389 sponge projects covering 22 percent of the 2020 total area requirement.

Financing the projects involves ministerial supervision. The Ministry of Housing and Urban-Rural Development and the Ministry of Water Resources periodically assessing the performance of the sponge cities through an evaluation index system, based on which the finance ministry allocates funds. Municipal governments were also mandated to find fundraising methods based on national guidelines to share the risks and benefits between the public and private sector (social capital).[49]

e According to China's definition of a 50-year storm intensity, Wuhan would have to develop the capacity to absorb about 65 percent to 80 percent of the annual rainfall and about 303 millimeters per day of rainfall.

Existing Global Blue-Green Practices

Optimal land zoning and the clear identification of elements (as was seen in Portland's Grey to Green initiative) proved beneficial in Wuhan. In the Indian context, expanding the area of assessment for land suitability and inventorying pre-existing natural features beyond the administrative needs of the city-specific development plan must be prioritised. This will help compliment the required blue-green interventions and can act as a major factor to synergise the environmental intentions of the regional plan and the city development plan.

Table 1: Summary of Select Global Key Blue-Green Infrastructure Initiatives

LOCATION	AREA (sq. km.)	POPULATION	INITIATIVE	SCALE	AGENCY	INTENT
Vancouver, Canada	114	6,31,486	**Rain City Strategy** Action plans: streets and public spaces; building and sites; parks and beaches	City	Board of Parks and Recreation, City of Vancouver	Improve and protect Vancouver's water quality. Increase Vancouver's resilience through sustainable water management. Improve Vancouver's livability by improving natural and urban ecosystems.

Existing Global Blue-Green Practices

LOCATION	AREA (sq. km.)	POPULATION	INITIATIVE	SCALE	AGENCY	INTENT
Singapore	718	56,90,000	**Active, Beautiful, Clean (ABC) Waters Program**	City	Public Utilities Board, Ministry of Environment and Water Resources, Government of Singapore.	To realise the full potential of the progressively developed drainage network of 17 reservoirs and 8,000 km of drains, canals, and rivers by integrating them to improve the quality of water, life and boosting recreational value.
Hoeksche Waard, The Netherlands	325.8	6,53,000	**Agro-land Improvement through Blue-Green Networking**	Regional	Dutch government, local stakeholders	Optimise agrobiodiversity, reducing pesticides, efficient resource management, and greater multifunctional value to land
30 Locations, The Netherlands			**Room for the River**	Regional	19 partners, including the provinces, municipalities, regional water authorities and Rijkswaterstaat	Manage higher water levels across four rivers and prevent flooding in cities along the rivers, improve river retention capacity during flood events. Room for the River approach is to restore the river's natural flood plain in places where it is least harmful to protect those areas that need to be defended

Existing Global Blue-Green Practices

LOCATION	AREA (sq. km.)	POPULATION	INITIATIVE	SCALE	AGENCY	INTENT
Portland, US	375.5	6,64,605	**Grey to Green Initiative** To alleviate loadings on the piped infrastructure system and reduce adverse impacts on urban watercourses and help implement the Portland Watershed Management Plan. For protecting natural resources, restoring critical ecosystems, and implement stormwater solutions that integrate the urban area with the natural environment.	City	Environmental Services, and other departments in co-ordination with local stakeholders, City of Portland Oregon.	30,000 planted street and yard trees capable of capturing 18 million gallons of stormwater annually, 867 new street planters added, 7,400 acres of land treated for invasive plant species, five culverts replaced, 398 eco-roofs covering an area greater than 11 acres added, 406 acres of natural land parcels acquired, and indigenous vegetation restored on up to 4,100 acres in consultation with private and public property owners
Wuhan, China	8569	1,06,00,000	**Sponge City Programme** Ensuring absorptive capabilities in urban infrastructure Providing 20 percent land with sponge features (for absorbing and utilising up to 70 percent rainfall) by 2020, increasing to about 80 percent land by 2030.	City	Ministry of Housing and Urban-Rural Development, Ministry of Water Resources, Ministry of Finance, private sector, and city Municipalities	Wuhan set technical targets related to annual rainwater absorption,and pre-zoning sponge regions

Source: Compiled by authors using data from Rain City Strategy, Vancouver; [50] *Active Beautiful, Clean Waters Design Guidelines, Singapore;* [51] *Grey to Green Accomplishments, Portland;*[52] *and Wuhan Sponge City Programme.*[53]

India's Blue-Green Interventions

In India, the term infrastructure is primarily associated with the 'grey'—engineered, brick and mortar features. Nevertheless, blue-green infrastructure alongside grey is slowly becoming part of urban planning at the national, regional and municipal level.

Central Ministries and Missions

Green infrastructure was first mentioned in an early discussion on India's environmental policy in the Fourth Five Year Plan (1964-69), which merely called environmental protection an important ideology of a healthy life and mentioned how countries around the world were impacted by environmental issues. Yet, the environment ministry was formed only a decade later in 1980. Several issues have since come under its ambit, such as controlling air and water pollution, and preserving forests, mangroves and other natural resources. Rechristened as the Ministry of Environment, Forest, and Climate Change in 2014, it remains the central point for planning, monitoring and implementing policies pertaining to environment and climate, while the Ministry of Water Resources and Ganga Development oversees India's national water resources (the country's blue infrastructure).

In 2008, India formulated the National Action Plan on Climate Change (NAPCC) in response to the UN Framework Convention on Climate Change and the UN's 'Green Economy Initiative'. The initiative listed out the macroeconomic, sustainability and poverty reduction implications of green investment in sectors like renewable energy and sustainable agriculture, and also provided guidance on catalysing increased investment in these areas.[54] The NAPCC includes 12 missions—National Mission for Green India; National Solar Mission; National Water Mission; National Mission for Sustainable Agriculture; National Mission on Sustainable Habitat; National Mission for Enhanced Energy Efficiency; National Mission for Himalayan Ecosystem; National Mission on Strategic Knowledge on Climate Change; National Wind Mission; Mission on Health (to deal with climate change impacts on human health); National Coastal Mission; and the Waste-to-Energy Mission. The missions dealing with sustainable habitat, water, and agriculture and forestry are multisectoral, overlapping and multi-departmental in nature.[55]

India's Blue-Green Interventions

Institutional, systemic and process barriers—including financial constraints, inter-ministerial coordination, lack of technical expertise and project clearance delays—are major challenges in the efficient implementation of the missions.[56] Additionally, there is "little synergy among the missions, which are still being viewed in terms of portfolios of ministries operating in different domains, and this will impact the ability to implement the policies".[57]

Crucially, the success of these missions is pegged to the achievements of the panchayats, councils and municipal corporations. Effective decentralisation and functional division are crucial to the success of these programmes. The prevalent top-down approach does not create enough capacity nor provide guidelines (especially related to funds, training and technological knowhow) to be followed by state governments to help the local bodies implement the missions.

In addition to the NAPCC, India has two national flagship projects—the Smart Cities Mission and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT)—focused on improving urban living and that include blue and green components as part of the mission intention. AMRUT works on issues of water supply, sanitation and green space upgradation, while the Smart Cities Mission works on solutions like sanitation, water supply, preserving open spaces and improving the quality of life of citizens.

For example, the rejuvenation of lakes is a major component of the Udaipur Smart City programme, which involves preventing sewage discharge, de-weeding lakes and stopping idol immersions.[58] The city's economy is tourism-dependent, with lakes forming a big part of this sector, and thus cleaning up the water and creating more habitable waterfronts and spaces is the crux of the programme. Similarly, water cleaning and the desilting project of the Godavari river, and developing the parks, gardens and green spaces in the surrounding areas are major components of the Nashik Smart City mission.[59] The interplay between and planning of the blue and green infrastructure will determine the success of both these and other smart cities.

Blue-Green Cities

Although a relatively new concept, several Indian cities—such as Delhi, Bhopal, Madurai and Bengaluru—are including blue-green components in their master or action plans, with the aim of enhancing existing natural blue systems in the city and the surrounding public spaces through a planned strategy.

However, these cities—and indeed many of India's other cities—are already high-density built areas with existing challenges, including mix land use, overlapping jurisdiction among different agencies, skewed development patterns, technical difficulties and socio-political will. Land scarcity in such high-density areas means there is limited space for blue-green installations, which suggests that high efficiency and adaptability in urban blue-green infrastructure development is needed.[60]

Blue-Green Masterplan, Delhi

Delhi is one of the first cities in India to include a blue-green policy focus in its 2041 masterplan. While the details of the policy are still being determined through public consultations, the overarching idea is to ensure that water bodies and green spaces are synchronously planned in an interdependent fashion. The current masterplan ends this year, and the Delhi Development Authority (DDA) will need to notify the new plan as soon as it is ready.[61]

According to the DDA's 2041 proposal, 'blue' infrastructure refers to water bodies like rivers, canals, ponds, wetlands and floodplains, and water treatment facilities, while 'green' refers to trees, lawns, hedgerows, parks, fields, and forests.[62]

The DDA has taken a practical approach by creating a multi-pronged strategy to ensure the policy is integrated into the masterplan. It is currently preparing a 60-layer digital map of the city[63] to include the different agencies under whose jurisdiction the specific water and land bodies fall. Subsequently, the 50 big drains (*nullahs*) that are currently governed by the different agencies will be cleaned up—pollutants

will be treated, and untreated outfalls and waste dumping in water sources will be stopped. Delhi generates about 3,800 million litres of sewage per day, half of which goes directly into water bodies without being treated,[64] so the cleaning up of drains will prove beneficial.

Next, the cleaned areas alongside the drains will be declared as buffer zones and green corridors that will be backed by creating walking and cycling paths through gardens. Low impact infrastructure like exercise areas, yoga gardens, open air theatres, museums, boating facilities, green houses, and community vegetable gardens will also be set up.[65]

A multiplicity of governing agencies has resulted in the poor implementation of policies and decisions in the city. The DDA is consulting with these agencies on the blue-green policy[66] to establish a common rulebook to ensure the integrated development of blue-green infrastructure in Delhi. Indeed, proper coordination and cooperation among the city's multiple municipal authorities, the DDA, the state government and development agencies will be crucial to the successful realisation of the blue-green policy and wider masterplan.

Blue-Green Masterplan, Bhopal

Madhya Pradesh's Bhopal is a city of lakes and among the 100 cities selected under the Smart Cities Mission. The Bhopal Municipal Corporation is in the process of finalising the 2021 masterplan, while the Bhopal Smart City Development Corporation Limited, a special purpose vehicle created under the Smart Cities Mission, will help create a separate 'green and blue masterplan' for the city, the main goals of which are to maintain and grow the green cover, to influence citizens' lifestyle indicators; and to promote an environmentally sustainable city.[67] It also aims to "create conditions for local and international businesses to thrive" in Bhopal and make the city "the place for people centric development and a cultural hub for arts, architecture, crafts and natural heritage".[68] The green and blue masterplan includes

initiatives on sustainable water management, making all buildings green, waste management and recycling, and creating a network of parks, cycling paths and green walkways by linking land parcels.[69]

Bhopal's previous masterplan expired in 2005; the city expanded without infrastructure services and urban planning guidelines, leading to a mushrooming of gated communities and townships and uncoordinated urban growth in the peri-urban areas.[70] Although the new draft masterplan is ambitious in scope, it appears to have been conceptualised without community participation to address all concerns. The Bhopal Citizens' Forum has filed a public interest litigation against it over concerns related to a historic lake and surrounding tiger habitat,[71] which could derail the plan or delay its implementation.

Blue-Green Action Plan, Madurai

In December 2014, the Madurai Municipal Corporation partnered with an international academic institution, a local NGO and citizen groups to create a blue-green action plan, driven by the severe water stress conditions faced by the city and the wider Vaigai Basin. This plan was developed through bottom-up stakeholder engagement.[72] For instance, 'water walks' were conducted near water sources, bringing together community members and representatives from government and local organisations to discuss the degraded river corridor and related issues. Managing the drainage and sewerage network, cleaning up the lakes, and green space development emerged as the top priorities for the blue-green plan through such discussions, and gave rise to the projects that became part of the blue-green plan.[73]

> "Land scarcity in India's high-density areas means there is limited space for blue-green installations, suggesting that high efficiency and adaptability in urban blue-green infrastructure development is needed."

The blue-green plan has been merged with ongoing work under the Smart Cities Mission to "accelerate economic growth via climate compatible development projects" funded by the larger mission.[74] This plan will also need to be linked with the Madurai masterplan to institutionalise all decisions and processes.

Bangalore Masterplan 2050 for Water Supply and Sewerage Management

Bengaluru has no institutional mandate for any kind of resiliency planning. A 2014 report, 'Future Proofing Indian Cities: Bangalore Action Plan for Water and Sanitation Infrastructure',[75] shows water and sanitation as key areas of vulnerability that are already having an impact on the city's liveability. The Bangalore Water Supply and Sewerage Board (BWSSB) oversees water supply and water and sanitation quality and has been working to reduce the leakages of water, increase water revenue, and improve sanitation standards and disposal processes.

In 2014, the BWSSB, the Indian Institute of Human Settlements and local stakeholders conceptualised a blue-green action plan to future-proof the city[76] through resource security, climate resilience, a move to a low carbon economy, and ecosystem protection. Consequently, the Masterplan 2050 for Water Supply and Sewerage Management was announced, which had three key drivers—population growth, water demand and climate change. The masterplan, being implemented through foreign loans, has been divided into a mix of short-term and long-term targets, including the implementation and continuous evaluation of technical aspects of the project, climate adaptation by setting up new approaches and network models, and creating warning systems through academic support and strategic stakeholder engagement.[77]

Table 2: Summary of Key Indian Blue-Green Infrastructure Initiatives

City	Area (sq. km.)	Population (As per censes 2011) in million	Initiative	Scale	Responsible Agency	Intent
Delhi	1483	16.7	Blue-Green Masterplan	City	Delhi Development Authority	To ensure that blue and green features are synchronously planned, mitigating pollution, and adapting to climate challenges.
Bhopal	1017	1.8	Blue-Green Masterplan	City	Bhopal Municipal Corporation and Bhopal Smart City Ltd	To maintain and grow the green cover, create an environmentally sustainable city, and improve health.
Madurai	148	1.02	Blue-Green Action Plan	City	Madurai Municipal Corporation	To mitigate and adapt to flooding and accelerate economic growth via climate compatible development projects.
Bengaluru	1307	9.1	Blue-Green Action Plan that culminated in the Water and Sewerage Masterplan 2050	City	Bangalore Water Board and Bangalore Municipal Corporation	To achieve resource security, climate resilience, a move to a low carbon economy, and ecosystem protection.

Source: Compiled by authors using data from Bengaluru Blue Green Action Plan;[78] India's National Action Plan on Climate Change;[79] Madurai plan;[80] Bhopal Blue Green Masterplan;[81] and Delhi Master plan.[82]

Adopting Blue-Green Infrastructure: Opportunities for Indian Cities

The evaluation of existing global and Indian blue-green interventions highlights the need for a multi-pronged, well planned strategy for blue-green infrastructure. Blue-green infrastructure has the potential to avert and mitigate climate emergencies, contribute towards environment enhancement and sustainable urban renewal, and lead to economic growth. India must strongly consider the benefits and opportunities in adopting such a strategy:

Institutionalising a Blue-Green Urban Framework

Although blue-green projects in cities are more likely to succeed when they operate at the local level with the participation of the authorities and community, an overarching framework should be established to define the national vision and determine guiding principles for such projects. For instance, guidelines on tackling uncertainties in terms of designing new water systems can aid quick decision-making at the local level.

Many Indian cities release annual environmental status reports, with details on natural features and pollution indicators. Such activities must be turned into an annual blue-green audit for all cities to create realistic policies to bridge existing gaps, and be accompanied by demographic data, such as on density and poverty, for a better understanding of the social challenges.

To streamline and ensure the integrity of the original blue-green canvas, governments must maintain uniform statutory terminologies and definitions, and undertake a comprehensive integration of all urban plans and records that highlight environmental features.

Having such a framework will ensure some conformity among all missions, in all projects incorporated by parastatal agencies, and in local projects as well.

> “Blue-green infrastructure can avert and mitigate climate emergencies, contribute towards environment enhancement and sustainable urban renewal, and lead to economic growth.”

Blue-Green Economic Agenda

India must club its ongoing green efforts with the 'blue economy' to create a blue-green economic agenda. The blue economy originates in the green economy concept of incorporating strategies to mitigate climate change and adaptation to result in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities."[83]

Investing in blue-green infrastructure is a costly proposition and will need to be understood through a cost-benefit analysis. For instance, creating a flood footprint damage accounting framework to measure the socioeconomic impact directly and indirectly caused by a flood event, and contrasting this against the economic benefit of having blue-green infrastructure using calculation and estimation tools that factor in local contexts and considerations. A typical blue-green infrastructure project may have several economic benefits, such as health improvement, lesser pollution, better amenities and quality of life, and social cohesion. At the same time, it could also cause a loss of trees or green spaces.

Fast-Tracking Sustainable Development Goals

The COVID-19 pandemic has hit global and domestic financing capabilities for projects related to the UN's Sustainable Development Goals (SDGs), with developing countries facing a US$1.7 trillion (INR 124 trillion) shortfall in financing SDG projects.[84] Blue-green infrastructure has the potential to fulfil multiple targets outlined in the SDGs, such as those related to water (SDG 6 and SDG 14), land (SDG 15) and climate change (SDG 13). Blue-green infrastructure can also accelerate progress on green employment prospects (SDG 1), food security (SDG 2), offsetting medical infrastructure load (SDG 3) and improving air and habitation quality in cities (SDG 11). It will also have implications for SDGs related to economic wellbeing, with returns on investment and startups increasing employment prospects (SDG 8), assured resilience (SDG 9), and social inclusion through greater and more equitable access to natural spaces (SDG 10).

Outcome-Based Policies

The blue-green concept could transform India's urban planning approach from input to output based by focusing on the outcomes of projects and processes. This means that required environmental outcomes or specific level of performance is specified in the framework and the method to achieve the outcome is flexible. There are performance indicators that are used to determine compliance and effectiveness of the outcome. Outcome based approaches are usually successful as they encourage innovative strategies, increase transparency, involve stakeholders to set outcomes and thus increase trust, and foster healthy regulatory compliance.

Blue-Green Foundation for Urban Planning

Many of India's urban planning statutes are outdated and follow regimental approaches through rigid land use plans and development control regulations. To adapt to an ever-evolving component like blue-green infrastructure, Indian cities must move towards dynamic urban planning that considers changes taking place around them. More intensive and transparent digital interfaces, like GIS mapping and live tracking, must be developed by the public sector to ensure real-time monitoring and evaluation of blue-green benefits. This is also necessary to keep up with innovations in urban planning ranging, such as environmental real-time GIS mapping or using artificial intelligence for sustainable urbanisation.

Multistakeholder, Multilevel Participation

All successful blue-green interventions—for instance, the Blue-Green Cities Research Project in Newcastle, UK—had a substantial level of community participation. In India, initiatives in Bengaluru and Madurai have also included considerable citizen involvement. Significant community participation and active interaction with government, planners, policymakers and other political representatives will improve the citizens' understanding of blue-green projects and encourage ownership in the planning, formulation, execution and monitoring of such activities.

Multi-Sectoral Work, Beyond Jurisdiction

The essence of blue-green infrastructure is its permeability and dynamic nature. Although a national framework for such projects is needed, the success can only be truly measured at the city level. For instance, Bhopal's blue-green masterplan falls under the Smart Cities Mission, but also involves the municipal corporation and other relevant local planning bodies working together, beyond jurisdictions, to integrate it with existing projects.

Similarly, sectoral overlaps must also be accounted for. For instance, the augmentation of a city's water sources should be accompanied by the upgradation of the surrounding green areas, which may have impacts on sectors like environment, transportation and agriculture. One agency will need to be the primary planning and implementation body for such a project, with all others assisting it. Urban local bodies, recognised by the Constitution as the primary planning agency in a city, must be empowered to take decisions pertaining to blue-green infrastructure and be provided adequate access to funds for execution.

Blue-Green Fund for India

The emergence of blue-green infrastructure will lead to job creation and stimulate economic and societal progress. Sectors like agriculture, renewable energy, transportation and manufacturing have blue and green elements with the potential to scale up. While India has a draft blue economy policy that envisions blue resources as a multiplier for national growth,[85] this should be combined with a green policy that takes climate change impacts into account. An environmentally resilient political agenda is necessary to ensure blue and green benefits can be gained. Given the high costs for creating or retrofitting blue-green infrastructure, cities will need to raise funds through bonds, finance pooling and creating new tax streams. This could be done through the creation of a blue-green fund

Digital Data Governance

A digital inventory of existing infrastructure should be created to compare with prospective blue-green infrastructure projects to ensure a holistic understanding of the overall benefits. For maximum accountability and transparency, these benefits could also be subject

to financial valuation. The digital inventory could be clubbed into the National Urban Data Bank and Indicators.[86] Advanced training must be imparted to practitioners in the government to understand how blue-green features of urban planning could be accounted. Such data banks will be crucial for creating policies, estimating scope of projects and funding, and monitoring outcomes.

Sustainable Land Management

Climate change cannot be mitigated only through greening and reversing land degradation. This will have to be coupled with sustainable land management strategies.

Sustainable land management is the use of land to meet changing human needs (agriculture, forestry, conservation), while ensuring the land's socioeconomic and ecological functions over the long term.[87] How land is utilised is critical to determining the infrastructure requirements of India's expanding cities. For instance, India is the world's largest consumer of groundwater,[88] which is unsustainable. The land uses in urban areas that intensively strain resource quality and consumption—such as agricultural, industrial, and residential—should evolve to include alternative practices for environmental sustainability.

The blue-green approach is critical for sustainable land management and must be considered for wastewater treatment, reuse and rainwater harvesting. This will be extremely beneficial to the climate-vulnerable agriculture sector,[89] and can help in reducing the financial burden on the agriculture sector.[90]

> "Blue-green infrastructure will lead to job creation in sectors like agriculture, renewable energy, transportation and manufacturing, and boost economic and societal progress."

Conclusion

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The concept of blue-green infrastructure is relatively new, but many global cities have already begun the transition, driven by exacerbating climate impacts and events. While the green infrastructure concept has found some acceptance in India,[91] the country must also consider including blue infrastructure in its sustainability transition. It is important to combine and protect hydrological elements of the urban landscape alongside the ecological while planning for adaptation and resilience.

Several scattered attempts are being made in cities across the country and at the central level to introduce blue-green infrastructure aspects for climate adaptation and mitigation. India needs an all-encompassing plan that acknowledges that its cities' economic and social stability is dependent on the environment, and that the existing blue-green resources will need to be planned mindfully for a sustainable future.

Endnotes

1 Chandra Tanushree, "Lessons from COVID-19 on climate change policy," Observer Research Foundation, April 14, 2020, https://www.orfonline.org/expert-speak/lessons-covid19-climate-change-policy-64548/

2 PTI, "Govt sticks to $5 trillion economy target; emphasis on infra aimed at achieving goal: DEA Secretary," The Economic Times, May 25, 2021, https://economictimes.indiatimes.com/news/economy/policy/govt-sticks-to-usd-5-trillion-economy-target-emphasis-on-infra-aimed-at-achieving-goal-dea-secretary/articleshow/80686511.cms.

3 Aparna Roy, "In Post-Covid19 recovery, India must make its development 'Climate Resilient'," Observer Research Foundation, April 17, 2020, https://www.orfonline.org/expert-speak/in-post-covid-19-recovery-india-must-make-its-development-climate-resilient-64758/

4 World Economic Forum in partnership with Marsh & McLenan and Zurich Insurance Group, *The Global Risks Report 2020*, 2020, https://www.weforum.org/reports/the-global-risks-report-2020.

5 Demuzere M, et. al., "Mitigating and adapting to climate change: multi-functional and multi-scale assessment of green urban infrastructure," Journal of Environmental Management 146, (2014), https://www.sciencedirect.com/science/article/pii/S0301479714003740

6 IPCC, *Global Warming 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*, 2018, https://www.ipcc.ch/sr15/chapter/spm/

7 Ministry of Earth Sciences (MoES), Government of India, *Assessment of Climate Change over the Indian Region*, New Delhi, 2020, https://link.springer.com/book/10.1007%2F978-981-15-4327-2.

8 World Health Organization, "Air pollution and child health: prescribing clean air. Summary", Geneva, 2018, https://www.who.int/publications/i/item/air-pollution-and-child-health

9 United Nations Department of Economic and Social Affairs, Population Division, *World Urbanization Prospects 2018 Highlights,* New York, United Nations, 2019, *https://population.un.org/wup/*.

10 Tewari, M., Godfrey. N., et al., Better Cities, Better Growth: India's Urban Opportunity. New Climate Economy, World Resources Institute, and Indian Council for Research on International Economic Relations. London, Washington, DC, and New Delhi, 2016, http://newclimateeconomy.report/workingpapers.

Endnotes

11 India, Ministry of Earth Sciences (MoES), *Assessment of Climate Change over the Indian Region*

12 "*Global Warming 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*".

13 T.V. Ramachandra et. al., "Green Spaces in Bengaluru: Quantification through Geospatial Techniques"

14 Snehal Fernandes and Badri Chatterjee, "World environment day: Mumbai lost 60% of its green cover in 40 years," *Hindustan Times*, June 27, 2017, https://www.hindustantimes.com/mumbai-news/40-years-of-development-cost-mumbai-60-of-its-green-cover-65-of-water-bodies-study/story-ySgLLxkoNbBALP3u28X9TI.html#:~:text=The%20study%2C%20led%20by%20the,towards%20a%20complete%20urban%20disaster.

15 Shantaram et. al., "Spatial Analysis of Green Cover Change in Mumbai City, India", Arboricultural Research and Education Academy Newsletter, December 2020, https://www.researchgate.net/publication/351372818_International_Perspectives_Spatial_Analysis_of_Green_Cover_Change_in_Mumbai_City_India

16 T.V. Ramachandra et. al., "Modelling and Visualization of Urban Trajectory in 4 cities of India," (Paper presented at the 32nd Annual Symposium on Space Science and Technology at the ISRO-IISc Space Technology Cell, India, January 7-8 , 2016).

17 T.V. Ramachandra et. al., "Modelling and Visualization of Urban Trajectory in 4 cities of India," (Paper presented at the 32nd Annual Symposium on Space Science and Technology at the ISRO-IISc Space Technology Cell, India, January 7-8 , 2016).

18 T.V. Ramachandra et.al., "Green Spaces in Bengaluru: Quantification through Geospatial Techniques"

19 Shantaram et. al., "Spatial Analysis of Green Cover Change in Mumbai City, India"

20 Browder, Greg; Ozment, Suzanne; Rehberger Bescos, Irene; Gartner, Todd; Lange, Glenn-Marie, Integrating Green and Gray: Creating Next Generation Infrastructure, Washington, DC, World Bank and World Resources Institute, 2019, https://openknowledge.worldbank.org/handle/10986/31430#:~:text=A%20new%20generation%20of%20infrastructure,water%20security%20and%20climate%20resilience.&text=It%20reviews%20approaches%20and%20examples,project%20appraisal%20processes%20and%20investments.

Endnotes

21 Nathalie Seddon et. al., "Understanding the value and limits of nature-based solutions to climate change and other global challenges," *Philosophical Transactions of the Royal Society B* 375, no.1794, (2020) https://royalsocietypublishing.org/doi/abs/10.1098/rstb.2019.0120.

22 Seddon et. al., "Understanding the value and limits of nature-based solutions to climate change and other global challenges"

23 Fargione et. al., "Natural Climate Solutions for the United States," *Science Advances*, 4, no.11, (2018) https://advances.sciencemag.org/content/4/11/eaat1869.

24 European Commission, "Ecosystem services and Green Infrastructure", Nature and Biodiversity, https://ec.europa.eu/environment/nature/ecosystems/index_en.htm

25 Australia, Department of Environment, Land, Water and Planning, *Planning a Green-Blue City*, Victoria, 2017, https://www.water.vic.gov.au/__data/assets/pdf_file/0029/89606/Green-blue-Infrastructure-Guidelines-Feb17.pdf

26 Brown and Mijic, "Integrating green and blue spaces into our cities: Making it happen,"

27 "Ecosystems and Human Well-being: Synthesis, 2005"

28 Abhinav Rajput, "Explained: What is the 'green-blue' policy proposed by Delhi Master Plan 2041?", The Indian Express, September 8, 2020, https://indianexpress.com/article/explained/delhi-master-plan-green-blue-policy-dda-6587961/

29 Trinomics et. al, 'Supporting the implementation of the European Green Infrastructure Strategy', EC DG ENV, ENV.B.2/SER/2014/0012, https://ec.europa.eu/environment/nature/ecosystems/pdf/Green%20Infrastructure/GI_DE.pdf

30 The Blue-Green Cities Research Project, *Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities Key Project Outputs*, United Kingdom, Blue-Green Cities Research Project, 2016 http://www.bluegreencities.ac.uk/documents/blue-green-cities-key-project-outputs.pdf

31 The Blue-Green Cities Research Project, *Flood Footprint assessment - Socioeconomic assessment of flooding impact on urban areas and wider economic systems*, United Kingdom, Blue Green Cities, 2016, http://www.bluegreencities.ac.uk/documents/floodfootprintassessment-dm.pdf

32 "Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities Key Project Outputs, 2016"

33 Shruti Ganpatye, "Rs 14,000 crore lost to floods in 10 years," Mumbai Mirror, September 11, 2019, https://mumbaimirror.indiatimes.com/mumbai/cover-story/rs-14000-crore-lost-to-floods-in-10-years/articleshow/71072687.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Endnotes

34 City of Vancouver council, *Rain City Strategy,* Vancouver, 2019 https://vancouver.ca/home-property-development/green-infrastructure.aspx#:~:text=Green%20rainwater%20infrastructure%3A%20sustainably%20managing,on%20public%20and%20private%20property.

35 City of Vancouver council, *Appendix B GRI Typologies,* Vancouver, 2019 https://vancouver.ca/files/cov/one-water-gri-typologies.pdf.

36 Singapore's National Water Agency, *Active Beautiful, Clean Waters Design Guidelines 4th edition*, Singapore 2018, https://www.pub.gov.sg/Documents/ABC_Waters_Design_Guidelines.pdf.

37 "Active Beautiful, Clean Waters Design Guidelines 4th edition, 2018"

38 Singapore's National Water Agency, 'Active, *Beautiful, Clean Waters Programme Certification*', https://www.pub.gov.sg/abcwaters/certification.

39 Ghofrani et. al., " A Comprehensive Review of Blue Green Infrastructure Concepts," *International Journal of Environment and Sustainability* 6, no.1 (2017), https://www.sciencetarget.com/Journal/index.php/IJES/article/view/728/218.

40 Ghofrani et. al., "A Comprehensive Review of Blue Green Infrastructure Concepts"

41 Rijkswaterstraat Ministry of Delta and Water Management, *Delta Work*, Netherlands, https://www.rijkswaterstaat.nl/english/water/water-safety/delta-works/index.aspx (accessed March 22, 2021)

42 Rijkswaterstraat Ministry of Delta and Water Management, *Room for the River*, Netherlands, https://www.rijkswaterstaat.nl/english/about-us/gems-of-rijkswaterstaat/room-for-the-river/index.aspx(accessed March 22, 2021)

43 Bureau of Environmental Services ,The City of Portland Oregon, *Portland Watershed Management Plan*, Portland Oregon,2005, https://www.portlandoregon.gov/bes/38965.

44 Bureau of Environmental Services ,The City of Portland Oregon, *Grey to Green Going Green for Clean Rivers*, Portland Oregon,2008, https://www.portlandoregon.gov/bes/article/321433.

45 Bureau of Environmental Services ,The City of Portland Oregon , *Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits,* Portland Oregon, 2010, https://www.portlandoregon.gov/bes/article/298042.

46 Bureau of Environmental Services ,The City of Portland Oregon, *Grey to Green Accomplishments*, Portland Oregon, https://www.portlandoregon.gov/bes/article/321331 (accessed March 22, 2021).

Endnotes

47 Li Jing, "Inside China's leading 'sponge city': Wuhan's war with water" city', The Guardian International Edition, January 23 2019, https://www.theguardian.com/cities/2019/jan/23/inside-chinas-leading-sponge-city-wuhans-war-with-water.

48 European Union Grow Green Project, *Using Nature to reshape cities and live with water: an overview of the Chinese Sponge City Programme and its implementation in Wuhan (summary),* European Union, 2021, http://growgreenproject.eu/wp-content/uploads/2021/01/Sponge-City-Programme_Summary.pdf.

49 "Using Nature to reshape cities and live with water: an overview of the Chinese Sponge City Programme and its implementation in Wuhan, 2021"

50 Vancouver, Canada, City of Vancouver Council, *Rain City Strategy*

51 Singapore, National Water Agency, *Active Beautiful, Clean Waters Design Guidelines 4th edition*

52 The City of Portland Oregon, Bureau of Environmental Services, *Grey to Green Accomplishments*

53 *Using Nature to reshape cities and live with water: an overview of the Chinese Sponge City Programme and its implementation in Wuhan (summary)*

54 United Nations Environment Programme, *Green Economy Initiative*, United Nations, 2009, Green economy | UNEP - UN Environment Programme.

55 Centre for Science and Environment, *Coping with Climate Change: An Analysis of India's National Action Plan on Climate Change Volume I*, CSE India, 2018, coping-climate-change-NAPCC.pdf (indiaenvironmentportal.org.in).

56 "Coping with Climate Change: An Analysis of India's National Action Plan on Climate Change Volume I, 2018".

57 Sujatha Byravan and Sudhir Chella Rajan, *An Evaluation of India's National Action Plan on Climate Change,* Centre for Development Finance, IMFR & IIT Madras, 2012, https://www.researchgate.net/publication/256043498_An_Evaluation_of_India's_National_Action_Plan_on_Climate_Change

58 Ministry of Urban Development Government of India, *Success Stories from Mission Cities*, New Delhi, 2017, https://smartnet.niua.org/sites/default/files/resources/Success%20Stories%20from%20Mission%20Cities%20Lowres.pdf.

59 Website of Nashik Smart City, "Nashik Smart City", NMSCDCL, Nashik Smart City.

60 Conghui Zhou and Yun Wu, "A Planning Support Tool for Layout Integral Optimization of Urban Blue–Green Infrastructure,", *MDPI Sustainability Journal* 12, no. 4, (2020), https://www.mdpi.com/2071-1050/12/4/1613.

61 Delhi Development Authority, *Planning*, India , https://dda.org.in/planning.aspx (accessed on March 22, 2021).

Endnotes

62 Abhinav Rajput, "In Master Plan Delhi 2041, focus on city's water bodies, green lungs and unauthorised colonies," *The Indian Express*, September 7, 2020, In Master Plan Delhi 2041, focus on city's water bodies, green lungs and unauthorised colonies | Cities News,The Indian Express.

63 Sidhartha Roy, "DDA to present 60-layered digital map of Delhi in a year," *Times of India*, November 11, 2019, DDA to present 60-layered digital map of Delhi in a year | Delhi News - Times of India (indiatimes.com).

64 Rajput, "In Master Plan Delhi 2041, focus on city's water bodies, green lungs and unauthorised colonies"

65 Rajput, "Explained: What is the 'green-blue' policy proposed by Delhi Master Plan 2041?," *The Indian Express*, September 8, 2020, https://indianexpress.com/article/explained/delhi-master-plan-green-blue-policy-dda-6587961/.

66 Abhinav Rajput, "Explained: What is the 'green-blue' policy proposed by Delhi Master Plan 2041?"

67 National Institute of Urban Affairs, *RFP for Appointment of Planning Consultant for Green and Blue Master Plan for Bhopal Smart City*, Bhopal Smart City Development Corporation Limited, 2016 https://smartnet.niua.org/sites/default/files/Green%20and%20Blue%20masterplan%20BSCDCL.pdf.

68 National Institute of Urban Affairs, RFP for Appointment of Planning Consultant for Green and Blue Master Plan for Bhopal Smart City

69 CEO, *Bhopal Smart City*, Bhopal Smart City Development Corporation Limited, October 2018, https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2018/CoESmartcityoct2018/IOT_SmartCity/BSCDCL 1-Nov-18.pdf.

70 Mrunmayi Wadwekar and Anand Wadwekar, "Urbanisation and Environment: A Case of Bhopal", (Paper presented at International Conference on Urban Sustainability: Emerging Trends, Themes, Concepts and Practices, 2018).

71 Sravani Sarkar, "Bhopal development plan draft triggers eco concern over Upper Lake, tiger habitat," *The Week* , September 3 2020, Bhopal development plan draft triggers eco concern over Upper Lake, tiger habitat - The Week.

72 Kumar A. Madhan and M. P. Vasimalai, "Future proofing of an Indian city: Lessons from Madurai", the website of United Nations Office for Disaster Risk Reduction Prevention Web, 2016, Future proofing of an Indian city: Lessons from Madurai | PreventionWeb.net.

73 "Future proofing of an Indian city: Lessons from Madurai"

74 "Future proofing of an Indian city: Lessons from Madurai"

75 Wankhade, Kavita & IIHS,. (2014). Future Proofing Indian Cities: Bangalore Action Plan for Green-Blue Infrastructure.

Endnotes

76 Atkins, *Future Proofing Indian Cities: Bangalore Action Plan for Water and Sanitation Infrastructure*, December 2014, WS Atkins International Limited, https://www.researchgate.net/publication/313621456_Future_Proofing_Indian_Cities_Bangalore_Action_Plan_for_Green-Blue_Infrastructure

77 G. Bhatt, V. Singh, V. Honnungar and P. Ravindra, "Delivering a sustainable and climate resilient water future for Bengaluru," *Australian Water Association Water e-Journal* 4, no.2 ,(2019), Delivering a sustainable and climate resilient water future for Bengaluru - Water Source (awa.asn.au).

78 "Future Proofing Indian Cities: Bangalore Action Plan for Green-Blue Infrastructure"

79 "Coping with Climate Change: An Analysis of India's National Action Plan on Climate Change Volume I, 2018".

80 "Future proofing of an Indian city: Lessons from Madurai"

81 "Urbanisation and Environment: A Case of Bhopal"

82 Rajput, "In Master Plan Delhi 2041, focus on city's water bodies, green lungs and unauthorised colonies"

83 Faruggia et. al., *Small States and the green and blue economy*, Commonwealth Insights, United Kingdom, 2015, Commonwealth-Insights-Small-states-and-the-green-and-blue-economy.pdf (commonwealthfoundation.com).

84 United Nations Environment Programme (UNEP), *Integrated Approaches to Sustainable Infrastructure*, 2019, https://www.greengrowthknowledge.org/sites/default/files/downloads/resource/Integrated_Approaches_To_Sustainable_Infrastructure_UNEP.pdf

85 Ministry of Earth Sciences, Government of India, https://pib.gov.in/PressReleseDetailm.aspx?PRID=1698608

86 Town and Country Planning Organisation, Government of India, http://tcpo.gov.in/national-urban-information-system

87 Columbia University Centre for International Earth Science Information Network, *What is Sustainable Land Management*, United States, http://www.ciesin.org/lw-kmn/slm/slm.html (accessed on March 22, 2021)

88 DTE Staff, "As told to Parliament (July 1, 2019): India world's largest groundwater user", Down to Earth, July 1, 2019, https://www.downtoearth.org.in/news/governance/as-told-to-parliament-july-1-2019-india-world-s-largest-groundwater-user-65370

89 Ministry of Agriculture and Farmers Welfare, Government of India, Impact of Climate Change on Agriculture (pib.gov.in)

Endnotes

90 Rahul Tongia, "India's Biggest Challenge: The Future of Farming," *The India Forum Journal Magazine on Contemporary Issues*, (2019), India's Biggest Challenge: The Future of Farming | The India Forum

91 Department of Environmental Protection, New York City, Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways, by Michael R Bloomberg and Cas Holloway, New York, 2012, https://smartnet.niua.org/content/6ebca067-1385-4765-b270-94542a7a4522

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