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Chapter 2

Blue-Green Infrastructure: Climate Risk Resilience of Indian Hill Cities

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Introduction

Hill cities of India stand like emerald stones against the broad canvas of the natural world, nestled amidst the country's magnificent mountains. These places are not just spectacular getaways but also priceless natural assets that should be preserved. Every hill city, from the snow-capped heights of the Himalayas to the lush slopes of the Western Ghats, has its own ecosystems full of life. Their very core is rooted in the old geological legends carved into the rocks, with peaceful meadows and tumbling waterfalls creating an amazing scene. It is essential to preserve these unique pockets of paradise. Acknowledging them as natural heritage protects not just a picturesque retreat but also an abundance of wildlife, geological marvels, and the cultural fabric created by these people in balance with their surroundings.

But as the population is growing in these pockets of natural heritage, the pace of urbanization is also increasing. The expression 'urbanization' refers to the intricate phenomenon of social, economic, and ecological growth of a place that is predominantly influenced by anthropogenic activities (Schneider, 2012). People moving from rural to urban areas boost city population density and lead to the growth of metropolitan areas. (Aksoy, Dabanli, Cetin, Kurkcuoglu, & Cengiz, 2022). "According to the UN World Cities Report 2020, the anticipated growth of the world's urban population would be centered in only a few countries, especially India, China, Brazil, and Nigeria, which are predicted to hold 35% of the total urban population".

"Urbanization poses several significant issues, one of which being the risks associated with climate change. Changes in land use, such as the conversion of green areas to impermeable surfaces, may arise from urbanization". (Akodewou, 2020). The ability to absorb rainwater decreases as cities grow and natural landscapes are replaced by impermeable surfaces like roadways and structures leading to a decline in blue-green elements of the urban centres. Heavy rainfall causes a surge in water runoff, which overwhelms urban drainage networks and causes flooding in low-lying regions. (Saghafian, 2008).

Blue-Green Infrastructure

Blue-Green Infrastructure (BGI) can be defined as "an integrated network of natural, adapted or man-made blue and green spaces in an urban context to mimic natural hydrological processes (such as flow control, detention, retention, filtration, infiltration and different forms of water treatment like reuse and recycling) for sustainable water and stormwater management in cities". (Driver & Mankikar, 2021)

"The implementation of BGI in urban design and planning offers a range of ecosystem services which can be categorized into provisioning services (food, fresh water, and fuelwood), regulating services (climate regulation, water regulation, and carbon sequestration), cultural services (recreational, spiritual and aesthetic) and supporting services (soil formation and nutrient cycling) " (Driver & Mankikar, 2021)

"The European Commission defines green infrastructure as a 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 system of green (land) and blue (water) areas has the potential to improve the condition of

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the environment, thereby improving citizens' health and quality of life. It also promotes a green economy, creates jobs, and improves biodiversity". (Driver & Mankikar, 2021)

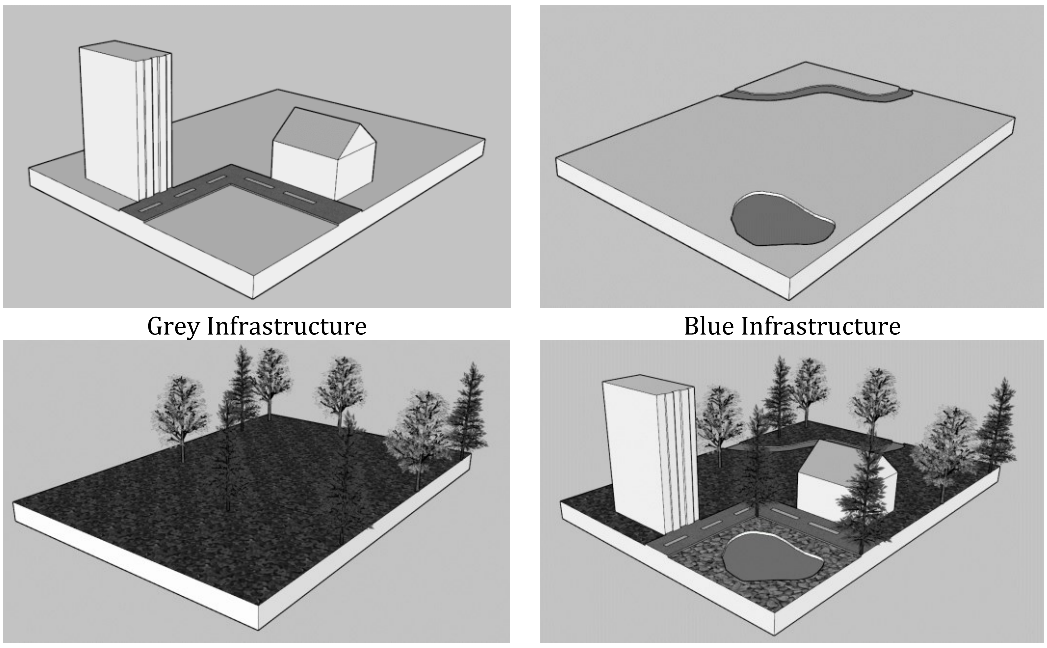

Figure 1. Blue, Green and Grey Infrastructure

As a result of rapid urban growth, several Indian cities are experiencing an overall decrease in green and blue features, with investigations on land-use changes pointing to ecological damages. Between 1973 and 2013, the built-up area in Bengaluru increased by 925 %, with green features reducing from 68% to 14 % and blue features reducing from 3 % to even lower than 1 %. In a comparable manner between 1977 and 2017, Mumbai experienced a 60% loss in greenery and a 65% reduction in water bodies. A scientific land-use land cover evaluation for Greater Mumbai published in 2020 shows up to a 2.5% reduction in greenery and a 1.4% reduction in lakes and rivers between 1999 and 2019. Between 2010 and 2030, Ahmedabad is predicted to lose approximately 50% of its greenery. The inability to efficiently optimize, manage, and keep track of the processes of urbanization is to blame for this massive damage to the environment. (Driver & Mankikar, 2021)

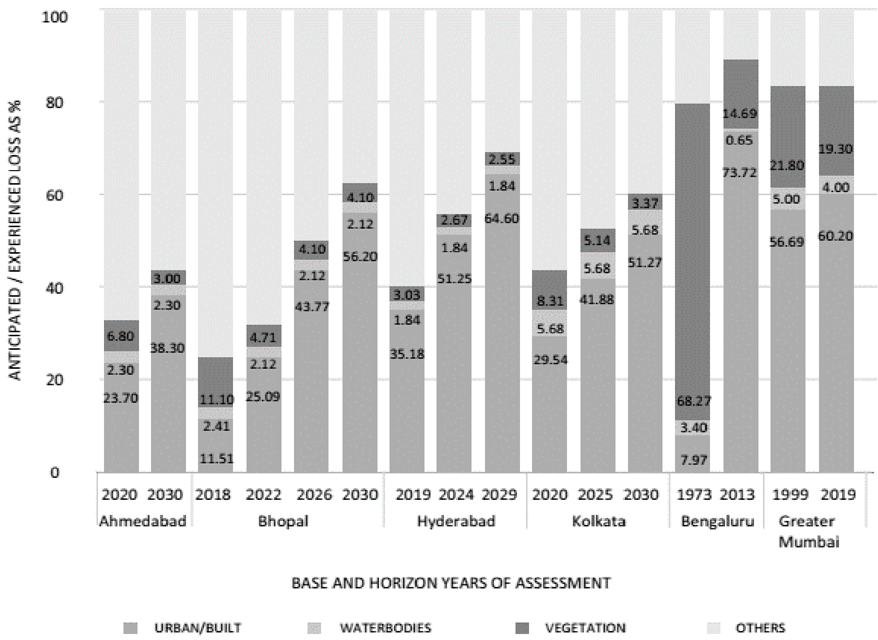

Figure 2. Loss in Blue-Green Areas and Rise in Built-up Areas in Major Indian Cities. ((Driver & Mankikar, 2021)

Dehradun: Capital of Hill State of India

Uttarakhand has become one of the most rapidly growing states, thanks to the manufacturing and tourism industries. As hill cultivation grew unstable and greater opportunities for employment and educational attainment grew more concentrated in urban areas, migration to cities from hill villages accelerated Uttarakhand's rapid urbanization. Unplanned urbanization, as well as difficulties in mobilizing human and financial resources, has resulted in substantial deficits in the supply of fundamental services and blue-green infrastructure in expanding urban areas. Increased deforestation and soil erosion in Uttarakhand's mountainous regions have increased surface runoff while decreasing groundwater recharge, potentially contributing to flooding downstream in the plain regions.

Dehradun, the capital city of the Uttarakhand state, is known for its natural beauty and pleasant climate. But in recent years, the city has been dealing with the negative effects of rapid urbanization, which has resulted in ecological degradation, increased vulnerability to the effects of climate change, and an overall decline in the standard of living of its residents

Dehradun, Uttarakhand's most populous city, is experiencing unprecedented urban growth. Untreated wastewater and fecal sludge are dumped directly into the Rispana, Bindal, and Suswa rivers, posing serious environmental and health hazards. This is exacerbated during the rainy season because wastewater gets combined with stormwater. Inadequate drainage systems and heavy human settlement on riverbeds prevent these rivers from executing their natural draining function. (India: Uttarakhand Integrated and Resilient Urban, 2021).

Dehradun's BGI, consisting of rivers, streams, lakes, parks, and forests, has been encroached upon and deteriorated as a result of urbanization. These elements combine to form the city's blue-green network, which provides multiple environmental, social, and economic benefits. Unfortunately, as Dehradun's urban development has grown, these essential elements of the city's natural environment have been disregarded resulting in an array of environmental and urban issues.

The prevailing policy landscape of Dehradun demonstrates a conspicuous separation between water conservation and green conservation efforts, disaster mitigation, climate resilience, and Development guidelines with each domain often functioning in isolation from the other. This compartmentalization is further compounded by the absence of effective integration into statutory planning frameworks. Dehradun is the capital of Uttarakhand, a hill state of India, and is very important for the state from various perspectives like social, economic, ecological, cultural, and administrative. Research in this domain is essential to modify policy and planning, protect the city's ecological heritage, and ensure the safety and well-being of its inhabitants in the face of an evolving climate and urban landscape.

This research tries to identify barriers and challenges to the implementation of Blue-Green Infrastructure in such hill cities of India so that the natural heritage can be preserved through the implementation of such innovative and sustainable approaches.

Material and Methods

The authors are particularly interested in the implementation of Blue-Green Infrastructure as a sustainable approach towards climate risk resilience of hill cities of India and associated barriers and challenges, specifically focusing on Dehradun city of Uttarakhand state of India for this research. Blue-Green Infrastructure helps in augmenting the drainage capacity of a region by providing natural drainage channels and permeable surfaces thereby decreasing rainwater runoff and increasing its percolation into the ground. Hence Blue-Green Infrastructure acts as an innovative sustainable approach for the protection of a city from urban flooding. However, implementation of BGI can face numerous challenges either citizens, stakeholders, implementing authority, or development framework, hence it is very crucial for this study to understand the existing drainage infrastructure of Dehradun and the barriers and challenges to the implementation of BGI within the city.

The research started with the identification of a prevailing issue that is affecting various natural heritages of India. After a series of discussions with the professionals and extensive desktop study, urban flooding was established as a major threat to hill cities and is a result of the cumulative effects of climate change and rapid urbanization. Then through extensive literature study, Dehradun being an urban flooding prone hill city was selected as the study area for the research and Blue-Green Infrastructure as an innovative sustainable solution to the identified issue. This was followed by the establishment of the objectives of the study.

The major objectives of the research include the identification of issues in existing drainage infrastructure and the Identification of barriers and challenges to the implementation of blue-green infrastructure in Dehradun. To achieve these objectives a qualitative research approach has been employed in which a comprehensive field survey was conducted by the authors for understanding the existing drainage infrastructure of the city and various issues related to it. This approach provides first-hand updated data about the prevailing issues and conditions and helps the author develop an understanding of the micro areas that the research is dealing with.

The primary field survey was followed by one-to-one expert consultation for the identification of barriers and challenges to the implementation of BGI in Dehradun. It is a very crucial step for the research as it helps the author explore the point of view of the implementing authorities including their concerns, their challenges, their demands, and their suggestions which are at the core of any project.

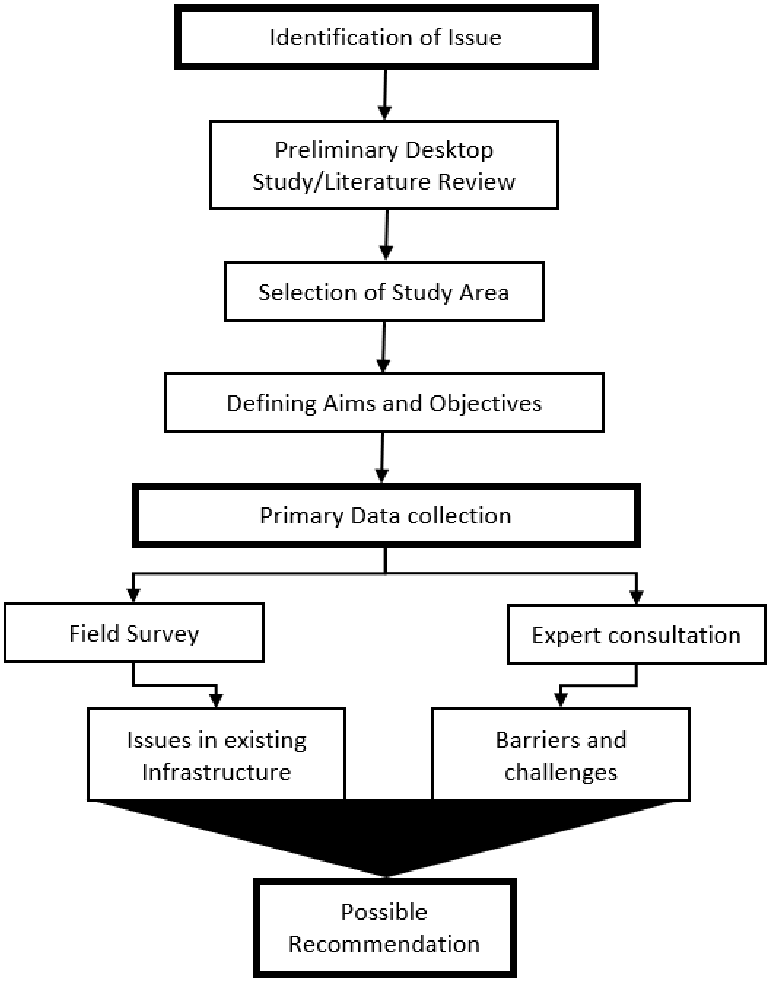

Figure 3: Structure of the Study (Developed by Author)

Several limitations were faced while following the above-mentioned methodology while conducting the research including time and resource constraints. Due to time and resource constraints, only 3 wards of Dehradun city could be covered for the field survey. Field surveys of more numbers and diverse typologies of wards would have given a more comprehensive picture of the condition of the city regarding drainage infrastructure and blue-green resources. Another major limitation of the research was the busy schedule of the experts. Due to the busy schedule of professionals involved in urban development of Dehradun city and time constraints only a limited number of professionals could be consulted.

Gathering Datasets

For fulfillment of the first objective i.e. identification of prevailing issues with the existing drainage infrastructure of Dehradun, a detailed field survey was conducted in 3 wards of Dehradun falling under the high flood risk zone of the city for 10 days. The issues in the existing drainage infrastructure of these wards which may contribute to urban flooding were observed and identified followed by visual documentation by capturing photographs of the faulty infrastructure.

For the second objective of the study i.e. identification of barriers and challenges, a one-to-one consultation was conducted with 9 professionals from 4 different organizations involved in the urban development of Dehradun i.e. Dehradun Nagar Nigam, Town Planning Department Dehradun, Dehradun Smart City Limited and

Mussorie Dehradun Development Authority. For one-to-one consultation, a semi-structured open-ended questionnaire was prepared focusing on experts' experience with BGI projects, barriers and challenges to implementation of blue-green infrastructure in Dehradun, and possible solutions and strategies that can be employed to overcome identified barriers and challenges. Criteria established for the selection of experts are as follows:

1. Should be working in one of the organizations responsible for the urban development of Dehradun city.
2. Should be involved in handling contextual issues like urban flooding and blue-green infrastructure.
3. Should have basic knowledge of the concept of blue and green infrastructure.
4. Should have basic knowledge of Master planning and statutory controls.
5. Should have at least 5 years of experience working in the field.

Criteria 3 & 4 were negotiable and a brief introduction to both of these concepts along with the aim and objective of the study was given to all the experts by the author.

Discussion and Conclusion

Field survey revealed numerous issues prevailing within the existing drainage infrastructure of the city and an intricate relationship between them contributing to Dehradun's susceptibility to urban flooding. In this section of the study, we discuss the overall implications of these issues. Lack of green spaces in private residential and commercial developments, lack of public green spaces, and impervious surface treatment of narrow access lanes lead to a decline in permeable surfaces within the city leading to reduced infiltration of rainwater into the ground. This rainwater which is not naturally absorbed into the ground gets accumulated on the surface and runs off, overwhelming drainage systems and contributing to urban flooding.

The absence of drainage infrastructure within the wards including narrow access lanes, along with clogged, damaged, insufficient, and encroached storm water drains further reduces the water handling capacity of the drainage network of the city. This system, designed to channel excess water, simply isn't equipped to handle current demands. Even during normal rainfall, limited capacity and issues like clogged drains (due to narrow channels, debris build-up, or damage) lead to pooling and localized flooding. However, heavy precipitation overwhelms the system entirely, causing widespread flooding across the wards. This situation highlights the urgent need for a comprehensive upgrade to the drainage network, addressing capacity limitations, blockage vulnerabilities, and the potential for wider, more easily maintained channels.

Disposal of solid waste into the major rivers of Dehradun like Rispana and Bindal contaminates these rivers leading to water and air pollution while at the same time decreasing their water handling capacity. Solid waste acts as a dam, accumulating in rivers and waterways. This accumulation creates blockages that impede the natural flow of water. During periods of heavy rainfall, these blockages can significantly exacerbate flooding downstream. Rising water levels trapped behind the blockage can overflow riverbanks, inundating surrounding areas and causing significant damage.

Sections of the society living along the river banks (Slums) and within the flood plains are highly vulnerable to flooding and are exposed to unhygienic living conditions. These communities often face a double threat during periods of heavy rain due to unsustainable construction practices. Firstly, the materials used for housing in these areas are frequently impermanent and flimsy, offering little protection against the elements. Flooding events can easily damage or destroy these structures, displacing residents and causing significant hardship. Secondly, the very location of these settlements, nestled along riverbanks, places them directly in the path of rising water levels. Unlike more permanent structures built on higher ground, these slum dwellings have a minimal defense against floodwaters. Investing in sustainable and flood-resilient housing solutions for these communities is crucial.

This comprehensive investigation into the wards' flooding issues has revealed a complex web of contributing factors. The lack of a balanced drainage network, encompassing both blue-green and grey infrastructure solutions, stands out as a critical shortcoming. This deficiency, coupled with limitations in existing infrastructure, unsustainable construction practices, and illegal settlement along the major rivers, creates a significant vulnerability to flooding. The findings underscore the urgent need for a holistic approach to flood mitigation within the wards. This knowledge will pave the way for the development and implementation of effective solutions that address drainage network limitations, promote sustainable construction practices, and integrate blue-green infrastructure.

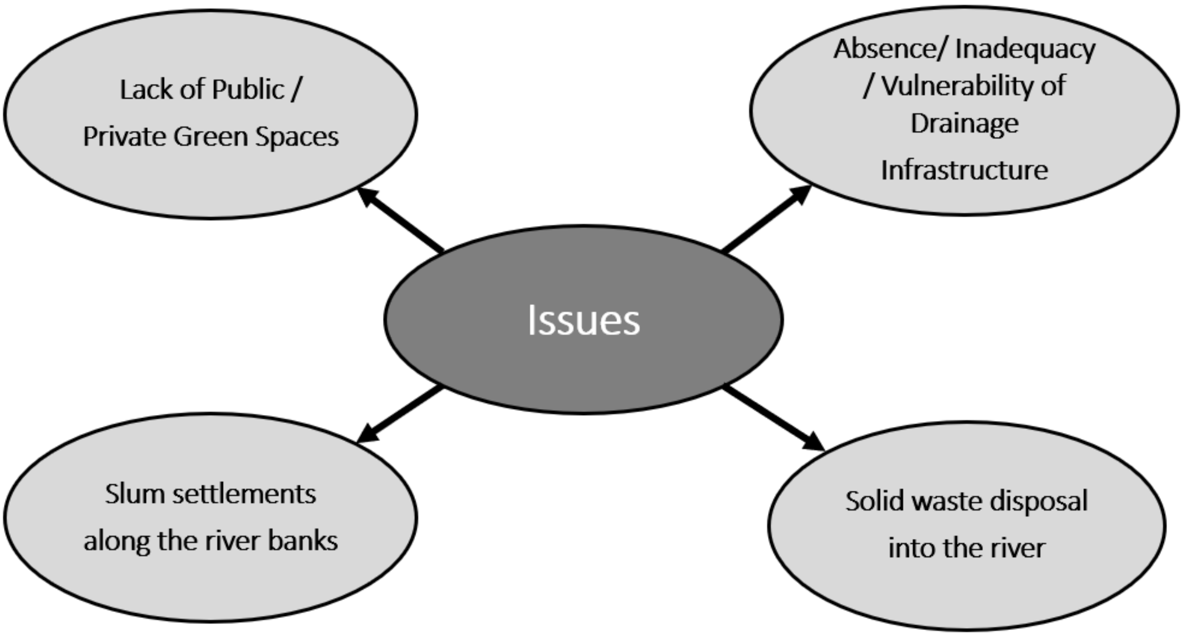

Figure 4: Prevailing issues with existing drainage infrastructure of Dehradun city

Implementation of BGI projects often requires the collaboration of multiple stakeholders like Development authorities, municipalities, water resource departments, political leaders, community members, etc. In the absence of strong and clear leadership, clear distribution of roles and responsibilities, and lack of interagency and interdepartmental coordination, these stakeholders may work in silos. This can lead to delayed project implementation, duplication of efforts, and creation of grey areas of responsibility and may lead to project failures.

The absence of a comprehensive and continuous monitoring system and a long-term vision, failure of BGI projects to adapt and remain effective in response to changing conditions, leading to missed opportunities; can pose challenges in obtaining ongoing funding or gaining public endorsement due to difficulty in measuring success and can lead to project decay and eventual collapse. Lack of strict legislation and regulation for blue-green infrastructure projects can lead to uncertainty for investors and developers due to ambiguity in the law, making evaluating project risk and return difficult. The absence of adequate legislative protections can also make existing blue-green resources of the city vulnerable to development pressures, eventually compromising their ecological advantages. The absence of stringent laws and regulations can result in a difficult setting for the implementation of BGI. Well-defined and enforceable rules may offer investors the required assurance, maintain consistent project standards, safeguard existing natural resources, and promote the incorporation of BGI (Blue-Green Infrastructure) into mainstream planning processes. It is essential to address this lack of legislation to fully utilize the potential of BGI to contribute to a more sustainable future.

Failure to integrate updated climate science into policy may result in BGI projects being developed using obsolete information, which could make them insufficient or ill-suited to tackle forthcoming climate concerns and can also result in missed chances to create BGI initiatives that provide the biggest advantages in response to a changing climate. The absence of robust policies that acknowledge the pressing need for climate change adaptation might also result in the neglect of nature-based solutions like Blue-Green Infrastructure (BGI) in favor of conventional, "grey" infrastructure alternatives. This can limit the procurement of capital required for the widespread adoption of BGI. Institutional inertia poses a major challenge, as many planning departments and construction corporations are deeply entrenched in traditional methodologies and technologies. This resistance to change fosters a preference for familiar and well-established practices, leading to stagnation in the adoption of innovative solutions like BGI. Consequently, the continued reliance on less sustainable infrastructure methods impedes environmental progress.

A lack of awareness and knowledge gaps about BGI further exacerbate this issue. Stakeholders may not fully understand the benefits and capabilities of BGI, leading to uncertainty and reluctance to support its implementation. This unfamiliarity breeds a perception of BGI as a risky and unproven approach, deterring stakeholders from endorsing it and perpetuating the dominance of traditional infrastructure practices. Moreover, the need for initial financial investments in training, design modifications, and novel technologies presents a substantial barrier. The perception of higher risks and costs, especially in regions with little prior experience with BGI, discourages decision-makers from departing from established norms. Community opposition, often manifesting as NIMBYism (Not In My Backyard), also significantly hinders the adoption of BGI. Local resistance to changes in land use or visual aesthetics can obstruct BGI projects, even when these initiatives offer broader community benefits. This localized opposition can slow down or halt the progress of BGI projects, undermining their potential environmental and social advantages.

The poor societal perception of BGI further complicates its adoption. Public skepticism about the effectiveness of BGI in addressing environmental issues compared to conventional infrastructure solutions diminishes support and willingness to invest in such projects. Aesthetic and functional concerns also play a role, as the public may perceive BGI as disorganized, untidy, or unsuitable for urban settings. Limited exposure to successful BGI implementations perpetuates negative perceptions, highlighting the importance of showcasing successful projects to build public trust and support. The lack of community empowerment poses another significant obstacle. If the benefits of BGI projects are not perceived as fairly distributed, or if certain groups bear a disproportionate share of the negative impacts, community resentment can undermine the success of these initiatives. Social exclusion from the planning process can result in projects that do not align with community needs, reducing their effectiveness and acceptance. Insufficient community participation can erode trust in implementing organizations, creating substantial barriers to project approval and execution. Additionally, without a sense of ownership and stewardship, communities may neglect BGI projects, compromising their long-term viability.

A bias towards alternate future land use presents a further challenge. In rapidly expanding regions, undeveloped land is often seen as a valuable asset for potential future developments such as housing or commercial buildings. This speculative development mindset can discourage the allocation of land for BGI, despite its immediate environmental and social benefits. Prioritizing short-term economic gains over integrated urban planning can lead to fragmented development, undermining the potential synergistic benefits of BGI and overall urban sustainability.

Onesite constraints like limited space available in densely populated urban areas, complicate the implementation of BGI features like rain gardens, bioswales, or green roofs. The presence of existing infrastructure, such as underground utilities and metro lines, further restricts available space and poses challenges during construction. Soil conditions and topography also play critical roles, as inadequate soil drainage, fertility, or contamination, as well as steep slopes or extremely flat areas, can impede the functionality and stability of BGI elements. Additionally, the compatibility of BGI projects with the surrounding environment is crucial; introducing inappropriate plant species or failing to consider local climate and wildlife interactions can undermine the long-term viability of these initiatives.

Design challenges present another significant barrier to BGI adoption. Striking a balance between functionality and aesthetics is essential but challenging, especially when integrating BGI into existing urban landscapes. The lack of established design standards and guidelines hampers designers' ability to create effective and compliant projects. Furthermore, maintenance considerations are critical; overly complex or difficult-to-maintain designs can lead to increased costs and project failures. Ensuring that BGI projects are both functional and easy to maintain requires meticulous planning and the involvement of diverse expertise from designers, engineers, and ecologists. Maintenance and performance challenges also impede the widespread adoption of BGI. Long-term planning and consistent funding for maintenance are vital but often lacking, leading to neglect and reduced effectiveness of BGI projects over time. Effective monitoring and performance evaluation are necessary to demonstrate the benefits of BGI, but these processes can be resource-intensive. Without proper monitoring, it becomes difficult to identify issues early and justify ongoing maintenance expenditures.

One of the primary obstacles is the lack of funding, driven by high upfront costs, uncertainties around return on investment (ROI), and limited public funding mechanisms. BGI projects often require substantial initial investments for design, construction, and materials, which can be higher compared to conventional "grey" infrastructure, especially for large-scale projects. This financial demand can be difficult to meet, particularly when competing with other infrastructure priorities for limited public or private funds. Moreover, although BGI provides long-term benefits such as improved water management, increased property values, and reduced energy consumption, these benefits are often difficult to quantify. Decision-makers may hesitate to fund BGI projects due to the intangible nature of these returns, preferring investments in traditional infrastructure with more straightforward cost-effectiveness metrics. Existing funding systems also pose a challenge, as they may not be well-suited to support BGI initiatives, necessitating the development of innovative financing approaches such as public-private partnerships, user fees, or impact investment projects.

Another significant barrier to BGI implementation is the lack of a continuous, transparent, and clear linkage between service providers and users. Mismatched needs and solutions can arise when designers and engineers do not fully understand the specific requirements and objectives of the communities they serve. Without effective communication and user interaction, BGI projects may be developed using a standardized approach, failing to address the unique concerns and desires of the local population. This disconnect can result in projects that are underutilized or do not foster a sense of community ownership. Additionally, the absence of clear identification of beneficiaries complicates the distribution of roles and responsibilities within the community. For instance, without a proper list of beneficiaries, it becomes challenging to determine who should bear environmental taxes related to BGI, impeding revenue generation and overall project sustainability.

Public opposition to new charges intended to fund BGI projects also presents a formidable challenge. The perception of fairness plays a crucial role in public acceptance of additional fees. Concerns over the equitable distribution of the financial burden can arise if certain groups feel they are paying more without receiving immediate benefits. Effective communication about the purpose of the charges, the allocation of funds, and the long-term advantages for the community is essential to address these concerns. Affordability issues further exacerbate public resistance, particularly among individuals with limited financial resources or those already facing economic hardships. Failing to consider affordability or providing exemptions for vulnerable communities can lead to widespread opposition. Additionally, a lack of trust in how funds will be used can erode public support. Transparency in fund allocation and the establishment of independent oversight mechanisms are critical to building public trust and encouraging support for BGI projects.

The comprehensive assessment of drainage infrastructure issues and the identified barriers and challenges to the implementation of Blue-Green Infrastructure (BGI) in Dehradun highlights the urgent need for coordinated and innovative solutions. The city's vulnerability to urban flooding is deeply rooted in a lack of permeable surfaces, inadequate drainage infrastructure, pollution of major rivers, and vulnerable slum settlements. Addressing these issues requires a multi-faceted approach that integrates BGI with traditional grey infrastructure, while also overcoming institutional, socio-cultural, knowledge, and funding barriers. Clear leadership, interagency cooperation, long-term vision, legislation, and public awareness are critical elements for successful BGI implementation. Moreover, effective design, maintenance, and funding mechanisms must be established to ensure the resilience and sustainability of BGI projects. By addressing these challenges comprehensively, Dehradun can enhance its flood resilience, promote sustainable urban development, and safeguard the well-being of its residents and natural resources.

In conclusion, the findings underscore the importance of holistic planning and collaboration among stakeholders to overcome the complex challenges facing Dehradun's drainage infrastructure and BGI implementation. By addressing institutional, socio-cultural, knowledge, and funding barriers, the city can unlock the full potential of BGI to mitigate urban flooding, enhance environmental quality, and promote community resilience. However, achieving these goals will require sustained commitment, innovative approaches, and inclusive decision-making processes to ensure that BGI projects meet the diverse needs of Dehradun's residents and contribute to a more sustainable and equitable urban future.

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Conflict of Interests

The author declares no conflict of interest.

References

Schneider, A. (2012). Monitoring land cover change in urban and peri-urban areas using dense time stacks of Landsat satellite data and a data mining approach. Remote Sensing of Environment, 689-704. https://doi.org/10.1016/j.rse.2012.06.006

Aksoy, T., Dabanli, A., Cetin, M., Kurkcuoglu, M. A., & Cengiz, A. E. (2022). Evaluation of comparing urban area land use change with Urban Atlas and CORINE data. Environmental Science and Pollution Research, 28995–29015. https://doi.org/10.1007/s11356-021-17766-y

United Nations Human Settlements Programme. (2020). UN-World Cities Report. https://doi.org/10.18356/c41ab67e-en

Akodewou, A. (2020). Land Use and Land Cover Dynamics Analysis of the Togodo Protected Area and Its Surroundings in Southeastern Togo, West Africa. Sustainability. https://doi.org/10.3390/su12135439

Saghafian, B. (2008). Flood Intensification Due to Changes in Land Use. Water Resources Management, 1051-1067. https://doi.org/10.1007/s11269-007-9210-z

Driver, B., & Mankikar, S. (2021). Blue-Green Infrastructure: An Opportunity for Indian Cities. ResearchGate.Wilensky, U. (1997). NetLogo Wolf Sheep Predation model. http://ccl.northwestern.edu/netlogo/models/WolfSheepPredation. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Yu, K. and Mostafavi, M. (2010) ‘La Tour vivante, eco-tower’, in *Ecological Urbanism*. 1st edition. Zürich: Lars Muller Publishers. Available at: http://dx.doi.org/10.3939/jola.2010.2010.10.84.

Asian Development Bank. (2021). Uttarakhand Integrated and Resilient Urban Development Project: Report and Recommendation of the President. ADB. Retrieved from https://www.adb.org/projects/documents/ind-38272-044-rrp

Mussorie Dehradun Development Authority. (2041). Dehradun Master Plan - 2041. Retrieved from http://mddaonline.in/wp-content/uploads/2023/04/Dehradun-Master-Plan-2.0A.pdf