

CONFERENCE PROCEEDINGS

Mumbai's blue-green framework workshop

A SUMMARY OF EXPERT PERSPECTIVES

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Introduction

Unpacking nature-based solutions for climate adaptation in Mumbai

Mumbai, with a population of 12.44 million (India, 2011), is one of the world's most populous cities, with a population density of 28426 persons per square kilometers (km²), compared to the national average of 382 persons/km². Over half the city's population lives in informal settlements, and 65% is employed in the informal sector, with inadequate access to basic amenities. Notably, accessible open spaces for recreation and green cover are extremely limited, with only 1.8 square meters (m²) per person compared to the city's benchmark of 6m² per person by 2040 (WRI B. M. 2022).

Mumbai is becoming increasingly vulnerable to climate risks, such as rising temperatures and erratic rainfall patterns. The city experiences urban heat island effects, particularly in informal settlements, where temperatures are 6–8°C higher than the surrounding areas. The city's green cover has decreased by 40% in the last two decades, worsening urban heat conditions. Rainfall data show a rise in extreme events, leading to flooding challenges exacerbated by poor stormwater drainage systems. Over 30% of Mumbai's population lives in areas prone to flooding, with routine waterlogging disrupting daily life (WRI 2023).

The Mumbai Climate Action Plan (MCAP) outlines strategies to address climate risks by enhancing green cover, increasing permeable surfaces, reducing heat island effects, and improving biodiversity (Figure 1). It aims to provide $6m^2$ of open space per capita by 2040 and integrate flood-resilient systems while managing surface runoff. As part of these goals, MCAP promotes the adoption of nature-based solutions (NbS) to combat urban heat and flood risks.

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This conference proceedings reflects the presentations and discussions of the participants and does not necessarily represent the views of WRI India or other participating institutions.

FIGURE 1 | Mumbai's blue green goals from the Climate Action Plan



What are nature-based solutions? And what doesn't constitute NbS?

NbS help cities increase biodiversity, strengthen natural assets, and improve community resilience to climate hazards. NbS are cost-effective, nature-positive solutions that provide environmental, social, and economic benefits. They aim to restore or enhance natural ecosystems, mitigating climate risks and improving human well-being. NbS include urban forests, green roofs, permeable surfaces, river restoration, and coastal protection measures like mangrove restoration and wetland rejuvenation. They are solutions that not only address the conservation of natural ecosystems but also their inter-relationships with people.

The concept of NbS lacks a universally agreed definition, with over 20 varying interpretations that differ in scope and focus. Some definitions restrict NbS to actions rooted in functioning ecosystems, excluding "nature-derived" solutions like wind and solar energy and "nature-inspired" techniques that mimic natural processes. Others adopt a broader perspective, including solutions that align with or replicate natural systems if they yield cobenefits. Actions that simply minimize humans' impact on nature, such as reducing waste or decreasing water use, are not considered NbS. Despite these differences, all definitions converge on the principle that working with nature enables the development of resilient, resource-efficient, and sustainable solutions (Esther Choi, 2023).

Box 1. How do blue-green infrastructure solutions or ecosystem-based adaptation, differ or are similar to the concept of nature-based solutions?

There is no universally agreed framework defining effective NbS. As per the International Union for Conservation of Nature (IUCN), NbS are actions to address societal challenges through the protection, sustainable management and restoration of ecosystems, benefiting both biodiversity and human well-being.

In this document, NbS refer to all efforts that incorporate natural elements, or represent nature in urban planning to promote sustainable development and resilient infrastructure while enhancing biodiversity and addressing community needs. The term is used inclusively, encompassing hybrid approaches, ecosystem-based adaptation, ecological conservation, blue-green infrastructure, and other scientific nature-positive solutions aimed at mitigating and adapting to Mumbai's climate challenges.

FIGURE 2 | Introductory session, Blue-green framework workshop, Mumbai



Photo credit: WRI India

NbS in the context of Mumbai

In the face of rapid urbanization and environmental degradation, natural ecosystems in Mumbai have been increasingly replaced by built infrastructure, reducing ecosystem services and exposing populations to climate risks (Figure 3). Local practices by indigenous communities and third-sector organizations have historically played a key role in nature restoration, improving ecosystem services and building resilience against climate risks due to environmental degradation. For instance, Koli communities have historically protected coastal ecosystems by integrating traditional ecological knowledge and sustainable practices for mangrove protection, maintaining marine biodiversity and dealing with waste. Adivasi communities, with their deep cultural connection with the environment, cultivate indigenous plant species and avoid mono-culture farming, following seasonal patterns to ensure soil and water conservation. Citizen rights organizations work to revive natural water resources for underserved communities, resident welfare associations promote neighborhood greening initiatives, and social enterprises advance decentralized recycling through innovative waste management. Additionally, practitioners contribute to nature-based design within the built environment, collectively fostering sustainability and resilience.

Given this background, the Blue-Green Framework (BGF) is essential for the city, focusing on local NbS practices and their modalities to enhance understanding of how these interventions can provide significant environmental, social, and economic benefits. By recognizing the systemic nature of these practices and their collective impact, the framework can help build long-term climate resilience in Mumbai.

Purpose of the workshop

Learning from local NbS practices for an aggregated impact

The BGF workshop in Mumbai brought together practitioners, policymakers, and researchers to discuss NbS for addressing the city's climate vulnerabilities. Over the past few years, WRI India partnered with several organizations, solution providers, and government entities to implement NbS projects for climate adaptation. During this period, we had multiple joint learnings to understand which projects work on the ground and which do not, in a complex space-crunched city like Mumbai.



Photo credit: WRI India.

To reach the blue-green goals set by the Mumbai Climate Action Plan (WRI B. M., 2022) through collaborations with line-departments and local partners, we adopted NbS strategies that could contribute to ecosystem benefits, community resilience, and a nature-positive economy.

The workshop was conducted to map out local practices, their successes and failures, and to discover opportunities for future nature-based projects. This was conceptualized to allow multiple practitioners in the city to connect, have alliances, learn from the outcomes of earlier projects, discover opportunities for future projects, and strategize for sharing resources. It was also intended for practitioners to understand the sociopolitical aspects, property tenures, market, and local economics to check the feasibility of NbS projects in Mumbai.

FIGURE 4 | Blue-green framework workshop, Mumbai



Photo credit: WRI India

Workshop summary

The blue-green framework workshop in Mumbai highlighted diverse NbS approaches employed by various practitioners and organizations (Figure 4). Discussions stressed the need for localized, community-driven practices, especially in vulnerable urban areas prone to heat and flood risks. Implementation challenges including ambiguous policies, limited resources, and the complexity of post project accountability were noted. Emphasis was placed on the need for systematic documentation, quantifiable outcomes, and robust stakeholder engagement to achieve long-term sustainability.

The workshop agenda was structured into three key themes. Sessions explored spatial interventions for climate adaptation through NbS in buildings, waterbodies, parks, and mangroves, demonstrating their role in shaping the urban form. Community-led efforts highlighted indigenous practices in coastal areas and forests; social enterprises' works on water conservation and waste recycling were also highlighted, underlining grassroots-driven sustainability. Educational efforts focused on promoting a nature-based approach through awareness and engagement. This categorization enabled cross-sectoral learning and collaboration to scale up NbS in Mumbai.

Session details

Introductory session and context setting

The workshop began with an overview of WRI India's ongoing efforts in promoting NbS focused on building climate adaptation to address flood and heat risks. The initiatives to strengthen resilience and sustainability – carried out in partnership with educational institutions and vulnerable neighborhoods – include urban forests, sponge infrastructure along rivers, and green spaces like parks and gardens. WRI India's collaborations with both governmental and nongovernmental organizations were highlighted, with a focus on the ongoing social and hydrological research for the Mithi river flood resilience as a key example of integrating NbS into urban ecosystems.

The core objective of the workshop was to aggregate the lessons learned from various locally led NbS practices and from practices that may not be defined as NbS, yet having a clear engagement of working with communities or local governments in adopting natural processes as solutions for addressing the infrastructural needs of the city. Through them, successes as well as challenges, while exploring areas for convergence across diverse initiatives, can be identified. The importance of documenting these insights to enhance collaboration and future implementation of NbS projects was emphasized.

The agenda and structure of the workshop were also outlined, which included interactive sessions and discussions centered on how different NbS/ blue-green practices carried out in specific locations in Mumbai could be scaled up or adapted to other areas in the city.

The challenge of defining appropriate scales for NbS projects was raised, particularly in large ecological units like river watersheds. The need to break down these large-scale projects into manageable catchments within a broader watershed was discussed. Further, participants discussed the necessity of increasing the diversity of agencies involved, particularly in collaborative efforts with the Brihanmumbai Municipal Corporation (BMC), to overcome the limitations of micro-level interventions and ensure macro-level impact.

Session 1: NbS in building plots

What are the opportunities and challenges of blue-green approaches in driving resilience and sustainability in the built environment?

This session explored the integration of NbS within building premises to address environmental and urban challenges such as waste and water management, energy efficiencies, and heat islands. Through case studies and discussions, it examined how innovations like urban farming and decentralized wastewater treatment can be implemented to promote sustainability in urban spaces with the help of blue-green infrastructure. The session also highlighted the complexities of operationalizing these solutions, including regulatory barriers, tenure, financial constraints, and stakeholder engagements.

FIGURE 5 | Waste-water recycling units installed in building premises









Photo credit: Manas Rath, LEAP Cities,

Case study A: Urban agriculture and decentralized wastewater treatment

Presented by: Manas Rath, Leadership, Excellence, and Partnership for Cities (LEAP Cities)

The expert from LEAP Cities shared insights, where the potential of NbS in creating interconnected urban systems that integrate food, water, and energy was highlighted. Addressing the built environment's dominance, the approach focused on promoting circular economies by decentralizing systems like wastewater treatment and urban farming.

Urban agriculture with vertical farming and rooftop gardens was highlighted as a key opportunity in Mumbai, while identifying underutilized spaces as potential sites. This strategy could reduce food costs, minimize wastage, and lower greenhouse gas emissions. However, challenges such as the lack of supportive policies, leasing models, and operational frameworks persist.

For wastewater management, decentralized solutions like Vision Earthcare's CAMUS (Prof HS Shankar, 2015) were presented. These systems use bio-mounds to treat wastewater, offering cost-effective, energy-efficient alternatives to traditional sewage treatment plants. While these solutions have been implemented in over 350 sites, scaling them requires addressing site-specific constraints and establishing robust frameworks for reuse (Figure 5).

Case study B: TheCityFix Labs' initiative/ organic farming at a BMC School, Mumbai

Presented by: Harshil Suresh, WRI India

WRI India shared experiences from TheCityFix Labs' initiative (Labs, 2023), a two-year accelerator program designed to be implemented under the Mumbai Climate Action Plan through pilot projects. The initiative introduced NbS pilot initiatives, such as ecological stream rejuvenation, vermifilter sewage treatment, food garden, siphonic surface drainage system, and portable farming systems.

One pilot project at a BMC school involved installing portable farming systems, which improved environmental awareness among students and demonstrated its benefits in health and reduced food wastage (Figure 6).

While impactful, the project faced significant challenges in securing permissions from multiple departments, addressing safety concerns in aging infrastructure, and maintaining stakeholder engagement.

Operational challenges included site-specific constraints like inadequate water supply and pest management, compounded by the financial burden on users. Frequent transfers of government staff like Mumbai. Further disrupted continuity and progress. It was highlighted that the scale of the project being small, these standalone efforts without broader institutional alignment often became liabilities.

FIGURE 6 | Organic farming solutions, BMC school, Mumbai



Photo credit: WRI India





Discussion

Key discussant: Deepti Talpade, WRI India

The session's discussions brought out critical insights into the challenges and opportunities of scaling NbS in built environments across Mumbai. Participants noted that weak enforcement of existing regulations, such as those for rainwater harvesting and sewage treatment plants (STPs), complicates retrofitting efforts in existing buildings. Aligning financial incentives with sustainability objectives, such as offering reduced premiums for adopting green initiatives, could motivate broader adoption of NbS.

Another challenge was the lack of skilled service providers and experts, which often led to poorly executed projects. It was suggested that standardized regulations and capacity-building programs could address this gap. Additionally, retrofitting existing buildings was recognized as particularly challenging due to their current conditions and limitations, requiring innovative approaches and better resource allocation.

Participants also stressed the importance of integrating urban farming and decentralized wastewater treatment into a cohesive framework. Leasing models and operational structures must be streamlined to overcome space and financial constraints, while pilot projects should include long-term plans for monitoring and stakeholder engagement.

Community and policy synergies emerged as vital for successful implementation. Greater collaboration among policymakers, technical experts, and communities is needed to address operational challenges. A robust framework that combines technical specifications with practical scalability, while incentivizing sustainable practices, was advocated as a way forward.

Key takeaways

- Policy and regulations: Enforcement of regulations needs to be strengthened to facilitate retrofitting and ensure consistent project quality. Financial incentives can further promote sustainable practices. A cohesive approach combining regulatory reforms and technical innovation is vital for the effective integration of NbS in Mumbai's built environment.
- Aggregating successes of pilot projects: This session highlighted the importance of aggregating the successes of pilot projects into broader frameworks to address urban challenges. Leasing models, long-term plans, and streamlined operational guidelines are crucial for scaling NbS in constrained urban spaces.
- Skilling and stakeholder engagement: Addressing the lack of skilled service providers through training and the lack of standardized frameworks is critical for consistent and high-quality implementation. Collaborative efforts involving communities, government institutions, and technical experts are critical to overcome implementation challenges and ensure the success of NbS in building premises.

Session 2: NbS in informal spaces

What lessons were learned from implementing green interventions in informal spaces in underserved neighborhoods?

Low-income settlements in cities like Mumbai face a range of environmental and social challenges, including inadequate green cover (leading to heat stress), poor waste and water management, and a lack of accessible public spaces. These issues exacerbate vulnerabilities to climate risks and negatively impact the quality of life for marginalized communities. The session on NbS in informal spaces focused on exploring innovative, community-driven approaches to address these challenges and understanding how green open spaces can be implemented in such areas.

Case study A: Lallubhai Compound (M-East Ward, Mumbai)

Presented by: Roshani Nuggehalli, Youth for Unity and Voluntary Action (YUVA)

The session began with an in-depth look at YUVA's transformative work in Lallubhai Compound, a resettlement colony in Mumbai's M-East Ward (Figure 7). This initiative sought to tackle critical issues such as waterlogging, waste management, and urban heat islands, all of which were exacerbated by poor resettlement infrastructure and service delivery.

YUVA engaged with the local community through codesign workshops to revitalize neglected open spaces. These spaces were transformed into inclusive areas catering to diverse groups, especially women, senior citizens, and children. The intervention involved planting native species of trees and plants with scientific care and organizing participatory activities like wall painting to ensure sustained community involvement.

The results were significant: improved accessibility for marginalized groups, enhanced biodiversity with new bird and insect species, and a stronger sense of community ownership. However, the project also faced several challenges, including disputes over land ownership, governance complexities, financial constraints, and the need for sustained community engagement. Despite these hurdles, YUVA scaled the initiative through its "Chalo Basti Badlein" (YUVA, 2024) campaign, extending similar efforts to other neighborhoods in the area.

Case study B: Ambojwadi (Malad, Mumbai)

Presented by: Deepti Talpade, WRI India

Another example came from Ambojwadi in Malad, where WRI India collaborated with YUVA to implement urban greening initiatives in a notified basti(settlement). This site posed unique challenges, including insecure land tenure, eviction risks, and resistance from private developers.

Efforts included clean-up drives, waste system mapping, and proposals for creating green spaces. While the Brihanmumbai Municipal Corporation expressed support for the project, local community societies and associated developers resisted. They feared that the addition of trees and other amenities could later hinder redevelopment efforts, as the BMC might restrict the removal of such features.

These obstacles highlighted the complexities of governance, trust-building within communities, and balancing stakeholder interests. Despite the setbacks, the project underscored the importance of adaptive strategies and collaborative problem-solving when implementing NbS in such challenging contexts.

FIGURE 7 | NbS approach in Lallubhai compound, a resettlement colony in Mumbai's M-East Ward.



Source: YUVA

Discussion

Key discussant: Rohit Mujumdar, School of Environment & Architecture

The presentations initiated discussions on approaches used in vulnerable neighborhoods to tackle climate risks. It was noted that standardized scientific processes for climate adaptation may not always suit local communities, given their unique contexts and sociocultural challenges. Instead, developing a toolkit of methods and solutions tailored to Mumbai's specific context would be more effective, where blue-green infrastructure (BGI) efforts can prioritize social needs.

For instance, participatory solutions like urban farming could be better integrated into communities that already possess the necessary capacity, rather than being implemented on an ad hoc basis. A relevant example is the situation in Sanjay Gandhi National Park (SGNP), where Adivasi communities, once engaged in farming, have been restricted from continuing their practices. Meanwhile, greening initiatives like the Miyawaki method are being proposed within the park, even though their long-term impacts remain uncertain. It was suggested that leveraging local traditional knowledge could serve as a cost-effective and context-sensitive strategy, enabling indigenous communities to contribute meaningfully to farming and greening projects in urban areas instead of experimenting on entirely new sites.

The discussion also emphasized the importance of considering the spectrum of land tenures in Mumbai, including "perceived tenure" as a critical factor when implementing NbS. Shifting focus from "open spaces" to "public commons" and understanding the potential of different tenure types could help identify suitable NbS strategies for specific contexts. For example, the failure of a peripheral greening strategy in Case B—on a resettlement and rehabilitation (R&R) site located on government land—serves as a caution against replicating this approach in similar tenure types. In contrast, areas currently used for informal dumping present opportunities for transformation into spaces for recreation, greening, or other NbS.

Key takeaways

- **Contextual toolkit development:** There is a need to create a toolkit for NbS or BGI that takes Mumbai's sociopolitical context into consideration. This toolkit should balance social needs and environmental objectives while exercising caution in decision-making. A single set of methods or tools cannot be universally applied to blue-green initiatives. Understanding the range of tenure types can provide insights into the strategies most suitable for specific locations.
- Leverage local capacities: Existing community capacities and traditional knowledge should be harnessed to design and implement context-specific blue-green solutions. Prioritization should consider the criteria of capacity, context, and urgency.

Session 3: Education and awareness initiatives How do education and awareness initiatives scale blue-green

interventions in Mumbai?

Understanding education and awareness practices is essential for scaling blue-green interventions for climate adaptation in Mumbai, as these approaches empower communities and institutions with the knowledge and skills needed to implement effective solutions. Education programs tailored to local socioeconomic and ecological contexts can bridge the gap between scientific knowledge and ground realities, fostering community ownership and participation in initiatives like urban greening, water management, and biodiversity restoration. By integrating traditional knowledge, participatory practices, and innovative tools, such initiatives can create a skilled, informed stakeholder base capable of designing, implementing, and sustaining blue-green interventions at scale.

FIGURE 8 | Map showing flooding spots and the runoff coefficients, Mumbai.

 Map showing the older cooperative housing societies with low runoff mostly experiencing flooding.



Source: Abhijit Ekbote, part of KRVIA studio.

Case study A: Participatory mapping and dissemination

Presented by: Abhijit Ekbote, urbanist/mapper

The presentation showcased a range of projects that explored methods of spatial mapping and analysis while engaging with or disseminating knowledge to government officers, academic groups, and practitioners. Mapping practices, such as building a city resource geographic information system (GIS) portal, analyzing historical maps, and conducting projects like Mumbai Water Narratives and Dharavi Amenities Mapping, have demonstrated the value of accessible, localized data in understanding urban challenges. These efforts have enabled stakeholders to identify patterns in land use, natural assets, water access, and infrastructure development, while addressing vulnerabilities like flooding and limited access to green space. Projects like Tree Census and Mapping Accessibility for Open Spaces further illustrate the potential of open-source platforms and community-driven data collection in tackling urban ecological issues (Figure 8). However, challenges such as funding, technical training, and institutional support indicate the need to strengthen knowledge-sharing frameworks and build technical expertise across diverse stakeholders. The presentation suggested that scaling up these participatory and data-driven practices can provide the foundation for effective, context-sensitive blue-green interventions at both neighborhood and city levels.

Case study B: Greening in M-E Ward through educational initiatives

Presented by: Avinash Kaur and Avinash Madhale, Tata Institute of Social Sciences (TISS)

The TISS presentation showcased the practice of greening and education in low-income communities, particularly in Mumbai's M-E Ward, aimed to address environmental challenges in areas with the lowest Human Development Index (HDI). (UNDP 2022) This community-driven initiative focused on transforming schools and open playgrounds into green spaces, creating a direct connection between local residents and nature. In schools, specifically for grades 7 and 8, the approach centered on curriculumbased interventions. Eco-clubs were set up, and educational sessions were held on topics like soil, waste management, and sustainability, helping students actively participate in the transformation of their school environments. Over six months, these efforts not only reactivated the spaces but also instilled long-term environmental awareness in the students. Additionally, the Majhi Vasundhara Abhiyan curriculum, covering biodiversity, waste, energy, and water, was piloted through lesson plans developed by the state government. The project extended beyond the classroom, with a community forum of 20-25 local participants, ensuring ongoing engagement and dialogue. Through this initiative, education and awareness were not only used to increase green cover but also to empower communities, creating a sustainable foundation for environmental change in vulnerable neighborhoods.

Discussion

Key discussant: Parth Bapat, independent biodiversity consultant

During the discussion, participants analyzed the practice of urban greening in vulnerable neighborhoods and explored key strategies that can raise awareness and empower communities to take action. The library space in M-East Ward, a part of the community for seven years, played a significant role in building stronger relationships with the community and deepening the understanding of greening and climate change. It became a hub for knowledge exchange, especially around indoor and food plants, where residents shared their preferences for plants with medicinal or food uses. These activities led to important conversations on plant care, watering mechanisms, and the resources people rely on. By involving the community in documenting their stories and plant practices, the initiative created a participatory learning environment, which helped build a stronger understanding of climate change and greening. The potential for scaling this initiative was discussed, with suggestions on how to incorporate it into the state curriculum. It was noted that the current curriculum broadly addresses environmental education but does not focus on specific plants and trainings associated with them. Two opportunities were proposed for scaling up: integrating plant care knowledge into textbooks and designing project-based learning activities tailored to specific local habitats, which could be documented through case stories.

For the practice on spatial mapping tools and knowledge creation through participatory modes, there was a discussion on how these could be mainstreamed into educational activities. Identified opportunities included incorporating GIS courses into educational programs at ward level for municipal officers and a structured 2-credit GIS course at Mumbai University on specific topics like water resource management, which can equip students and teachers, with the skills to handle and analyze data independently. On participatory mapping approaches, the Dharavi project provided a valuable example, where community members were involved in designing the data collection form and giving feedback on the final map, fostering local ownership and improving the accuracy of the data. Additionally, it was pointed out that open-source platforms like Mapillary10 and Field Papers offer accessible tools for small organizations and communities to map and track urban spaces, although concerns were raised about the impact of advanced technologies like artificial intelligence (AI) on the openness of these platforms. While there is potential to scale up these efforts to improve walkability and inform blue-green interventions at a city level, the involvement of local authorities, such as BMC, remains a critical gap that needs to be addressed.

Key takeaways

- **Enabling environments for learning:** Building participatory learning environments through interest in people and enable long-term engagement in environmental action in their neighborhoods.
- **Curriculum integration:** Scientific greening education should involve case stories from project-based learning and focus on local habitats and specific plant species, rather than just broad environmental concepts in state curricula.
- Open-source data: The need for accessible urban data to support blue-green interventions is crucial. Open-source platforms and participatory mapping processes help practitioners, government officials, academic institutions, and the public; but currently there is a shortage of such resources.
- Mainstreaming participatory mapping practices: The integration of participatory mapping practices and GIS tools into formal educational streams to equip communities as well as officials with the necessary skills to support blue-green interventions requires further exploration.

eco-clubs and forums, and conducting colearning sessions in community spaces like libraries can cultivate

Session 4: NbS through social enterprises

How can social enterprises leverage nature-based solutions to ensure resource equity in marginalized urban areas?

This session explored the role of social enterprises if NbS were to address systemic challenges in urban resource management, focusing on equitable access to water and waste management in marginalized communities. The discussion highlighted governance barriers, caste and class biases, and the potential of community-led initiatives in bringing about dignity and sustainability while achieving environmental and social goals.

FIGURE 9 | Session discussion, Blue-green framework workshop, Mumbai



Photo credit: WRI India

Case study A: Equity and dignity in access to water

Presented by: Sitaram Shelar, Pani Haq Samiti

The Pani Haq Samiti representative emphasized the significance of water as a fundamental right and the persistent inequities in water access within Mumbai. Despite sufficient water availability through city-owned dams, approximately 20 lakh people, particularly slum dwellers, face denial of water due to governance issues and discriminatory tenure policies. He highlighted how slum residents often pay significantly more for water compared to affluent households, with some spending up to 25% of their income on this basic resource.

Advocacy efforts by Pani Haq Samiti, supported by over 25 civil society organizations, succeeded in influencing Mumbai's 2022 water policy and securing a court judgment recognizing water as a fundamental right and hence safeguarding water for all. However, systemic hurdles, procedural delays, and entrenched biases continue to pose challenges. The initiative showcased the importance of sustained collective movements, combining grassroots activism and data-backed advocacy to address structural inequities.

Case study B: Waste management and sustainable livelihoods for marginalized communities

Presented by: Jyoti Mhapsekar, Stree Mukti Sanghatana (SMS)

Stree Mukti Sanghatana (SMS) has organized over 5,000 women waste pickers into self-help groups (SHGs) across Mumbai, promoting decentralized waste management practices, such as composting and bio-methanation, in addition to advocating for zero-waste campuses. These initiatives not only reduce transport costs and methane emissions but also provide sustainable livelihood opportunities for marginalized women duly trained through skill development initiatives.

SMS advocated for waste segregation at source and eco-friendly packaging under extended producer responsibility (EPR). The organization introduced cost-effective solutions, such as fiber-reinforced plastic (FRP) pits for wet waste processing. It facilitated waste management training programs in schools, colleges, and communities. Despite these achievements, significant challenges including public apathy, lack of awareness about segregation, and mixing of hazardous waste and domestic waste remain. Structural issues like insufficient training for municipal workers and system challenges in policy implementation further complicate the efforts.

Discussion

Key discussant: Lubaina Rangwala, WRI India

The discussions centered around systemic barriers and opportunities for scaling NbS through social enterprises. In water access, governance mechanism and policies tied to tenure disproportionately disadvantage slum residents, while in waste management, segregation at source remains poorly enforced despite available infrastructure. Participants stressed the importance of delinking basic services like water from tenure security, advocating for temporary provisions as outlined by court judgments, until permanent housing solutions are available.

The session also highlighted the role of governance and accountability in enabling systemic change. For instance, while BMC engineers take pride in providing high-quality water, procedural complexities restrict access for informal settlements. Similarly, the waste sector suffers from a lack of holistic laborfocused policies and financial viability for decentralized solutions. The discussion called for engaging retired government officials as advisors to streamline processes and overcome institutional inefficiencies.

Community-led solutions and collaborations were seen as vital for addressing these challenges. Successful models, such as Pune's SWaCH initiative (SWaCH, 2007)-India's first waste picker-owned cooperative that partners with the municipal corporation to provide door-to-door waste collection and promote sustainable solid waste management-were highlighted as examples of effective public-private partnerships. Participants advocated for replicating similar cooperative models in Mumbai to institutionalize sustainable waste management practices. The discussion also highlighted the need for cultural and behavioral shifts, emphasizing public responsibility in waste segregation and addressing societal biases against slum dwellers and waste workers.

Key takeaways

- **System improvement:** Strengthen enforcement of equitable resource (water) access policies and simplify bureaucratic processes for water and waste-related services. Address systemic restrictions and promote financial sustainability for localized solutions.
- **Decentralized solutions:** Expand zero-waste campuses and promote scalable, focused waste management models. Ensure adequate training for waste pickers and municipal workers to improve efficiency and safety.

- Workforce welfare: Recognize and support waste pickers' contributions to the ecosystem through better working conditions, financial compensation, and access to health and safety resources.
- **Scaling successful models:** Strengthen partnerships between social enterprises, governments, and nongovernmental organizations (NGOs) to replicate successful models like Pune's SWaCH initiative in Mumbai.

Session 5: NbS for indigenous communities

How can traditional knowledge and participatory approaches drive nature-based solutions for indigenous communities in urban areas?

This session explored how NbS can integrate traditional knowledge and participatory approaches to address the challenges that indigenous communities face in urban centers like Mumbai. The discussions focused on leveraging local expertise to prevent ecological degradation, navigating governance hurdles and encouraging sustainable development through community-led interventions. Case studies from Versova Koliwada, Dharavi Koliwada, and Sanjay Gandhi National Park highlighted the complexities and opportunities of working with indigenous communities in rapidly urbanizing landscapes.

Case study A: Versova Koliwada - A community-led approach to creek restoration

Presented by: Ketaki Bhadgaonkar and Jai Bhadgaonkar, Bombay 61

The Bombay 61 team presented their work with the fisherfolk community of Versova Koliwada, emphasizing the impact of urbanization on coastal livelihoods. The degradation of creeks due to pollution and development pressures has forced the fishers to abandon traditional creek fishing, pushing them into deepsea mechanized fishing (Figure 10).

Through the TAPESTRY project, the organization employed participatory mapping and dialogue to co-develop solutions with the community. Interventions included mapping waste hotspots, local experiments, and community engagement events (seafood festivals and samvad khadicha (Conservations of the Creek)), in addition to designing and implementing a net filter system to reduce waste flow into the creek, which collected substantial amounts of plastic waste. While this initiative showcased the potential of blending traditional practices with modern techniques, systemic challenges such as funding constraints and political resistance hindered broader implementation.

FIGURE 10 | Degradation of Mangroves in Mumbai



Source: Bombay 61.



Presented by: Samidha Patil and Kareena Kochery, urbz

The urbz representatives shared insights from their participatory urban planning work in Dharavi Koliwada, a centuries-old settlement facing displacement under redevelopment schemes. By embedding their practice within the community, urbz facilitated an action-based comprehensive development plan that prioritized the community's cultural heritage and ecological connections (Figure 11).

Efforts included mapping existing uses of land and water, designing solutions like boat docking facilities, and promoting urban fish farming. These initiatives underlined the importance of viewing the environment as an extension of the community rather than as a resource to be engineered. However, challenges such as jurisdictional conflicts and lack of demarcation of koliwada boundaries limited the scalability of these solutions.

FIGURE 11 | Community-led redevelopment and preservation, Dharavi, Koliwada



Source: Illustrated by urz.

Case study C: Sanjay Gandhi National Park - Integrating traditional knowledge in climate action

Presented by: Rohit Mujumdar, School of Environment & Architecture

This presentation examined the displacement of Adivasi communities in SGNP, highlighting the disconnect between traditional knowledge systems and urban planning processes. The Adivasi perspective of the forest as a "garden" illustrates their sustainable practices of cultivation and care. However, restrictive regulations and relocation efforts threaten these practices, eroding their cultural and ecological heritage.

The presenter emphasized the need to incorporate traditional knowledge into planning while considering the evolving realities of urban landscapes. The session also questioned whether climate planning adequately reflected the needs of indigenous communities and called for a shift in language and policy frameworks to ensure inclusivity.

Discussion

Key discussant: Ninad Raut, Godrej & Boyce

The discussion centered on the integration of traditional knowledge and technological solutions to develop effective NbS for indigenous communities. Participants emphasized the need for defining ecosystem buffers to protect biodiversity while actively involving communities in data collection, implementation, and maintenance. The importance of establishing institutional frameworks to support community engagement was also highlighted, especially in navigating jurisdictional complexities and land-use permissions.

A persistent theme was the necessity of balancing a community's traditional practices and modern tools. Water-related traditional knowledge, while invaluable, requires recognition and adaptation to modernday challenges. For example, a net filter system rooted in traditional fishing practices effectively reduced plastic waste in the creek but incurred some queries for its low capacity and potential to trap fish eggs and larvae. This highlights the need to refine such solutions by integrating indigenous knowledge with technical innovations. Participants noted that the system relies on heavy machinery due to the lack of integration with traditional knowledge and the challenge of incorporating it, making it essential to develop processes that align indigenous knowledge with technical innovations.

Discussions also explored the systemic barriers that indigenous communities face, including the lack of formal recognition of koliwada boundaries and the displacement of Adivasi communities from the Sanjay Gandhi National Park. These issues, compounded by restrictive policies and evolving urban contexts, stressed the urgency of integrating community-specific solutions into broader frameworks like the climate action plan.

Finally, participants deliberated on the scalability and viability of current interventions, suggesting a mixed approach that combines bottom-up innovations with scientific rigor. This would ensure that the solutions are not only effective but also adaptable to the dynamic urban environment.

Key takeaways

- Knowledge systems: Effective NbS for indigenous communities requires a balance between traditional practices and modern technology, recognizing the value of both in addressing ecological and social challenges.
- **Community-centered approaches:** Solutions must prioritize participatory processes, ensuring that interventions are codeveloped with communities to reflect cultural and ecological needs.
- Scaling up in a dynamic urban environment: Addressing systemic hurdles i.e., jurisdictional conflicts, unclear land tenure, and insufficient funding is critical for scaling up community-led NbS projects.
- Inclusive planning: Viewing the environment as an extension of the community rather than as a resource for unplanned use can guide inclusive and context-sensitive planning efforts.

Session 6: NbS in streets and open spaces

How can nature-based solutions transform urban streets and open spaces into sustainable, inclusive ecosystems?

This session explored the integration of NbS into urban streets and open spaces, highlighting real-world projects that address challenges such as flooding, urban heat islands, and biodiversity loss. Presenters shared insights into practical implementation, the importance of public participation, and how such projects can reclaim and transform underutilized spaces. Discussions highlighted the importance of funding, institutional frameworks, and the role of political and community support in scaling up these initiatives effectively.

Case study A: Project One Green Mile

Presented by: Debanil Pramanik, Studio POD

Studio POD representative presented the "One Green Mile" project, a transformation of a 1.8 km underutilized stretch along Senapati Bapat Marg in Mumbai. Designed as a pilot project to address traffic congestion and reclaim public space, it focused on converting neglected areas under flyovers into vibrant community hubs.

Through collaboration with the BMC and private stakeholders, the project created accessible spaces for reading, leisure, and recreation, reclaiming 2.3 acres of public land and planting 100-odd trees. However, the pre-existing concretization posed challenges, as utilities under the carriageway limited the introduction of bio-swales, deeper planters, and larger trees. Despite these constraints, the initiative demonstrated how integrating public consultation, political buy-in, and localized solutions can drive impactful urban transformations.

Case study B: Project Marol Urban Forest

Presented by: Neha Chavan, Studio Piplikput

Studio Piplikput's Marol Urban Forest project was an effort to transform a 1 km stretch along the Mithi River into a biodiversity-rich, self-sustaining urban forest. The project merged urban and industrial lands, creating a public plaza with an amphitheater and a forest space with diverse vegetation, including Miyawaki plantations and butterfly gardens (Figure 12).

Water management systems, such as a 35 million liter per day (MLD) sewage treatment plant (STP), constructed wetlands, and recharge pits, played a pivotal role in the initiative's sustainability. The project also showcased biodiversity improvements, with increased sightings of birds and insects. Challenges included back-and-forth design modifications, procurement of native tree species, and contractor sensitization. There was significant learning for replication, particularly in implementing innovative solutions like eco-STP, bio-retention ponds, and urban forests, through existing government processes.



Source: Studio Piplikput.

Discussion

Key discussant: Dhawal Ashar (WRI India)

The discussion highlighted the complexities of implementing NbS in urban streets and open spaces. A major focus was on the challenges of funding, with participants noting that while budgets for implementation, such as those from the BMC garden department, are available, funding for design remains a critical gap.

Scalability was linked to robust institutional frameworks and political buy-in. The political economy plays a significant role in this alignment, with pressure groups and advocacy needed to drive NbS adoption as part of a larger urban framework.

Participants emphasized the need for greater sensitization about native plants and trees, which are often difficult to procure due to limited availability and preference for exotic plants. This requires changes in procurement policies, awareness campaigns, and the administration prescribing species selection processes that enhance biodiversity rather than aesthetics alone.

The participants also discussed the need for standardization in biodiversity and water management systems to scale up NbS projects effectively. Institutional frameworks, such as the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) scheme, were seen as crucial for addressing policylevel challenges. Moreover, long-term sustainability requires shifting NbS projects from only beautification efforts to scientifically-driven urban systems, with monitoring frameworks and community involvement as central components.

Key takeaways

- design phase remains a challenge. Strengthening financial frameworks and advocating for design-phase support are essential for comprehensive planning.
- Sensitization on native species: NbS projects must prioritize native species of plants and trees to enhance biodiversity and sustainability. Procurement challenges and a lack of awareness among contractors and stakeholders necessitate targeted sensitization efforts and revised procurement policies.
- Integrated frameworks for scalability and sustainability: Projects like One Green Mile and and ensure long-term impact.

Session 7: NbS in rivers and wetlands How can rivers and wetlands serve as catalysts for urban

ecological resilience?

This session explored the transformative potential of NbS for managing and restoring rivers and wetlands, focusing on projects that combine ecological restoration, biodiversity conservation, and community engagement. Case studies from Godrej & Boyce and Lemnion Green Solutions highlighted approaches to mangrove conservation and waterbody rejuvenation, pointing out the role of multi-stakeholder collaboration and innovative methodologies in addressing urban challenges.

FIGURE 13 | Mangrove conservation efforts





Source: Godrej & Boyce

Securing design-phase funding: While budgets for implementation are available, funding for the

Marol Urban Forest highlight the importance of aligning institutional frameworks and political interests. Success depends on robust policies, community ownership, and collaboration, to bridge governance gaps

Case study A: Mangrove conservation

Presented by: Ninad Raut, Godrej & Boyce

Godrej & Boyce (Godrej & Boyce Mfg. Co. Ltd., n.d.) has been at the forefront of mangrove conservation in Mumbai, protecting over 100 acres of mangrove ecosystems since the 1940s (Figure 13). Their approach combines conservation, research, and community engagement, to maintain biodiversity while mitigating urban ecological challenges. The mangroves, recognized as Mumbai's second-largest green lung, serve as carbon sinks, sequestering approximately 1.2 million tons of carbon.

Despite challenges like pollution from nearby dumping grounds and illegal encroachments, Godrej & Boyce developed a collaborative model involving local fishing communities. The approach emphasizes a balance between protection and access, allowing registered fishers to continue traditional fishing practices while restricting illegal activities. A mangrove nursery and mobile application enhance awareness and restoration efforts, while collaborations with organizations like Worldwide Fund for Nature (WWF) and WRI India aim to develop policy guidelines for wetland management. These initiatives emphasize how inclusive conservation practices can benefit both ecology and livelihoods.

Case study B: Stream rejuvenation

Presented by: Pooja Tendulkar, Lemnion Green Solutions

The Waterbody in situ ecological rejuvenation (WISER) project of Lemnion Green Solutions at IIT Bombay focused on a stretch of a stream connecting Vihar and Powai Lakes. The project aimed to retain water for landscape gardening use and to improve biodiversity through nature-inspired interventions. Using ecological restoration techniques, the team implemented loose boulder structures, native vegetation, and communitydriven activities like plantation drives.

The initiative faced challenges such as solid waste dumping, silt deposition, and invasive species, along with limited data and funding. However, the results were significant after implementation: improved water quality, enhanced biodiversity, and the creation of a serene space that promoted mental well-being for students and visitors. Community engagement was integral, as stakeholders from IIT, including professors and maintenance staff, were involved in every stage of the process.

Discussion

Key discussant: Shweta Wagh, Kamla Raheja Vidyanidhi Institute for Architecture and Environmental Studies (KRVIA)

The discussion highlighted the complexity and diversity of NbS approaches for urban rivers and wetlands, with a focus on scalability, sustainability, and governance. Participants explored the necessity of aligning restoration efforts with local conditions and community needs while addressing systemic challenges. Godrej & Boyce's inclusion of fishing communities as partners in mangrove conservation served as a model for balancing ecological and livelihood needs. Similarly, Lemnion emphasized that stakeholder involvement at IIT Bombay was crucial for achieving project goals and creating a sense of ownership among users.

Participants agreed that while NbS draws inspiration from nature, its implementation often involves engineered solutions tailored to specific contexts. For instance, the mangrove project emphasized ecological restoration with minimal intervention, whereas the stream rejuvenation initiative relied on engineered structures to mimic natural systems. This diversity in approaches highlights the need for site-specific strategies rather than a one-size-fits-all solution.

Scalability emerged as a key challenge. The natural survival rate of mangroves is only 30%, which can rise to 60% with interventions. Work at IIT Bombay demonstrated that biomimicry, informed by reference ecosystems, can guide effective nature-positive solutions. However, it was also noted that many funders often prioritize immediate results over long-term ecological benefits. This underlines the need to educate stakeholders on the slower, adaptive processes of NbS.

Another key point was the undervaluation of existing ecosystems and the need for policy shifts to prioritize ecological restoration. Tools like ecosystem valuation models could help advocate for preserving natural assets by quantifying their benefits in economic terms. Examples include the eastern coast of Mumbai, where conservation efforts are active, compared to the western coast, where degradation continues. These contrasts highlight the critical need to bridge the gaps between policy frameworks and on-ground realities.

Key takeaways

- Inclusive conservation models: Projects like Godrej & Boyce's mangrove conservation demonstrate how involving local communities in restoration efforts can enhance ecological outcomes and ensure sustainability.
- **Context-specific NbS approaches:** As highlighted by Lemnion, effective NbS requires designing solutions tailored to site-specific conditions, informed by ecological and social contexts.
- Bridging policy and practice: Participants emphasized the importance of quantifying restoration work using various methods like ecosystem valuation models to help advocate for restoration. They also stressed the need for collaborative frameworks to bridge the gap between grassroots efforts and policy implementation.

Conclusion and the way forward

The blue-green framework workshop highlighted the critical need for nature-based solutions to tackle climate risks, enhance biodiversity, and address urban challenges in Mumbai.

The workshop was successful in understanding various practices along with their unique challenges, innovations, and modalities. Almost all the practitioners highlighted the need for a platform or collective action to resolve implementation challenges. Each practice, irrespective of its challenges, has worked towards achieving intended outcomes with available resources, showcasing a unique combination of struggle, practical solutions, and pathways for the future.

The workshop was productive in identifying both successes and challenges while exploring areas of convergence across diverse initiatives. While this workshop has provided good prospects to aggregate the lessons learned from various practices, further deliberation is required to determine the best ways to influence city-level planning.

This platform allowed multiple practitioners in the city to connect, form alliances, learn from experiences, discover opportunities for future projects, and strategize for sharing resources. The discussions also helped in building consensus on NbS efforts, encouraging a common language, and structuring a framework for shared learning.

Building on the learnings and discussions, the following steps can be undertaken to operationalize and scale up NbS in the city:

- 1. BGF: Establishing a structure like the Blue-green Framework for Mumbai to ensure effective governance, implementation, and scalability of these practices. Institutionalizing guidelines for design, execution, and maintenance can facilitate systematic engagement with urban local bodies.
- 2. Practice book/ inventory: Developing an inventory of NbS practices across Mumbai, documenting interventions, challenges, and outcomes, and sharing them through an interactive platform emerged as a key suggestion. This inventory can serve as a reference for practitioners and policymakers, helping operationalize city-wide blue-green strategies.
- 3. Deliberation: More deliberation is needed on how to strengthen these practices for collective impact and define the way forward.
- 4. Scaling: Expanding pilot projects into city-wide campaigns by ensuring financial sustainability and civic alignment. For example, Mithi river catchment project for flood mitigation can integrate multiple pilots to create a larger ecosystem impact.
- 5. Collaborations: Strengthening collaborations by bringing together government agencies, NGOs, and community groups to promote knowledge exchange, partnerships, and capacity-building. Platforms such as workshops, blogs, and forums should be used to share the best practices and lessons learned from existing interventions.

APPENDIX A

Session-wise speakers and discussants

Session 1: NbS in Building Plots

Presentations: Manas Rath (LEAP Cities), Harshil Suresh (WRI India) Discussant: Deepti Talpade (WRI India)

Session 2: NbS in Informal Spaces

Presentations: Roshni Nuggehalli (YUVA), Deepti Talpade (WRI India) Discussant: Rohit Mujumdar (SEA)

Session 3: Education and Awareness Initiatives

Presentations: Abhijit Ekbote (Urbanist/Mapper), Avinash Madhale & Avinash Kaur (TISS) Discussant: Parth Bapat, (Independent Biodiversity Consultant)

Session 4: NbS through Social Enterprise

Presentations: Sitaram Shelar (Pani Haq Samiti), Jyoti Mhapsekar (Stree Mukti Sanghatana) Discussant: Lubaina Rangwala (WRI India)

Session 5: NbS in Indigenous Communities

Presentations: Rohit Mujumdar (SEA), Jay Bhadgaonkar and Ketaki Bhadgaonkar (Bombay61), Samidha Patil & Kareena Kochery (Urbz)

Discussant: Ninad Raut (Godrej & Boyce)

Session 6: NbS in Streets and Open Spaces

Presentations: Debanil Pramanik (Studio POD), Neha Chavan (Studio Piplikput) Discussant: Dhawal Ashar (WRI India)

Session 7: NbS in Rivers and Wetlands

Presentations: Pooja Tendulkar (Lemnion Solutions), Ninad Raut (Godrej & Boyce) Discussant: Shweta Wagh (KRVIA)

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Shweta Wagh, KRVIA	BGF	Blue Green Framework
Chitra Mhaske, Vanashakti	WRI	World Resources Institute
Firdos Khan, Vanashakti	NbS	Nature-Based Solutions
Tarun Gupta, AYG Realty	MCAP	Mumbai Climate Action Plan
Tanisha Arora, Purpose	MCAI	
Anushri Tiwari, Urban Biodiversity Hub	BMC:	Brihanmumbai Municipal Corporation
Ketan Bhutada, Organica Biotech	YUVA	Youth for Unity and Voluntary Action
Natasha Zarine, EcoSattva	TISS	Tata Institute of Social Sciences
Shomita Bhattacharya, EcoSattva	SMS	Stree Mukti Sanghatana
Kiran Awchar, EcoSattva	SHG	Self-Help Group
Dr Chandra Shankar, Vision Earth Care	SGNP	Sanjay Gandhi National Park
Shweta Jhunjhunwala, Mumbai Donut Colab	STP	Sewage Treatment Plant
Jairaj Rajguru, Advanced Centre for Water Resources Development and Management (ACWADAM)	AI	Artificial Intelligence
Richa Vuppuluri, The George Washington	CAMUS	Continuous Advanced Mite Utilizing S
University (GWU)	EPR	Extended Producer Responsibility
D Parthasarathy, IIT Bombay	FRP	Fiber-Reinforced Plastic
Sana Chohan, IIT Bombay	GIS	Geographic Information System
Ajay Nayak, Educated Environments	WWE	Worldwide Fund for Nature
Chitra Venkatraman, Researcher, University of Australia		
	111	Indian institute of lechnology
	AMRUT	Atal Mission for Rejuvenation and Urb

ABBREVIATIONS

Mite Utilizing System (in reference to decentralized wastewater treatment)

enation and Urban Transformation

Resettlement and Rehabilitation

R&R KRVIA

Kamla Raheja Vidyanidhi Institute for Architecture and Environmental Studies

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ABOUT WRI INDIA

WRI India, an independent charity legally registered as the India Resources Trust, provides objective information and practical proposals to foster environmentally sound and socially equitable development. Our work focuses on building sustainable and livable cities and working toward a low-carbon economy. Through research, analysis, and recommendations, WRI India puts ideas into action to build transformative solutions to protect the earth, promote livelihoods, and enhance human well-being. We are inspired by and associated with World Resources Institute (WRI), a global research organization. Know more: www.wri-india.org.



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