Planning Blue Green Infrastructure For Social Wellbeing in Class 1 Cities (Gwalior)

A Thesis

submitted in partial fulfillment of the requirements for the Award of the Degree

of

Master Of Planning (Urban Planning)

in

Department of Architecture and Planning

by

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under the supervision of
Prof. Savita Raje



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I hereby certify that the work which is being presented in the thesis entitled **"Planning Blue Green Infrastructure For Social Wellbeing in Class 1 Cities (Gwalior)"** in partial fulfillment of the requirements for the award of the Master of Planning Urban Planning and submitted in the Department of Architecture and Planning of the Maulana Azad National Institute of Technology, Bhopal is an authentic record of my own work carried out during the period from July 2025 to July 2026 under the supervision of Prof.Savita Raje, Associate Professor, Department of Architecture and Planning, Maulana Azad National Institute of Technology, Bhopal

The matter presented in this thesis has not been submitted by me for the award of Any other degree of this or any other Institution.

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Date:

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This is to certify that the thesis entitled "**Planning Blue Green Infrastructure For Social Wellbeing in Class 1 Cities (Gwalior)**" is a piece of research work carried out by **Shourya Shrivastava**, Scholar No.**24209011108** under my guidance and supervision for the degree of Master of Planning (Urban Planning) from the Department of Architecture and Planning of Maulana Azad National Institute of Technology, Bhopal (M.P.) India

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ABSTRACT

India's Class 1 cities face growing problems of urban flooding, heat stress, and poor air quality, which grey infrastructure alone cannot fully solve. Blue-Green Infrastructure (BGI), which combines water bodies and green spaces, offers a more sustainable solution.This study looks at how BGI can be planned to improve social wellbeing in Gwalior, Madhya Pradesh. Using GIS mapping, BGI per capita calculations, and NDVI analysis, the study identifies how green and blue spaces are unevenly distributed across the city's wards. A survey of 600 residents across six wards, using a six-item Social Wellbeing Index (SWI), measured how residents experience these spaces, along with interviews with key stakeholders.The results show that wards with more BGI per person also have higher wellbeing scores, especially for safety and social interaction. Water bodies are found to be neglected but highly valued by residents. The study proposes a ward-wise planning framework that prioritises improvement, connectivity, and conservation based on BGI levels, offering a model that other Class 1 cities can adapt.

Keywords: Blue-Green Infrastructure, Social Wellbeing Index, BGI Per Capita, Spatial Analysis, Class 1 City, Gwalior

सारांश

भारत के क्लास 1 शहरों में शहरी जलभराव, हीट स्ट्रेस, और वायु गुणवत्ता जैसी समस्याएं बढ़ रही हैं, जिन्हें केवल ग्रे इंफ्रास्ट्रक्चर पूरी तरह हल नहीं कर सकता। ब्लू-ग्रीन इंफ्रास्ट्रक्चर (बीजीआई), जो जल निकायों और हरित क्षेत्रों को जोड़ता है, एक बेहतर टिकाऊ विकल्प है। यह अध्ययन यह देखता है कि ग्वालियर, मध्य प्रदेश में सामाजिक खुशहाली बढ़ाने के लिए बीजीआई की योजना कैसे बनाई जा सकती है। जीआईएस मैपिंग, बीजीआई प्रति व्यक्ति गणना, और एनडीवीआई विश्लेषण से पता चला कि शहर के वार्डों में हरित और जल क्षेत्र असमान रूप से फैले हैं। छह वार्डों के 600 निवासियों पर सर्वेक्षण, छह-सूत्रीय सामाजिक खुशहाली सूचकांक (एसडब्ल्यूआई) के माध्यम से किया गया, जिसमें निवासियों के अनुभवों को मापा गया, साथ ही प्रमुख हितधारकों से बातचीत भी की गई। परिणाम दर्शाते हैं कि जिन वार्डों में प्रति व्यक्ति अधिक बीजीआई है, वहां सुरक्षा और सामाजिक संपर्क में खुशहाली स्कोर भी अधिक है। जल निकाय उपेक्षित हैं लेकिन निवासियों द्वारा अत्यधिक महत्वपूर्ण माने जाते हैं। अध्ययन एक वार्ड-वार योजना ढांचा प्रस्तुत करता है, जो बीजीआई स्तर के आधार पर सुधार, संपर्क, और संरक्षण को प्राथमिकता देता है, जिसे अन्य क्लास 1 शहर अपना सकते हैं।

मुख्य शब्द: ब्लू-ग्रीन इंफ्रास्ट्रक्चर, सामाजिक खुशहाली सूचकांक, बीजीआई प्रति व्यक्ति, स्थानिक विश्लेषण, क्लास 1 शहर, ग्वालियर

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LIST OF ABBREVIATIONS

AMRUT – Atal Mission for Rejuvenation and Urban Transformation

BGI – Blue–Green Infrastructure

CEMDE – Centre for Environmental Management of Degraded Ecosystems

DDA – Delhi Development Authority

EKW – East Kolkata Wetlands

EKWMA – East Kolkata Wetland Management Authority

ES – Ecosystem Services

GIS – Geographic Information System

GI – Green Infrastructure

GCC – Greater Chennai Corporation

GMC- Gwalior Municipal Corporation

MoHUA – Ministry of Housing and Urban Affairs

MoEFCC – Ministry of Environment, Forest and Climate Change

NbS – Nature-Based Solutions

NDVI – Normalized Difference Vegetation Index

NMSH – National Mission on Sustainable Habitat

NUPF – National Urban Policy Framework

PMC – Pune Municipal Corporation

SDG – Sustainable Development Goals

SRFDCL – Sabarmati Riverfront Development Corporation Limited

TNUIFSL – Tamil Nadu Urban Infrastructure Financial Services Limited

UGS – Urban Green Spaces

ULB – Urban Local Body

URDPFI – Urban and Regional Development Plans Formulation and Implementation Guidelines

WHO – World Health Organization

1. INTRODUCTION

Cities around the world are under strain from rapid urban growth and increasing climate change effects. Urban areas are particularly vulnerable, as heat is magnified by the urban heat island (UHI) effect, and flooding is exacerbated by hard surfaces that hinder rainwater absorption. This is particularly critical in India, where fast-expanding cities often struggle with inadequate infrastructure. Urban flood incidents lead to significant economic losses from property damage, flooded buildings, and severe traffic congestion due to waterlogged roads and failed drainage systems. These incidents highlight the fact that traditional "grey" infrastructure, such as pipes and drains, is insufficient on its own (Starkey et al., 2025). We must develop sustainable, resilient planning strategies centered on the well-being of urban communities (Xue et al., 2025).

Blue-green infrastructure (BGI), a type of nature-based solution (NbS), presents an exciting opportunity for the future (Lubaina et al., 2025; Starkey et al., 2025). BGI incorporates networks of natural elements, such as rivers and ponds ("blue"), as well as parks, trees, and green roofs ("green"), to manage stormwater, cool cities, enhance air quality, and promote biodiversity (Choe et al., 2020; Thorsson et al., 2025). Concepts like "sponge cities" are examples of BGI and aim to absorb and recycle rainwater (Lubaina et al., 2025; Lu et al., 2025).

Importantly, BGI goes beyond just environmental advantages; it significantly boosts the social wellbeing of those living in cities (Choe et al., 2020; Lamond et al., 2022). Social wellbeing encompasses having positive relationships, feeling part of a community, maintaining good physical and mental health, experiencing safety, and accessing the necessary resources for a decent life (Xue et al., 2025). Research increasingly shows that access to quality BGI is linked to better mental health (for example, reduced stress and anxiety) (Choe et al., 2020; Peng et al., 2022; Twohig-Bennett & Jones, 2018) , promotes physical activity (Choe et al., 2020; Zhang et al., 2023) , encourages social interaction and cohesion (Choe et al., 2020; Firth et al., 2019) , and enhances people's sense of place (Choe et al., 2020). BGI creates environments where individuals can unwind, connect, and rejuvenate (Choe et al., 2020; Thorsson et al., 2025). This makes BGI a crucial part of infrastructure, not just for environmental management, but for fostering vibrant, healthy, and socially interconnected urban communities (Lamond et al., 2022; Liu et al., 2023).

In India's Class 1 cities, which have populations of 100,000 or more and experience significant development pressures and social diversity, planning BGI to enhance social well-being is essential (Xue et al., 2025). However, there is room for improvement, as integrating BGI with a clear focus on social outcomes isn't standard practice yet (Starkey et al., 2025). Often, planning centers on technical goals, such as flood prevention, overlooking opportunities to maximize BGI's contributions to community well-being. Challenges include fragmented policies, insufficient funding, poor coordination among city departments, limited public engagement, and obstacles to ensuring fair access and maintenance (Furlan et al., 2023; Lubaina et al., 2025; Starkey et al., 2025; Kremer et al., 2024). Ensuring the social equity of how BGI is distributed and accessed is a major concern to guarantee that all communities benefit (Kremer et al., 2024; Zhao, 2025).

Consequently, this thesis report aims to explore how BGI planning in Indian Class 1 cities can enhance and prioritize social well-being strategically. The thesis will examine the types of BGI suitable for India, their specific impacts on various aspects of social well-being, current planning practices, and barriers to effective implementation (Alves et al., 2022).

1.1 About Blue Green Infrastructure

Blue-green infrastructure (BGI) (fig.1) is a strategically planned, thoughtfully designed network of natural and semi-natural spaces that blends with urban environments (Mell, 2017; Scott et al., 2020). It incorporates "blue" features, such as rivers, ponds, and wetlands; "invisible blue" features, such as rainwater and sustainable drainage systems; and "green" elements, such as parks, urban forests, green roofs, street trees, and gardens (Scott et al., 2020; Tzo, 2025).

Unlike traditional gray infrastructure, which focuses on quickly draining water through pipes and concrete channels, BGI harnesses natural processes to provide a variety of ecosystem services. Key roles it plays include managing stormwater runoff to reduce the risk of flooding (Aboelnga et al., 2025), mitigating the urban heat island effect, improving air and water quality, increasing biodiversity, and establishing enjoyable recreational areas (Jia et al., 2025; Scott et al., 2020). Related concepts, such as nature-based solutions (NbS), sustainable drainage systems (SuDS), and sponge cities, highlight the importance of using natural or nature-inspired systems to foster more resilient and sustainable urban spaces (Mell, 2017).

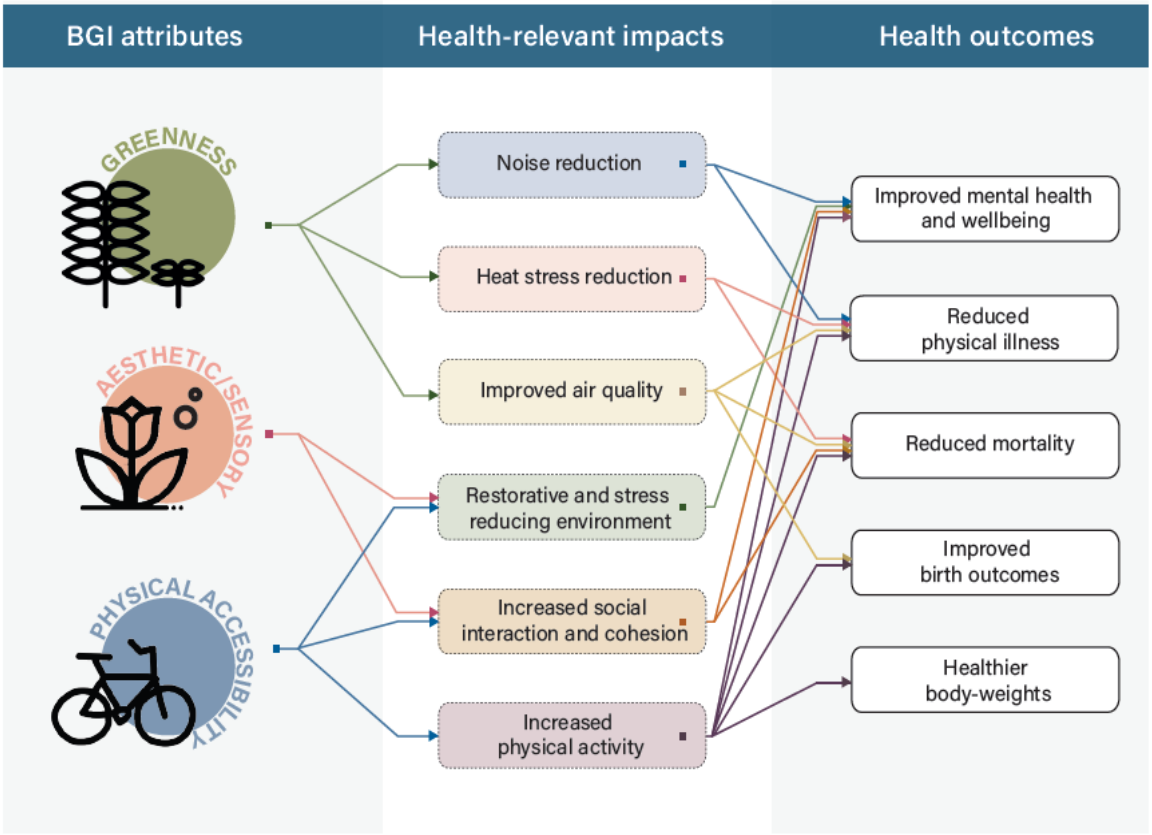


Figure 1: Interrelationship b/w BGI and Health Outcomes *Source: (Choe, E.Y et al., 2020)*

1.2 Social Wellbeing

Social wellbeing pertains to the overall quality of individuals' lives within their community, encompassing aspects that extend beyond mere economic considerations to include several critical dimensions (Keyes, 1998; USIP, 2011). It entails fostering positive relationships and robust social connections, experiencing a sense of belonging, and promoting social cohesion in the neighbourhood (BetterUp, 2021). Furthermore, it encompasses the enjoyment of good physical and mental health, the assurance of safety and security, and access to the essential resources required for a fulfilling life, such as clean air and water (USIP, 2011; Jagiroad College, 2023).

The role of BGI (fig.2) is pivotal in enhancing social wellbeing by creating accessible and attractive public spaces that promote physical activity, provide avenues for stress reduction and mental rejuvenation (Choe et al., 2020; Nitoslawski et al., 2024; Zhang et al., 2021), facilitate social interactions (Choe et al., 2020), and reinforce community identity or sense of place. Notably, the attainment of social wellbeing through BGI necessitates a focus on social equity, ensuring that the advantages of these green and blue spaces are equitably distributed and available to all residents, irrespective of their

socioeconomic background (Kabisch et al., 2019; Sustainability Directory, 2025).



Figure 2: Wellness Attributes *Source Compiled By Author*

1.3 Defining Class 1 Cities

As per the Census of India, a Class 1 city (fig.3) is primarily defined by its population, specifically having 100,000 (1 lakh) or more residents. Cities that exceed this population threshold are generally characterized by increased population density, elevated economic activity, and more sophisticated infrastructure compared to smaller towns. They typically function as important administrative, commercial, and industrial centers, providing residents with improved access to advanced services such as specialized healthcare, universities, and a variety of employment opportunities.

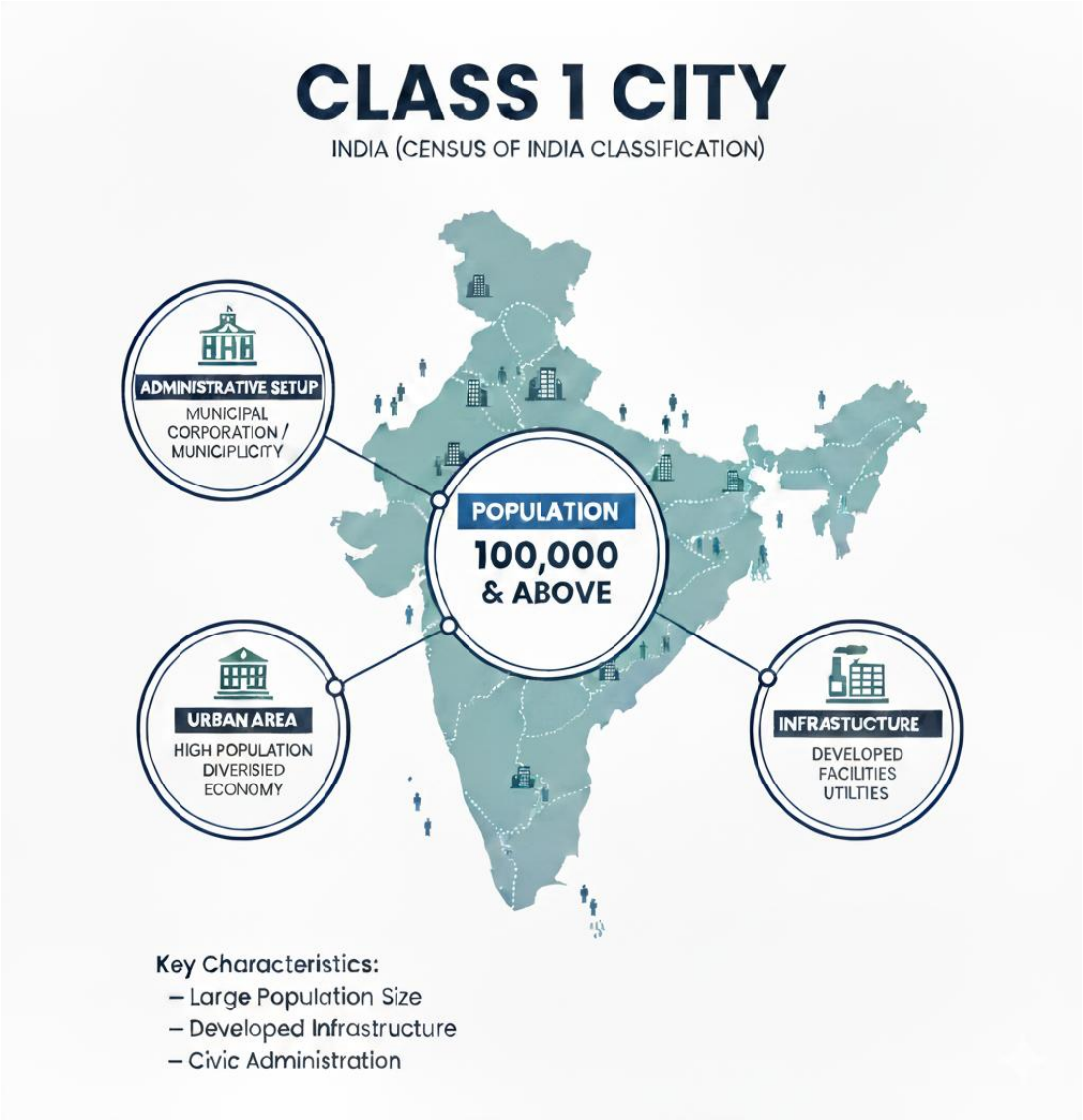


Figure 3: Characteristics Of Class 1 Cities In India Source Compiled By Author

1.4 Need For Study

India's Class 1 cities are undergoing a wave of rapid urbanization, which is placing immense strain on infrastructure and heightening their vulnerability to the repercussions of climate change, such as severe rainfall, urban flooding, and rising temperatures (Bai & Xing, 2025). Traditional 'grey' infrastructure methods-relying on engineered systems like pipes and drains-are proving ineffective and often financially burdensome in tackling these complex challenges (Starkey et al., 2025).

Additionally, urban planning often takes place within isolated departments, resulting in fragmented efforts that miss the opportunity to address intertwined environmental and social concerns comprehensively (Kuller et al., 2018; Kuller et al., 2019 cited in Thorsson et al., 2025).

Blue-Green Infrastructure (BGI) presents itself as a multifunctional, nature-inspired alternative with promising potential to bolster urban resilience, alleviate flood risks, and diminish the urban heat island effect (Choe et al., 2020; Thorsson et al., 2025; Bai & Xing, 2025). However, the advantages of BGI reach far beyond mere environmental management. Significant evidence indicates that BGI can substantially elevate social wellbeing by enhancing mental and physical health, encouraging social interactions and community ties, alleviating stress levels, and reinforcing residents' connection to their surroundings (Choe et al., 2020; Liu et al., 2023; et al.,Peng et al., 2022). These social aspects are vital in constructing truly livable and sustainable urban spaces, particularly in the densely populated and diverse cities of India.

Even though there's a lot of potential here, there's still a big gap when it comes to adding social wellbeing goals into planning for Blue-Green Infrastructure (BGI) in India. Right now, when BGI is implemented, it mostly focuses on technical aspects like hydrology or ecology, with social benefits often seen as just nice extras instead of being central to the planning process (Starkey et al., 2025; Thorsson et al., 2025). There just aren’t clear frameworks or guidelines that are tailored for planners in India’s Class 1 cities on how to really assess what communities need and design BGI projects that actually enhance social outcomes (Furlan et al., 2023; Alves et al., 2022). Plus, making sure that the social benefits of BGI are fairly distributed and accessible to different socioeconomic groups is another huge challenge that definitely needs to be addressed in the planning stages (Kremer et al., 2024; Zhao, 2025).

Therefore, this study is crucial in bridging the divide between BGI's capacity to enhance social wellbeing and the prevailing planning methodologies in Indian Class 1 cities. By exploring the specific connections between BGI typologies and dimensions of social wellbeing within the Indian urban milieu, scrutinizing existing planning strategies and obstacles, and integrating residents’ perspectives, this research seeks to develop a dedicated planning framework. Such a framework will empower urban planners and policymakers with the tools and insights required to proactively and effectively utilize BGI for cultivating healthier, fairer, and socially vibrant urban environments.

1.5 Title

Planning Blue Green Infrastructure For Social Wellbeing in Class 1 Cities (Gwalior)

1.6 Aim

To study the available BGI approaches and develop a strategic planning framework for integrating Blue-Green Infrastructure (BGI) into urban development processes to explicitly enhance social wellbeing within the context of Indian Class 1 cities.

1.7 Objectives

The research will be conducted in two phases, corresponding to the M.Plan thesis structure:

For Phase-I :

1. To understand the core concepts of Blue-Green Infrastructure (BGI) and social wellbeing.

This objective will be achieved through an in-depth literature review that explores definitions, theoretical foundations, and global interpretations of BGI and social wellbeing. It will help establish the conceptual base needed for the study.

2. To identify different BGI types suitable for India and study their specific links to social wellbeing.

This includes reviewing Indian and international examples to classify major BGI typologies and examining how each contributes to wellbeing outcomes such as health, recreation, equity, and community resilience**.**

3. To analyze existing national and state government policies related to urban planning and BGI.

This involves reviewing policy documents, urban missions, state guidelines, and regulatory frameworks to understand the level of policy support, gaps, and opportunities for integrating BGI into planning practice.

For Phase-II :

4. To select a representative Class 1 city for an in-depth case study.

A suitable city will be chosen based on population size, planning relevance, availability of data, and the diversity of existing BGI systems, ensuring it reflects common challenges in Indian urban contexts.

5. To examine the selected city's Master Plan to assess its current approach to BGI and social wellbeing.

The Master Plan will be evaluated to understand how it addresses green spaces, water bodies, ecological networks, public access, and wellbeing-related provisions.

6. To map the existing BGI distribution in the case study city using GIS and analyze its accessibility and equity.

Spatial data will be used to create maps of parks, lakes, rivers, open spaces, and green networks. Accessibility and distribution will be assessed across neighbourhoods to identify gaps and inequalities.

7. **To understand local perspectives on BGI by interviewing planners, officials, and residents about benefits, uses, and challenges.**

Semi-structured interviews will be conducted to capture experiential knowledge, usage patterns, perceived benefits, and barriers related to BGI at the community and governance level.

8. **To develop a strategic planning framework to help Indian cities use BGI to improve social wellbeing.**

Insights from the conceptual review, policy analysis, spatial mapping, and interviews will be synthesised to propose a context-specific planning framework linking BGI and social wellbeing for Indian cities.

1.8 Scope

1. Indian Class 1 Cities (Population ≥ 100,000). Specific case study will be selected from this category.
2. Planning of Blue-Green Infrastructure (including types like parks, water bodies, street trees, SuDS elements, etc.) with an explicit emphasis on enhancing multiple dimensions of Social Wellbeing (mental health, physical activity, social cohesion, safety, sense of place).
3. A strategic planning framework and guidelines, rather than detailed site-specific designs.

1.9 Limitations

1. Findings from specific case studies may not be fully generalizable to all Class 1 cities due to unique local contexts.
2. Access to detailed, disaggregated spatial or socioeconomic data at the neighborhood level within Indian cities can be challenging.
3. Establishing direct causal links between BGI interventions and specific social wellbeing outcomes is complex and often beyond the scope of planning research; the study will focus on associations, perceptions, and planning processes.
4. Time and resources may limit the number of case studies or the scale of primary data collection (e.g., number of interviews/surveys).

2. LITERATURE REVIEW

Table 1: Focus,Key Findings,Research Gaps Found In selected Literatures Source: Complied By Author

Author(s)	Year	Paper Title	Country/Context	BGI Type / Theme	Social Outcomes / Focus	Key Findings	Research Gaps / Limitations
Zhao, W.	2025	Smart city technologies for sustainable urban planning: Evidence and equity lessons from Shenzhen	China	Smart City / BGI Integration	Urban equity, sustainability planning	Integrating smart technologies with BGI enhances sustainability and spatial equity	Limited long-term social impact data and transferability to other city contexts.
Pedersen Zari, M. et al.	2025	Indigenous knowledge driven nature-based solutions: Findings from an international design competition	Global	NBS / Indigenous Frameworks	Equity, decolonial planning	Indigenous knowledge can guide inclusive NBS design and strengthen social cohesion.	Competition-based outputs lack field validation and measurable social outcomes.
Thorsson, S. et al.	2025	A framework for integrated assessment of blue-green infrastructure	Sweden	Blue-Green Infrastructure	Integrated climate and social benefits	Framework links BGI interventions to climate adaptation, social benefits and costs.	Needs stakeholder validation and testing across socio-economic contexts
Bai, Y.; Xing, Y.	2025	Harnessing green infrastructure for urban heat island mitigation	China	Green Infrastructure	Climate resilience, wellbeing	GI reduces urban heat island effects and improves thermal comfort	Limited assessment of social perceptions and economic feasibility.
Adams, C.; Moglia, M.; Frantzeskaki, N.	2024	Design principles for mainstreaming of nature-based solutions in cities	Global	Nature-Based Solutions	Mainstreaming and governance	Outlines governance and institutional principles to mainstream NBS in cities.	conceptual; requires empirical pilots to measure social impacts.

Cooper, C.; Cunningham, N.; Bracken, L.	2023	Exploring different framings of NBS: Governance and quality of life outcomes	UK / Europe	NBS Governance	Citizen participation, governance	Governance framing shapes NBS outcomes and public perception. Inclusive governance ensures equitable access.	Few studies link governance models with actual wellbeing gains.
Bush, J.; Doyon, A.	2019	Building urban resilience with nature-based solutions: How can urban planning contribute?	Global	Urban Planning / NBS	Urban resilience, adaptation	Highlights planning's role in integrating NBS for resilience and social wellbeing.	Needs long-term data on planning-led NBS impacts.
Baró, F. et al.	2019	Under one canopy? Distributional environmental justice implications of street tree benefits in Barcelona	Spain	Urban Forestry / Justice	Equity in ecosystem benefits	Street tree benefits are unevenly distributed; poorer areas gain less.	Lacks participatory and equity-focused planning analysis.
Wendling, L.A. et al.	2018	Benchmarking NBS and smart city schemes against SDG indicators	Europe	Smart City / NBS Assessment	SDG-linked metrics	Compares NBS and smart city frameworks with SDG goals, showing overlap in climate, health, and inclusivity metrics.	Limited social impact validation within SDG-linked urban projects.
Starkey, E. et al.	2025	Maximising urban resilience using SuDS: Community-led water management	UK	Sustainable Drainage Systems	Community participation	Promotes community-driven SuDS as cost-effective BGI for flood resilience and civic engagement.	Few case studies evaluate long-term social outcomes of participation.

Conti, M.E. et al.	2021	Fostering sustainable cities through resilience thinking: The role of nature-based solutions	Italy	NBS / Urban Resilience	Resilience-based planning	Integrates resilience thinking with NBS, stressing multifunctional urban design for sustainability.	Empirical validation of resilience–wellbeing link remains limited.
Rayan, M.; Gruehn, D.; Khayyam, U.	2022	Planning for Sustainable Green Urbanism: Community-Led Perspective	Pakistan	Green Infrastructure	Community engagement, wellbeing	Community-led approaches strengthen green infrastructure planning and local ownership.	Limited cross-city evidence on scalability and governance support
Das, M.; Das, A.	2026	Use and perception of cultural ecosystem services from green spaces: Kolkata Megacity Region	India	Urban Green Space	Cultural ecosystem services	Highlights how cultural and recreational ecosystem services improve wellbeing in dense urban areas.	Lacks longitudinal data on social and mental health benefits.
Gupta, D.; Das, S.	2025	Assessing the value of Yamuna Biodiversity Park in Delhi: A hedonic price approach	India	Urban Biodiversity / Green Space	Economic valuation, wellbeing	Quantifies economic value of urban biodiversity through property price analysis.	Excludes non-economic wellbeing indicators like cultural or social value.
Thakur, A.	2025	Sustainable urban policy in hill cities: Shimla case study	India	Urban Regeneration / Policy	Hill urbanism, regeneration	Shows how land-use planning and ecosystem-based policy improve hill city resilience.	Limited integration of BGI in slope and drainage management.

Singh, A.; P, V.	2023	Stakeholder Perceptions on Barriers to Implementing Green Roofs in Urban India: Delhi Case Study	India	Green Roofs / NBS	Stakeholder perception	Identifies cost, awareness, and policy gaps as key barriers to green roof adoption.	Few quantitative studies link policy incentives with adoption rates.
Sanyal, J. et al.	2023	Challenges and opportunities for implementing green infrastructure for flood management: Mumbai case study	India	Flood Management / GI	Urban flood resilience	Highlights BGI's potential to mitigate flooding and improve livability in dense urban areas.	Implementation hindered by governance fragmentation and data gaps.
Murthy, A.; S, R.	2023	Assessing the social equity of urban green infrastructure: Chennai case study	India	Urban Green Infrastructure	Social equity, accessibility	Reveals unequal access to green spaces across income groups; emphasizes social justice in GI planning.	Lacks participatory mapping and perception-based evidence.
P, S.; K, S.	2024	Urban Green Space Equity in India: A Systematic Review	India	Urban Green Space	Policy and planning approaches	Synthesizes national evidence on green space inequality and planning inefficiencies.	Few empirical assessments linking equity with health and wellbeing outcomes.
Kadam, A.; Sharma, R.	2024	Sustainable Urban Planning in India: Smart City Policies and Green Governance	India	Smart City / Green Governance	Policy integration	Reviews smart city projects showing weak integration of green governance and ecological targets.	Insufficient coordination between policy, design, and citizen participation.

Ali, M.J. et al.	2025	UGS accessibility, utilization and health: Kolkata Metropolitan Context	India	Urban Green Space	Accessibility, health	Demonstrates that accessible and well-distributed green spaces improve physical and mental health outcomes.	Lacks behavioral data on frequency and duration of park use.
Waghmare, S. et al.	2024	Revitalizing urban landscapes: Green space rejuvenation in Indian cities	India	Urban Green Space	Social cohesion, recreation	Highlights the social and ecological benefits of rejuvenating degraded green spaces through participatory planning.	Limited long-term evaluation of social inclusion impacts.
Kumar, S. et al.	2023	Linking remotely sensed urban green space with wellbeing indicators	India	Urban Green Space	Equity, access, wellbeing	Uses satellite data to correlate green cover with neighborhood wellbeing and air quality.	Needs finer-scale socioeconomic data for stronger causal analysis.
R.C.	2019	Creating urban green spaces in educational institutions: Implications for wellbeing	India	Institutional Green Space	Livability, heat reduction	Shows that on-campus green spaces enhance student wellbeing, concentration, and social interaction.	Narrow focus on university settings; broader urban implications underexplored.
-	2024	Residents' perception towards ecosystem services of urban green spaces in India	India	Urban Green Infrastructure	Perception and satisfaction	Residents value recreation, air quality, and aesthetic benefits most among ecosystem services.	Perception data not linked to demographic or spatial variations.

-	2024	Role of urban green spaces and water access in city livability	India	Urban Blue-Green Infrastructure	Livability, access	Combined green and blue spaces enhance comfort, recreation, and psychological wellbeing.	Limited exploration of socioeconomic disparities in access.
-	2022	Geospatial analysis of urban green space distribution and equity in Indian cities	India	Urban Green Space	Equity, spatial analysis	Reveals spatial inequality in green cover among Indian Class 1 cities.	Requires integration of social indicators with spatial data.
Lubaina, S.; Asifa, I.; Agha, S.A.	2025	Sponge city as a nature-based solution: Insights from Karachi, Pakistan	Pakistan	Sponge City / Urban Resilience	Stakeholder engagement	Stakeholders recognize sponge city potential for urban resilience and flood control.	Implementation barriers include weak governance and limited funding.
Saqib, A.; Khan, M.S.U.; Rana, I.A.	2024	Bridging nature and urbanity through green roof resilience framework	Pakistan	Green Roofs / NBS	Urban resilience framework	Reviews green roofs as multifunctional infrastructure improving resilience and urban biodiversity.	Lacks quantitative data on user wellbeing and cost efficiency.
T, J.; M, P.	2023	Mainstreaming urban green infrastructure in Global South cities: Learnings from South Africa and India	India / South Africa	Urban Green Infrastructure	Framework development	Compares policy integration of GI, showing governance and finance as key enabling factors.	Limited post-implementation assessment of social outcomes.

Nagargoje, S.V.; Patil, S.G.	2025	Comparative analysis of global urban resilience frameworks: Pathways for India	India	Urban Resilience / Frameworks	Resilience patterns, planning	Maps resilience frameworks globally and identifies policy gaps in Indian adaptation planning.	Needs localized indicators for social resilience measurement.
Almheiri, A. et al.	2024	Climate change hazards and the resilience of coastal cities in GCC countries	Gulf Region	Coastal Resilience / NBS	Climate adaptation	Reviews climate risks and highlights BGI as vital for flood and heat adaptation.	Few case studies assess social readiness and policy enforcement.
Gharbi, D. et al.	2023	Allergenic tree pollen as a public health risk in Johannesburg and Cape Town	South Africa	Urban Forestry / Health	Public health and ecosystem services	Identifies urban tree pollen as a major health risk, highlighting the need for allergen-sensitive urban greening.	Lacks social inclusion in planning allergen-free species selection
Santo-Tomás Muro, R. et al.	2020	Green infrastructures in the peri-urban landscape: Well-being perception	Spain	Peri-urban Green Infrastructure	Wellbeing, perception	Residents associate peri-urban green areas with relaxation and social interaction.	Limited demographic diversity and spatial sampling in perception data.
Apud, A. et al.	2020	Suitability analysis and planning of green infrastructure in Montevideo	Uruguay	Green Infrastructure	Planning suitability	GIS-based model identifies optimal sites for multifunctional GI integrating ecology and social use.	Model lacks social validation through participatory mapping.

Zhou, W. et al.	2021	Urban tree canopy cooling effects in socially vulnerable communities in the US	USA	Urban Forestry / Equity	Cooling, vulnerability	Demonstrates stronger cooling benefits in low-income areas, reducing heat exposure inequality	Does not assess long-term equity outcomes of urban forestry programs.
Dantas, G. et al.	2023	Fostering urban cohesion: Morphological adaptations in Budapest	Hungary	Urban Morphology / Design	Social cohesion	Examines how adaptive design and mixed-use morphology enhance social interaction and cohesion.	Limited quantitative link between spatial form and wellbeing.
Kumar, P. et al.	2024	Planning, implementation, and governance of NBS for urban sustainability in Global South	Global South	NBS Governance	Implementation gaps	Reviews NBS governance challenges in developing cities; stresses institutional capacity and policy coherence.	Lacks region-specific social performance indicators.
Elsharqawy, H.R. et al.	2022	Evolutionary urban resilience: Multifunctional flood framework	Egypt	Urban Resilience / Flood Management	Integrated adaptation	Proposes adaptive flood management combining BGI and social learning for resilient urban systems.	Few applications tested in data-scarce or informal urban contexts.

Thorsson, S. et al.	2025	Decision support for BGI: Social and cost trade-offs	Sweden	Blue-Green Infrastructure	Cost-benefit and social value	Develops a decision model linking climate adaptation benefits with social outcomes and maintenance costs.	Needs user-centric data to refine social benefit valuation.

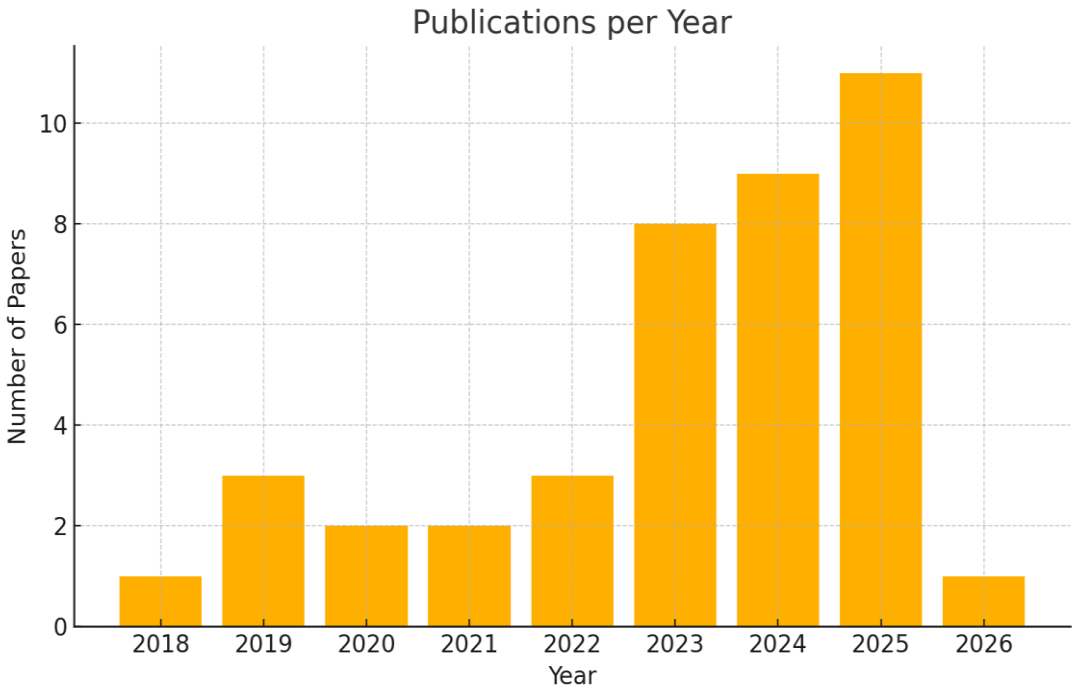


Figure 4: Publications per Year for selected Literature *Source: Author*

In past three years, we see more and more literature being published both in Global Level, South Asian level as well as Indian level (fig. 4).

2.1 Blue–Green Infrastructure Typologies and Their Social Outcomes

The literature (Table 1) has been organized by key themes, including green infrastructure, blue-green systems, urban green spaces, green roofs, nature-based solutions, and planning and governance frameworks. These themes reflect different ways in which cities integrate natural systems into urban planning to improve resilience, environmental quality, and social well-being.

2.1.1 Green Infrastructure

Green Infrastructure (GI) refers to networks of natural and semi-natural elements-parks, green buffer, green corridors, and wetland systems-designed to deliver ecosystem services within cities. Studies show GI consistently reduces urban heat, improves air quality, and enhances recreational opportunities; it also provides mental-health benefits and supports social cohesion when accessible and well-maintained. Typical methods in the literature are spatial analysis (remote sensing, GIS), field surveys of users, and scenario or modelling approaches for ecosystem services. Key social outcomes reported include improved thermal comfort, increased physical activity, and enhanced social interaction, but benefits are unevenly distributed across socio-economic groups.

Common gaps are: limited longitudinal evidence of wellbeing outcomes, insufficient integration of participatory assessment, and weak analysis of maintenance and governance costs. For Class-1 cities, GI planning needs to prioritise equitable distribution (especially in high-density neighbourhoods), embed community stewardship models, and pair spatial targeting with social outreach. Future research should use mixed-methods-combining high-resolution spatial data with household surveys-to measure both ecological and social returns over time.

2.1.2 BGI & Water-Sensitive Design (BGI / Sponge City / SuDS)

Blue–Green Infrastructure (BGI) and water-sensitive approaches (Sponge City, SuDS) combine water management with green spaces to reduce flood risk, recharge groundwater, and create multifunctional urban amenities. Evidence highlights their effectiveness in attenuating floods, improving water quality, and creating co-benefits such as public open space and biodiversity gains. Evaluations commonly use hydrological modelling, performance indicators, and case-based assessments; a growing subset incorporates social indicators (perception, health co-benefits). Social outcomes include

increased sense of safety in flood-prone areas, new recreational spaces, and livelihood opportunities where water reuse is integrated. Major research gaps are institutional fragmentation, long-term maintenance financing, and limited participatory implementation studies-especially in rapidly urbanising Global South contexts.

For Class-1 Indian cities, BGI offers an opportunity to integrate stormwater management with urban greening, but success requires cross-departmental governance, clear maintenance responsibilities, and community involvement in design and upkeep. Research should focus on cost–benefit assessments that explicitly quantify social and health co-benefits, and on piloting replicable governance models.

2.1.3 Urban Green Spaces, Parks, and Street Trees (UGS)

Urban green spaces, such as parks, recreational spaces and pocket gardens, as well as street-tree networks, provide city residents with direct daily contact with nature. The literature shows strong associations between access to UGS and physical and mental health, social interaction, and thermal comfort-particularly valuable in dense urban environments. Research methods range from accessibility and equity mapping to household surveys and hedonic valuation studies. The most commonly reported social outcomes are increased recreational use, improved mental well-being, and localized cooling. However, distributional inequities are widespread. Research gaps include the social impacts of iterative management, such as how quality and safety affect use; allergen and public health trade-offs for tree planting; and gendered or age-specific access barriers. In Class-1 Indian cities, urban green space (UGS) planning should combine spatial equity targets with investments in quality lighting and amenities, as well as safe access routes. Policymakers should adopt participatory maintenance programs and species selection strategies that balance cooling benefits with health considerations. Researchers should measure use patterns and well-being outcomes over time.

2.1.4 Green Roofs and Vertical Greening

Space-efficient green infrastructure (GI) solutions that add greenery, lower runoff, and insulate highly developed areas include vertical gardens and green roofs. Reviews and case studies demonstrate the benefits of stormwater retention, thermal regulation, and aesthetic enhancement. Numerous studies also highlight the potential social benefits of green roofs and vertical greening in residential and institutional settings. However,

recurring themes include adoption barriers such as costs, structural constraints, and policy incentives. The evidence of social outcomes, such as improved occupant comfort and well-being, is often limited to small-scale or campus contexts, and there are few studies that have been carried out in large cities. The research gaps include long-term maintenance studies, large-scale cost-effectiveness analyses, and equity implications. In Class-1 Indian cities with little ground area, green roofs have potential. Public buildings, educational institutions, and affordable housing could be priority targets. Scaling up will require research linking rooftop greening to measurable social outcomes in diverse socioeconomic contexts, technical retrofit guidelines, and subsidy programs.

2.1.5 Nature-Based Solutions (NBS) as Integrated Interventions

Nature-based solutions (NBS) are broad, multisectoral approaches that use natural processes to adapt to climate change and promote health and social resilience. The literature presents NBS as a means of incorporating ecological functions into urban planning through multifunctional parks, urban wetlands, and hybrid engineered–natural systems. Key social benefits include improved well-being, cultural ecosystem services, and strengthened community stewardship when projects are co-designed. Methodologically, NBS studies combine policy reviews, comparative frameworks, and pilot evaluations. However, major gaps remain in the translation from concept to policy, the development of standardized metrics for social outcomes, and the evaluation of heterogeneous institutional contexts. In Indian Class-1 cities, promoting NBS requires integrating ecological goals into zoning and development codes, aligning financial instruments, and supporting the integration of local knowledge (including indigenous practices). Researchers should prioritize standardized social impact indicators and cross-case studies documenting policy pathways and implementation lessons.

2.1.6 Planning, Governance, and Smart City Integration

This cluster covers the frameworks and tools that link BGI/NBS with planning processes, governance structures, and smart city technologies. Studies show that effective and equitable implementation depends on governance design, stakeholder participation, and data-driven monitoring using smart sensors and GIS. Social outcomes depend heavily on governance choices; participatory models tend to deliver higher local acceptance and sustained benefits. Common methods include benchmarking, policy analysis, and

decision support frameworks. However, there are persistent gaps in the literature: limited empirical evidence on long-term governance reforms, difficulty integrating informal settlements into planning systems, and uneven data availability for monitoring social indicators. For Class-1 Indian cities (fig. 5), integrating BGI into municipal planning requires institutional mandates, capacity building, and interoperable data platforms. Practical recommendations include establishing cross-sector coordination units, incorporating equity targets into BGI projects, and adopting straightforward, locally relevant monitoring indicators that capture social well-being as well as ecological performance.

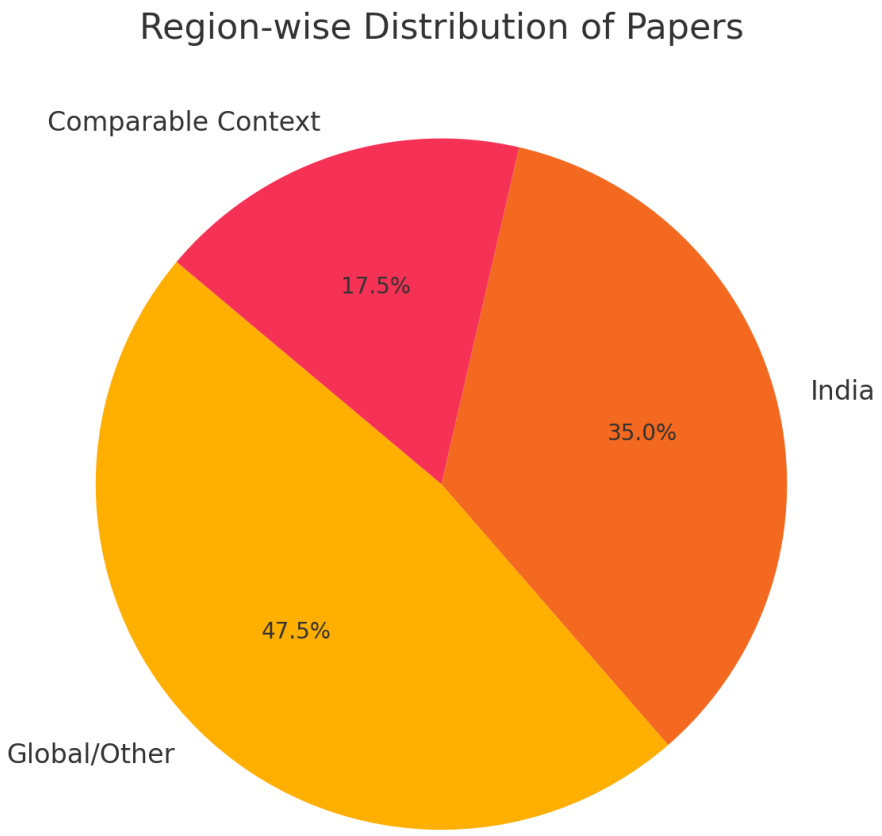


Figure 5: Region Wise Distribution of Papers *Source: Author*

2.2 Policy and Institutional Framework for Blue–Green Infrastructure (BGI) in India

Blue–Green Infrastructure (BGI) is gaining recognition in India through multiple national missions, policy frameworks, and emerging state-level strategies. While there is currently no single, dedicated national policy for BGI, its principles are integrated across various programs related to urban sustainability, climate resilience, water management, and green cover enhancement. The following tables summarise the major national (Table 2) and sub-national (state and city-level) (Table 3) policy instruments that either directly support or indirectly facilitate the implementation of BGI in India.

Table 2: National Level Policies And Frameworks *Source: Compiled by the author*

Policy / Mission	Year	Nodal Ministry / Agency	Relevance to BGI	Remarks
National Mission on Sustainable Habitat (NMSH)	2021 (Revised)	Ministry of Housing and Urban Affairs (MoHUA)	Promotes sustainable urban planning through themes such as *"Urban Planning, Green Cover and Biodiversity"*, aligning with BGI principles of climate resilience and ecological design.	Provides a broad national framework to integrate BGI into city-level planning and development strategies.
National Urban Policy Framework (NUPF)	2018	MoHUA / National Institute of Urban Affairs (NIUA)	Advocates for compact, resource-efficient, and environmentally sustainable cities, indirectly supporting BGI adoption.	Serves as a guiding framework linking BGI to sustainable urbanisation goals.
Smart Cities Mission (SCM)	2015 – ongoing	MoHUA	Encourages projects focused on *riverfront rejuvenation, lake restoration, open spaces, and green corridors*-all of which are core BGI components.	Demonstrates operational examples of BGI through city-level smart initiatives.
Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0)	2021	MoHUA	Focuses on *rejuvenation of water bodies, creation of urban parks, and water-sensitive planning*.	Provides direct funding support for blue and green infrastructure initiatives.

Wetlands (Conservation and Management) Rules	2017	Ministry of Environment, Forest and Climate Change (MoEFCC)	Establishes *State Wetland Authorities* responsible for wetland protection, aligning with the "blue" aspect of BGI.	Institutionalises wetland management across states, critical for blue infrastructure conservation.
National Mission for Clean Ganga (NMCG)	2014 – ongoing	Ministry of Jal Shakti	Emphasises *riverfront development, floodplain rejuvenation, and urban wetland restoration*.	Serves as a model for integrating ecological restoration and water management in urban areas.
Urban Greening Guidelines (TCPO)	2014	Town and Country Planning Organisation (TCPO), MoHUA	Provides design and management frameworks for *urban green spaces and tree cover*.	Offers technical guidance for states and cities implementing BGI elements.

At the national scale (Table 2), India's approach to Blue–Green Infrastructure emerges from a **convergence of existing urban, environmental, and water policies** rather than a standalone strategy. Missions such as **NMSH, NUPF, Smart Cities, and AMRUT 2.0** collectively advance BGI principles by promoting **water-sensitive, green, and climate-resilient planning**. However, the absence of a unified framework results in fragmented implementation and inconsistent monitoring across cities. Strengthening inter-ministerial coordination and integrating BGI indicators within mission performance frameworks can help bridge this gap.

2.2.1 Sub-National and City-Level Policy Instruments for BGI Implementation

While national missions set the direction, **state and city-level policies** (Table 3) play a crucial role in translating BGI concepts into on-ground actions. Several states and urban local bodies have initiated measures that integrate blue and green systems within their **planning, water management, and biodiversity strategies**. These instruments provide the most direct policy and institutional pathways for embedding BGI within local urban development agendas.

Table 3: State/City Level Policies/ Programs *Source: Compiled by the author*

Policy / Instrument	Level	State / City	Relevance to BGI	Remarks
Karnataka State Water Policy (2022)	State	Karnataka	Promotes conjunctive use of surface and groundwater resources, waterbody rejuvenation, and sustainable watershed management.	Strengthens the "blue" component of BGI through integrated water policy.
Bengaluru Urban Forestry and Tree Management Manual (2025)	City	Bengaluru, Karnataka	Provides technical guidance for expanding and maintaining urban tree cover.	Operationalises the "green" component of BGI at city scale.
East Kolkata Wetlands (Management Act and Plan 2021–2026)	State–City	West Bengal / Kolkata	Legally protects urban wetlands and integrates waste treatment with ecosystem restoration.	Serves as a national benchmark for blue-green governance.
Master Plan for Delhi 2041 (MPD-2041)	City	Delhi (NCT)	Incorporates provisions for protecting the Yamuna River, ridge zones, and urban greens.	Demonstrates integration of BGI principles within a statutory Master Plan.
State Wetland Authorities (under 2017 Rules)	State	All States	Mandated to identify, notify, and manage wetlands across the state.	Provides institutional structure for blue infrastructure management.
Pune River Rejuvenation Projects (Mula–Mutha and Ramnadi)	City	Maharashtra / Pune	Combines flood control, ecological restoration, and riverside public spaces.	Illustrates project-based BGI interventions under AMRUT and Smart Cities.
Sabarmati Riverfront Development Corporation Ltd. (SRFDCL)	City–SPV	Gujarat / Ahmedabad	Hybrid model combining flood management, green public space creation, and river ecology enhancement.	Serves as an early large-scale BGI project in India, though with noted social equity issues.

Kerala State Biodiversity Strategy and Action Plan (2022–2032)	State	Kerala	Promotes urban biodiversity, wetland protection, and coastal ecosystem restoration.	Integrates BGI within biodiversity planning and climate resilience agendas.
Tamil Nadu Green Mission and Urban Forestry Initiative (2022)	State	Tamil Nadu	Aims to increase tree cover and restore urban ecosystems under AMRUT 2.0 and state schemes.	Provides model for state-led BGI scaling with climate co-benefits.
City-Level Wetland and Lake Restoration Guidelines (various ULBs)	City	Maharashtra, Tamil Nadu, Karnataka	Focus on fencing, rejuvenation, and monitoring of urban lakes and ponds.	Reflect widespread adoption of BGI-oriented actions through municipal circulars.

At the sub-national level, BGI-related initiatives are **diffused across sectoral policies**, including **state water policies, biodiversity plans, forestry manuals, and urban wetland restoration programs**. These instruments reveal that BGI principles are being **implemented indirectly** through existing governance mechanisms rather than as a formalised policy framework. However, the absence of a **cohesive, multi-sectoral strategy** limits the potential for scaling and institutional coordination. Developing an integrated **State Urban BGI Policy Framework**, supported by financial mechanisms and interdepartmental governance, could help translate these fragmented efforts into structured, outcome-driven interventions.

2.3 Problem Formulation

Problem Statement

India's Class 1 cities are facing mounting environmental and social pressures due to rapid and frequently unplanned urbanization. The intensifying impacts of climate change, such as recurrent flooding, extreme rainfall, and urban heat islands, are exposing the limitations of conventional gray infrastructure systems. These systems are costly, fragmented, and poorly adapted to complex urban challenges. Despite growing awareness, urban planning in India continues to operate in silos with limited coordination between departments addressing water management, open spaces, and community well-being.

Blue-green infrastructure (BGI) offers an integrated, nature-based alternative capable of simultaneously addressing environmental and social challenges. However, BGI planning in India remains primarily focused on technical and ecological performance, while its social benefits-such as enhanced well-being, inclusivity, and equity-receive little systematic attention. The absence of context-specific frameworks, inadequate policy guidance, and insufficient consideration of local social needs restricts the effective implementation of BGI in Indian cities.

The gap between BGI's potential and its practical realization in improving social well-being is a critical problem for urban planners and policymakers.

Without approaches that systematically integrate community needs, social equity, and environmental resilience, BGI's potential as a transformative planning tool for sustainable, livable Class 1 cities remains largely unrealized.

2.3.1 Key Reasons for the Study

Rapid Urbanization and Climate Vulnerability

India's Class 1 cities are expanding at an unprecedented rate, leading to environmental degradation, frequent urban flooding, and rising heat stress. Conventional grey infrastructure is proving insufficient to cope with these complex and interlinked challenges, emphasizing the need for integrated, adaptive, and sustainable planning solutions.

Growing Importance of Blue–Green Infrastructure (BGI)

Globally, BGI has emerged as a multifunctional approach that integrates water management, ecological restoration, and urban livability. Yet, in India, its implementation is still limited, fragmented, and heavily oriented toward technical objectives rather than broader social outcomes.

Neglect of Social Wellbeing in Planning Frameworks

Current urban planning practices often overlook the social and psychological dimensions of sustainability. While evidence shows that access to blue and green spaces improves mental health, social interaction, and community cohesion, these benefits are rarely prioritized or measured in Indian planning contexts.

Lack of Context-Specific Frameworks for Indian Cities

Most available BGI models and policies are developed for Western or temperate contexts. There is a pressing need to reinterpret and adapt these approaches for India's dense, diverse, and socio-economically stratified cities, ensuring that benefits are equitably distributed across communities.

Bridging Research and Policy Gaps

Despite an increasing number of studies on BGI and nature-based solutions, systematic reviews focusing on the social wellbeing dimension within Indian urban environments remain scarce. This study addresses that gap by synthesizing evidence and identifying context-relevant planning pathways for Class 1 cities.

3. METHODOLOGY

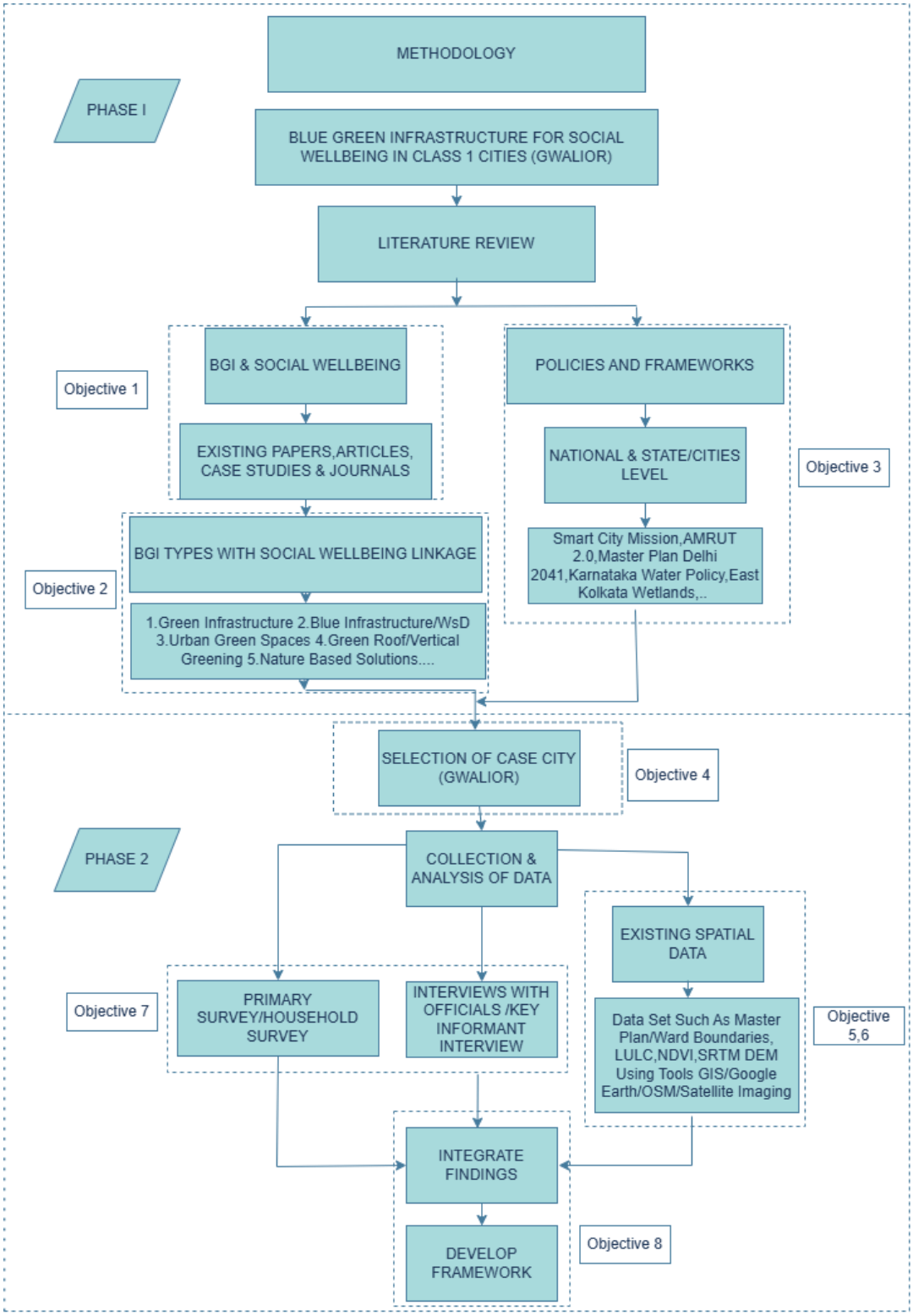


Figure 6 : Methodology flowchart *Source: Author*

Table 4: Methodologies/Tools Used In literatures *Source: Compiled By Author*

Author(s)	**Year**	**Paper Title**	**Inferred Methodology / Tools**
Zhao, W.	2025	Smart city technologies for sustainable urban planning: Evidence and equity lessons from Shenzhen	Policy/Governance Analysis / Case Study / Cost-Benefit Analysis
Pedersen Zari, M. et al.	2025	Indigenous knowledge driven nature-based solutions: Findings from an international design competition	Design Competition Analysis / Qualitative Analysis
Thorsson, S. et al.	2025	A framework for integrated assessment of blue-green infrastructure	Framework/Model Development / Cost-Benefit Analysis
Bai, Y.; Xing, Y.	2025	Harnessing green infrastructure for urban heat island mitigation	GIS / Spatial Analysis / Quantitative Modeling
Adams, C.; Moglia, M.; Frantzeskaki, N.	2024	Design principles for mainstreaming of nature-based solutions in cities	Policy/Governance Analysis / Framework/Model Development
Cooper, C.; Cunningham, N.; Bracken, L.	2023	Exploring different framings of NBS: Governance and quality of life outcomes	Policy/Governance Analysis
Bush, J.; Doyon, A.	2019	Building urban resilience with nature-based solutions: How can urban planning contribute?	Policy/Governance Analysis / Literature Review
Baró, F. et al.	2019	Under one canopy? Distributional environmental justice implications of street tree benefits in Barcelona	GIS / Spatial Analysis / Social Equity Analysis
Wendling, L.A. et al.	2018	Benchmarking NBS and smart city schemes against SDG indicators	Framework/Model Development / Indicator Analysis

Starkey, E. et al.	2025	Maximising urban resilience using SuDS: Community-led water management	Literature Review / Policy Analysis / Community-Led Framework
Conti, M.E. et al.	2021	Fostering sustainable cities through resilience thinking: The role of nature-based solutions	Literature Review / Framework/Model Development
Rayan, M.; Gruehn, D.; Khayyam, U.	2022	Planning for Sustainable Green Urbanism: Community-Led Perspective	Community Engagement / Interviews / Surveys / Stakeholder Analysis
Das, M.; Das, A.	2026	Use and perception of cultural ecosystem services from green spaces: Kolkata Megacity Region	**Case Study (India)** / Interviews / Surveys
Gupta, D.; Das, S.	2025	Assessing the value of Yamuna Biodiversity Park in Delhi: A hedonic price approach	**Case Study (India)** / Hedonic Pricing Model (Finance)
Thakur, A.	2025	Sustainable urban policy in hill cities: Shimla case study	**Case Study (India)** / Policy/Governance Analysis
Singh, A.; P, V.	2023	Stakeholder Perceptions on Barriers to Implementing Green Roofs in Urban India: Delhi Case Study	**Case Study (India)** / Interviews / Surveys / Stakeholder Analysis
Sanyal, J. et al.	2023	Challenges and opportunities for implementing green infrastructure for flood management: Mumbai case study	**Case Study (India)** / Barrier Analysis
Murthy, A.; S, R.	2023	Assessing the social equity of urban green infrastructure: Chennai case study	**Case Study (India)** / GIS / Spatial Analysis / Social Equity Analysis
P, S.; K, S.	2024	Urban Green Space Equity in India: A Systematic Review	**Systematic Literature Review (India)** / Policy/Governance Analysis
Kadam, A.; Sharma, R.	2024	Sustainable Urban Planning in India: Smart City Policies and Green Governance	**Review (India)** / Policy/Governance Analysis

Ali, M.J. et al.	2025	UGS accessibility, utilization and health: Kolkata Metropolitan Context	**Case Study (India)** / GIS / Spatial Analysis
Waghmare, S. et al.	2024	Revitalizing urban landscapes: Green space rejuvenation in Indian cities	**Review (India)** / General Analysis
Kumar, S. et al.	2023	Linking remotely sensed urban green space with wellbeing indicators	GIS / Spatial Analysis / Quantitative Modeling
R.C.	2019	Creating urban green spaces in educational institutions: Implications for wellbeing	Case Study / General Analysis
-	2024	Residents' perception towards ecosystem services of urban green spaces in India	**(India)** / Interviews / Surveys / Stakeholder Analysis
-	2024	Role of urban green spaces and water access in city livability	General Analysis / Review
-	2022	Geospatial analysis of urban green space distribution and equity in Indian cities	**(India)** / GIS / Spatial Analysis / Social Equity Analysis
Lubaina, S.; Asifa, I.; Agha, S.A.	2025	Sponge city as a nature-based solution: Insights from Karachi, Pakistan	**Case Study (Comparable Context)** / Interviews / Surveys / Stakeholder Analysis
Saqib, A.; Khan, M.S.U.; Rana, I.A.	2024	Bridging nature and urbanity through green roof resilience framework	Framework/Model Development
T, J.; M, P.	2023	Mainstreaming urban green infrastructure in Global South cities: Learnings from South Africa and India	**(India)** / Framework/Model Development / Policy Analysis
Nagargoje, S.V.; Patil, S.G.	2025	Comparative analysis of global urban resilience frameworks: Pathways for India	**(India)** / Framework/Model Development / Literature Review
Almheiri, A. et al.	2024	Climate change hazards and the resilience of coastal cities in GCC countries	**(Comparable Context)** / Systematic Literature Review

Gharbi, D. et al.	2023	Allergenic tree pollen as a public health risk in Johannesburg and Cape Town	**(Comparable Context)** / General Analysis
Santo-Tomás Muro, R. et al.	2020	Green infrastructures in the peri-urban landscape: Well-being perception	Interviews / Surveys / Stakeholder Analysis
Apud, A. et al.	2020	Suitability analysis and planning of green infrastructure in Montevideo	**(Comparable Context)** / GIS / Spatial Analysis
Zhou, W. et al.	2021	Urban tree canopy cooling effects in socially vulnerable communities in the US	GIS / Spatial Analysis / Social Equity Analysis
Dantas, G. et al.	2023	Fostering urban cohesion: Morphological adaptations in Budapest	GIS / Spatial Analysis / Social Equity Analysis
Kumar, P. et al.	2024	Planning, implementation, and governance of NBS for urban sustainability in Global South	**(Comparable Context)** / Systematic Literature Review / Policy/Governance Analysis
Elsharqawy, H.R. et al.	2022	Evolutionary urban resilience: Multifunctional flood framework	**(Comparable Context - Egypt)** / Framework/Model Development
Thorsson, S. et al.	2025	Decision support for BGI: Social and cost trade-offs	Framework/Model Development / Cost-Benefit Analysis

3.1 Methods and Tools Used In Existing Papers

The review of national and international research papers (Table 4) on **Blue–Green Infrastructure (BGI)** and social wellbeing revealed that researchers used a variety of methods depending on the focus, scale, and data availability of their studies (fig. 7). Although the approaches differed, most could be grouped under a few main types of methods and tools that together built a clear understanding of how BGI influences urban life and wellbeing.

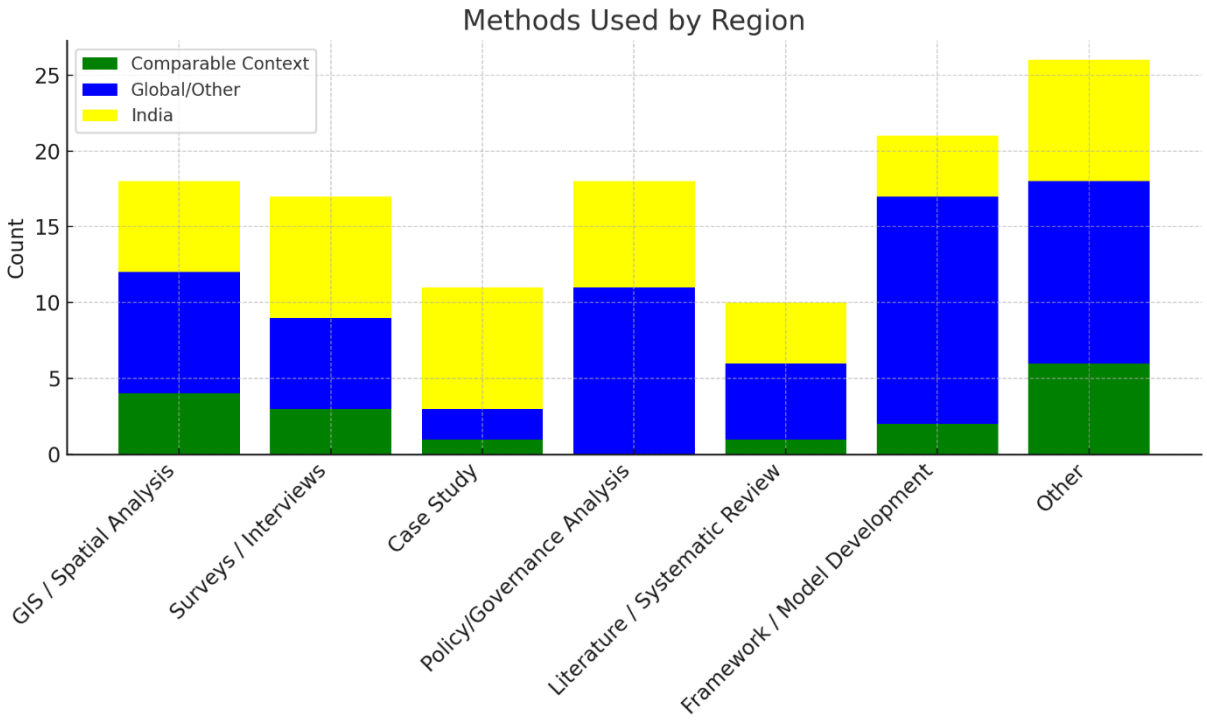


Figure 7: Methods Used By Region For BGI And Social Wellbeing Source:Compilied By Author

3.1.1 Spatial and Quantitative Methods

Many studies used **Geographic Information System (GIS)** and **spatial analysis** to map, measure, and compare green and blue spaces within cities. These tools helped in identifying the location, distribution, and accessibility of parks, lakes, and other natural assets. Some studies also used satellite imagery and remote sensing to assess factors such as **urban heat island reduction, green cover,** or **proximity of BGI to communities**. These spatial methods provided measurable evidence of how physical access to green and blue spaces affects environmental comfort and equity among different social groups.

3.1.2 Policy and Governance Analysis

A considerable number of papers focused on policy review and governance analysis. They examined how planning regulations, government missions, and institutional mechanisms influenced the implementation of BGI. These studies often compared the effectiveness of existing frameworks like the Smart Cities Mission, AMRUT, or the National Urban Policy Framework, and discussed challenges such as coordination gaps, funding, or lack of data. This approach helped in identifying policy enablers and barriers related to embedding BGI into urban development.

3.1.3 Framework and Model Development

Several authors developed conceptual or analytical frameworks to connect BGI with wider goals like climate resilience, health, or social wellbeing. Such studies proposed models to evaluate how ecological systems interact with social systems in urban environments, often using indicator-based approaches or cost–benefit tools to assess performance. These frameworks were useful for designing systematic ways to evaluate and compare cities or projects.

3.1.4 Social Perception and Participatory Methods

Many recent papers, especially from India and the Global South, used **surveys, interviews,** and **stakeholder analysis** to understand how people perceived and used blue–green spaces. These studies explored themes such as sense of safety, inclusivity, recreational use, and psychological benefits. Participatory tools helped highlight that BGI was not just an environmental feature but also a social space that supported wellbeing, cultural value, and community belonging..

3.1.5 Economic and Indicator-Based Approaches

Some studies included **cost–benefit analysis, hedonic pricing,** or **indicator benchmarking** to estimate the economic and social value of BGI. This approach quantified benefits like improved property values, reduced health risks, and enhanced livability, linking BGI more directly with measurable wellbeing outcomes.

It was evident that the most effective research approaches were mixed-methods, combining spatial data, policy review, and social perception analysis. Spatial tools like GIS helped visualise where BGI existed and who had access to it; policy analysis

explained why it was implemented the way it was; and social perception methods showed how people actually experienced its benefits. Together, these methods built a more complete picture of how Blue–Green Infrastructure contributes to social wellbeing, forming the foundation for the methodology adopted in the present study.

3.2 Methods And Tools to be adopted for Case City

Three core methods were selected for this study: **surveys, interviews, and spatial data analysis**. These methods were chosen because they were most effective in capturing both the physical distribution of blue–green infrastructure and the human experiences associated with it, together providing a balanced mix of quantitative and qualitative understanding suited to the context of Indian Class 1 cities, where social data is limited but spatial and policy information is more readily available.

The thesis followed a mixed-methods approach, combining primary and secondary data to explore how BGI contributes to social wellbeing in Gwalior, the selected case city. Surveys and interviews captured residents' and stakeholders' perceptions and lived experiences in relation to blue-green spaces, while spatial analysis helped map and visualise their distribution and identify disparities across wards. This integrated approach ensured that the findings were both evidence-based and people-centred. The detailed application of each method including data sources, sampling, and analytical procedures is presented in Chapters 7 and 8.

3.2.1. Surveys

A structured questionnaire was administered to residents across selected wards of Gwalior, covering the use of blue–green spaces, perceived benefits, and personal experiences connected to wellbeing such as **physical health, recreation, safety, inclusivity, and social interaction**. The responses helped quantify the relationship between access to BGI and aspects of social wellbeing across different population groups, detailed in Chapter 8.

Purpose: To collect first-hand information from users and quantify the relationship between access to BGI and aspects of social wellbeing.

3.2.2. Interviews

Semi-structured interviews were carried out with selected stakeholders, including municipal officials, elected representatives, and residents, to gather deeper insights into the planning, maintenance, and governance aspects of BGI in Gwalior. These discussions complemented the survey results with qualitative perspectives on institutional challenges, local experiences, and aspirations ,detailed in Chapter 8.

Purpose: To complement survey results with qualitative perspectives that explain institutional challenges, local experiences, and success stories from on-ground stakeholders.

3.2.3 Spatial Data Analysis

Spatial data, including land use maps, satellite imagery, and GIS datasets, were used to identify and map existing blue–green infrastructure elements such as parks, lakes, wetlands, open spaces, and green corridors across Gwalior. The analysis focused on the distribution, accessibility, and proximity of these features in relation to residential areas and population density, providing a spatial understanding of where BGI was concentrated and how this related to equity and quality of life ,detailed in Chapter 7.

Purpose: To provide a spatial understanding of where BGI is concentrated, who has access to it, and how this affects equity and quality of life.

4. STUDYING THE CASE EXAMPLES

4.1 Analysis of BGI Case Studies and Their Social Wellbeing Outcomes

Blue–Green Infrastructure (BGI) interventions in India demonstrate varied approaches to integrating ecological restoration, water management, and community wellbeing. Table 5 summarises key desk examples from major Indian cities, highlighting the type of BGI implemented, the social wellbeing benefits observed, and lessons relevant to Class 1 cities. The analysis shows that social outcomes-such as improved recreation, health, livelihood security, and social cohesion-are strongest where communities are engaged and public accessibility is prioritised.

4.1.1 East Kolkata Wetlands



Figure 8: East Kolkata Wetlands *Source:Mapcarta*

The East Kolkata Wetlands (EKW) (fig.8) are one of India's most remarkable examples of integrated blue-green infrastructure. Spanning nearly 12,500 hectares on the eastern outskirts of Kolkata, this Ramsar-listed site operates as a natural wastewater treatment system and supports local livelihoods, biodiversity, and recreation. The wetlands receive

a significant portion of the city's wastewater, which is naturally treated through a network of fishponds, marshes, and canals. This ecological process sustains one of India's largest urban aquaculture systems and provides employment for nearly 100,000 people engaged in fishing, vegetable farming, and related activities.

From a social well-being perspective, the EKW demonstrates how ecological infrastructure can directly support livelihood security, food systems, recreation, and environmental health. The network of water bodies regulates temperature, reduces urban heat, and mitigates flooding during heavy rainfall. The wetlands provide essential economic stability for many households through low-cost, nature-based livelihood opportunities. The landscape also serves as an informal recreational area for the surrounding communities. Open water bodies, green fields, and bird habitats offer opportunities for relaxation and mental well-being.

However, the East Kolkata Wetlands (EKW) face significant developmental pressures, including land conversion, pollution, real estate encroachment, and inadequate management coordination. Despite these challenges, the East Kolkata Wetlands Management Authority plays a critical role in conserving the site through land use regulations, ecological monitoring, and community awareness initiatives. EKW is a globally recognized model of how blue-green systems can support environmental sustainability and human well-being simultaneously, making it an essential reference for Indian Class-1 city planning.

4.1.2 Tholkappia Poonga (Adyar Eco Park), Chennai



Figure 9: Master Plan For Adyar Eco Park *Source: Chennai River Restoration Trust*

Tholkappia Poonga, also known as the Adyar Eco Park (fig.9), is a flagship ecological restoration project located along Adyar Creek in Chennai. The site, once a degraded and heavily polluted estuarine zone, has undergone extensive restoration under the supervision of the Tamil Nadu Forest Department and the Tamil Nadu University Institute of Forestry and Soil Science (TNUIFSL) (fig. 10). The project involved removing invasive species, rehabilitating mangrove ecosystems, restoring natural tidal flows, and establishing pathways for environmental education.



Figure 10: Adyar Eco Park *Source: Chennai River Restoration Trust*

Rather than a recreational park, the park is designed as a biodiversity conservation zone. It features mangrove forests, freshwater wetlands, mudflats, and native plant species that support migratory birds, fish breeding, and ecological stability. This ecological revival has improved air quality, moderated local temperatures, and restored the estuary's hydrological function.

Benefits to social well-being include educational opportunities, nature interpretation trails, guided visits for students, and psychological relief through exposure to nature. Although public access is limited to protect biodiversity, the site remains a living classroom for learning about coastal ecosystems, climate resilience, and environmental stewardship. As a BGI project focused on restoration, Tholkappia Poonga illustrates how cities can reclaim ecologically sensitive zones to enhance resilience and community awareness.

4.1.3 Yamuna Biodiversity Park, Delhi

The Yamuna Biodiversity Park (YBP) (fig.11), developed by the Delhi Development Authority in partnership with the University of Delhi's Center for Environmental Management and Development (CEMDE), is one of India's most successful examples of urban ecological restoration. Spanning more than 450 acres along the Yamuna floodplain, the park consists of restored wetlands, grasslands, forest patches, and water bodies that replicate the region's natural ecosystems.



Figure 11: Yamuna Biodiversity Park *Source: Delhi Biodiversity Foundation*

The site was originally barren and degraded due to flooding, sand mining, and pollution. Through scientific restoration efforts, native species were reintroduced, hydrological functions were restored, and habitat zones were established to support migratory birds and local wildlife. Today, the park plays a significant role in improving microclimatic comfort, reducing urban heat, and enhancing air quality.

The YBP provides multiple social well-being benefits. It serves as an outdoor learning center for environmental studies and hosts thousands of school visits annually. Visitors enjoy walking trails, bird-watching areas, and nature interpretation zones that promote mental relaxation and physical activity. The park also fosters community connection by offering residents a peaceful refuge from the dense urban environment.

4.1.4 Mula–Mutha River Rejuvenation Project, Pune

The Mula–Mutha River Rejuvenation Project (fig.12) represents Pune's most ambitious attempt to integrate Blue–Green Infrastructure into a rapidly urbanizing landscape. Historically, the Mula and Mutha rivers acted as lifelines for the city, providing water, ecological habitat, and cultural value. However, decades of urban growth led to unchecked sewage discharge, encroachment, and severe ecological degradation. In response, Pune Municipal Corporation (PMC), under the Smart Cities Mission, initiated a multi-phase rejuvenation program aimed at improving river health while enhancing social wellbeing.



Figure 12: Mula-Mutha River Project Source: Pune Municipal Corporation

Key components of the project include riverbank stabilization, sewage treatment infrastructure, rejuvenation of riparian vegetation, floodplain restoration, and the creation of publicly accessible walking and cycling corridors. The proposal also includes landscaped parks, biodiversity patches, and recreational nodes along strategic riverfront stretches. The aim is not only to clean the river but to re-establish it as a vibrant public space accessible to diverse communities.

From a social wellbeing perspective, the project offers opportunities for physical activity, recreation, urban cooling, and mental relaxation. Improved walkability and green space access particularly benefit residents who previously lacked public open spaces.

However, concerns have been raised about equity and displacement, especially of informal settlements historically located along the riverbanks. These issues highlight a critical tension between large-scale environmental projects and the need for inclusive planning.

Environmental benefits include improved water quality, restored hydrological flows, and enhanced biodiversity potential. The project also contributes to climate adaptation by reducing flood risks and providing multifunctional landscapes.

The Mula–Mutha case demonstrates both the promise and challenges of implementing BGI at a metropolitan scale. When supported by equitable governance, community engagement, and strong monitoring, such projects can significantly enhance environmental quality and social wellbeing in fast-growing Indian cities.

4.1.5 Sabarmati Riverfront, Ahmedabad

The Sabarmati Riverfront Development (fig.13) in Ahmedabad is one of India's most widely recognized riverfront transformation projects. Undertaken by the Sabarmati Riverfront Development Corporation Ltd. (SRFDCL), the project aimed to reclaim the riverbanks, prevent flooding, and transform the river corridor into an accessible, structured public space. Before redevelopment, the river suffered from pollution, seasonal flooding, and unregulated slum encroachment along its banks. The project repositioned the river as a central urban asset that supports recreation, tourism, and environmental management.



Figure 13: Sabarmati Riverfront *Source: SRFDCL*

It includes continuous promenades, landscaped parks, cultural plazas, ghats, pedestrian bridges, and cycle tracks. Flood protection walls and controlled embankments ensure safety during high monsoon flows. The project improved urban walkability and increased access to public spaces, repositioning Ahmedabad as a model for waterfront regeneration.

Benefits to social well-being include improved recreational opportunities, enhanced pedestrian safety, and accessible open spaces in a city with limited green infrastructure. The promenades offer residents clean, walkable, aesthetically appealing environments that promote physical activity and mental well-being. Cultural and social events hosted along the riverfront further strengthen community engagement.

However, the project has faced criticism for displacing informal settlements, losing riparian ecology, and having hard-engineered embankments. Some scholars argue that, although the project enhances the city's image and public realm, it does not fully embody the principles of ecological BGI because it only partially restores natural riverine systems.

Despite these trade-offs, the Sabarmati Riverfront remains a significant reference point for understanding the relationship between urban design, infrastructure-led renewal, and social outcomes in Indian cities.

Table 5 presents five Indian BGI case studies across varied typologies and governance models. The cases collectively demonstrate that social wellbeing outcomes from BGI are strongest where ecological restoration is paired with inclusive public access, institutional accountability, and sustained maintenance

Table 5: India Case Studies *Source: Compiled by the author*

City / Project	Type of BGI Intervention	Key Social Wellbeing Outcomes	Governance / Implementation Features	Lessons for Class 1 Cities
East Kolkata Wetlands (West Bengal)	Natural wastewater treatment wetlands, aquaculture, agriculture, and flood buffering	• Livelihoods for > 100,000 people • Flood-risk reduction • Community resilience • Accessible open spaces • Food security	Managed by East Kolkata Wetland Management Authority (EKWMA) under statutory protection	Productive BGI can deliver both ecological and social benefits when legally protected and community-based.

Tholkappia Poonga (Adyar Eco Park, Chennai)	Restoration of mangroves and wetlands into a public ecological park and education centre	• Public access to green–blue space • Environmental education • Enhanced recreation and mental health • Micro-climate improvement	Developed by Tamil Nadu Urban Infrastructure Fund with state forest and municipal agencies	Restoration-driven BGI can serve as inclusive public infrastructure if access and maintenance are institutionalised.
Yamuna Biodiversity Park (Delhi)	Floodplain and ridge restoration with wetlands, grasslands, and woodlands	• Nature education • Recreational use • Mental and physical wellbeing • Urban cooling and air-quality benefits	Joint initiative of Delhi Development Authority and CEMDE (Delhi University); part of city's biodiversity network	Biodiversity-based BGI enhances social wellbeing when linked to learning and community programmes.
Mula–Mutha River Rejuvenation (Pune)	River clean-up, bank stabilisation, riparian parks, and promenades under the Smart Cities Mission	• Recreational access • Improved riverfront image • Potential wellbeing through open spaces • Concerns over resettlement and equity	Implemented by Pune Municipal Corporation with AMRUT 2.0 and Smart Cities funding	Large BGI projects must embed social equity and participation to avoid exclusion of vulnerable communities.
Sabarmati Riverfront (Ahmedabad)	Engineered riverfront redevelopment with flood control and green public spaces	• Public recreation and aesthetic value • Tourism and cultural use • Loss of informal livelihoods and housing for marginal groups	Implemented by Sabarmati Riverfront Development Corporation Ltd (SRFDCL, SPV)	Shows the potential and pitfalls of BGI without equitable planning-needs inclusive rehabilitation and ecosystem restoration.

5. INFERENCES AND TAKEAWAYS

5.1 Inferences From the Tool and Methodology Study

A review of the literature shows that research on blue-green infrastructure (BGI) consistently relies on mixed-methods approaches. However, three broad patterns are most relevant to this thesis. First, spatial tools, such as geographic information systems (GIS) and remote sensing, are the dominant method for understanding the distribution, accessibility, and environmental performance of BGI. These tools help identify spatial inequalities and are therefore essential for Indian Class 1 cities, where access to open space is uneven.

Second, many studies emphasize policy and governance analysis, demonstrating that institutional fragmentation and inadequate coordination often impede effective BGI implementation. This underscores the importance of viewing BGI as both an ecological asset and a governance challenge that requires clear planning frameworks.

Third, social perception methods, such as surveys, interviews, and stakeholder analysis, are increasingly used, especially in Global South contexts. These approaches reveal how communities experience and value BGI. They demonstrate that social well-being benefits cannot be measured through spatial data alone.

The methodological review suggests that the most suitable way to evaluate BGI's contribution to social well-being is through an integrated approach combining spatial assessment, policy understanding, and community perspectives. This aligns with the mixed-methods design adopted in the present study.

5.2 Inferences From the Case Study Analysis

An analysis of selected Indian case studies shows that blue-green infrastructure (BGI) generates meaningful social well-being outcomes when ecological restoration is combined with public access and community involvement. Projects such as the East Kolkata Wetlands, the Yamuna Biodiversity Park, and the Adyar Eco Park illustrate how restoring natural systems can improve the microclimate, biodiversity, and overall environmental quality. These improvements support mental and physical well-being. These projects highlight the importance of nature-based restoration in urban areas.

Projects that offer direct public access, such as the Sabarmati Riverfront and parts of

the Mula–Mutha Rejuvenation, deliver additional benefits through recreation, walkability, and social interaction. However, these examples also reveal recurring challenges related to displacement, uneven access, and limited ecological sensitivity. This shows that social well-being gains can be undermined if equity and inclusion are not central to planning.

The case studies suggest that effective BGI requires balancing ecological function, public accessibility, and inclusive governance. When these factors align, BGI acts as both environmental and social infrastructure for Indian cities.

5.3 Takeaways

Several takeaways emerge from the literature review and case study analysis:

a. BGI functions as both ecological and social infrastructure.

It mitigates urban flooding, heat stress, and degradation while improving mental health, recreation, social interaction, and sense of place.

b. Social well-being must be an explicit planning objective.

Most existing Indian policies focus on ecological or engineering outcomes. The social dimension-including health, safety, and inclusion-is rarely prioritized.

c. Spatial Equity Is a Central Challenge in Indian Cities

GIS-based evidence shows an uneven distribution of green and blue spaces across income groups, wards, and neighborhoods.

d. A mixed-methods approach is the most suitable method for Indian Class 1 cities.

Surveys, interviews, spatial analysis appropriately may reflect best practices and suit contexts where social data is scarce but experiential knowledge is rich.

6. SELECTION OF CASE CITY (GWALIOR,MADHYA PRADESH)

6.1 Why Gwalior? - Justification For Case City Selection

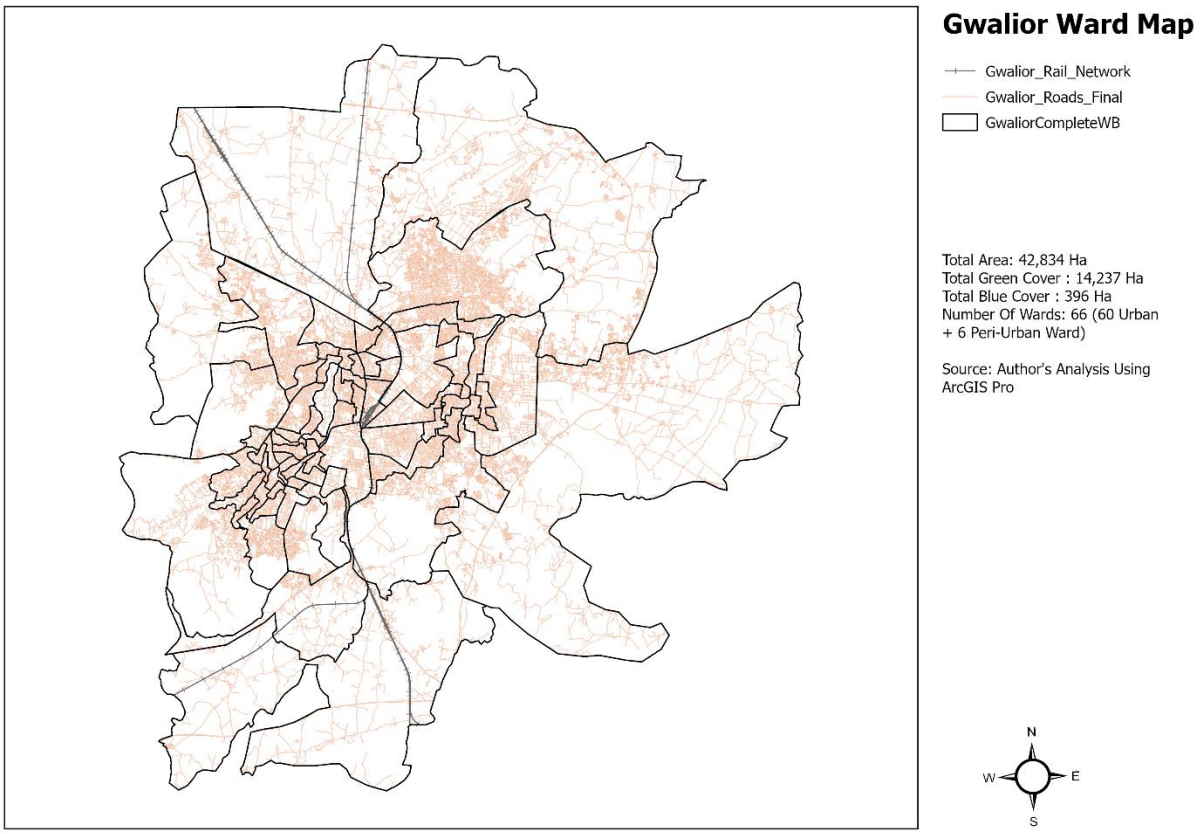


Figure 14:Gwalior Ward Map With Road and Rail Network Source: Author's Analysis Using ArcGIS Pro

The selection of a case city for in-depth field analysis required a city that genuinely represents the planning challenges facing India's rapidly urbanising Class 1 cities. Several Indian cities were considered before Gwalior (fig. 14) was identified as the most suitable choice. The selection was based on eight criteria evaluated systematically, as shown in Table 6.

Table 6 Gwalior Case City Selection Criteria *Source: Author's Analysis*

Selection Criterion	Requirement	Gwalior's Position
Population Class	Class 1 city (Census of India)	Class 1 - Population 12.02 lakh (2011), ~16.31 lakh projected (2025)
BGI Assets Present	Existing green and blue features to study	Fort hillock, Tighra &Ramaua Reservoir, Rivers, parks and water bodies across 66 wards
Spatial Inequity	Visible gap in BGI distribution across wards	68% of inner-city wards below 5 sqm/person - extreme inequity confirmed by GIS analysis
Policy Coverage	Covered under national BGI-related schemes	Covered under AMRUT 2.0 and Smart Cities Mission
Data Availability	Ward-level spatial and demographic data accessible	GMC ward boundaries, Census 2011, DP 2035 all available
Topographic Diversity	Varied terrain to test BGI planning constraints	Rocky ridges, fort hillock, flat plains - full topographic spectrum present
Institutional Access	GMC officials accessible for interviews	GMC Sub-Engineers and planning officials available for primary data
Representativeness	Represents mid-size Class 1 cities across India	Comparable to Jabalpur, Raipur, Agra - findings replicable for similar cities

No other city considered combined all eight criteria as effectively as Gwalior. The presence of significant existing BGI - including the ecologically important Tighra Reservoir and the forested fort hillock - alongside severe BGI deficiency in the dense urban core creates exactly the kind of spatial equity contrast that this study requires to generate meaningful findings.

6.2 Location Of Gwalior

Gwalior is located in the Chambal Division of northern Madhya Pradesh, at approximately 26 degrees 13 minutes North latitude and 78 degrees 10 minutes East longitude. It lies roughly 120 kilometres south of Agra and 410 kilometres north of Bhopal. The city is the administrative headquarters of Gwalior District and the Gwalior Division. The Key Location Map (fig.14) below shows Gwalior's position within India, within Madhya Pradesh, and at the GMC ward level with the six selected survey wards highlighted.

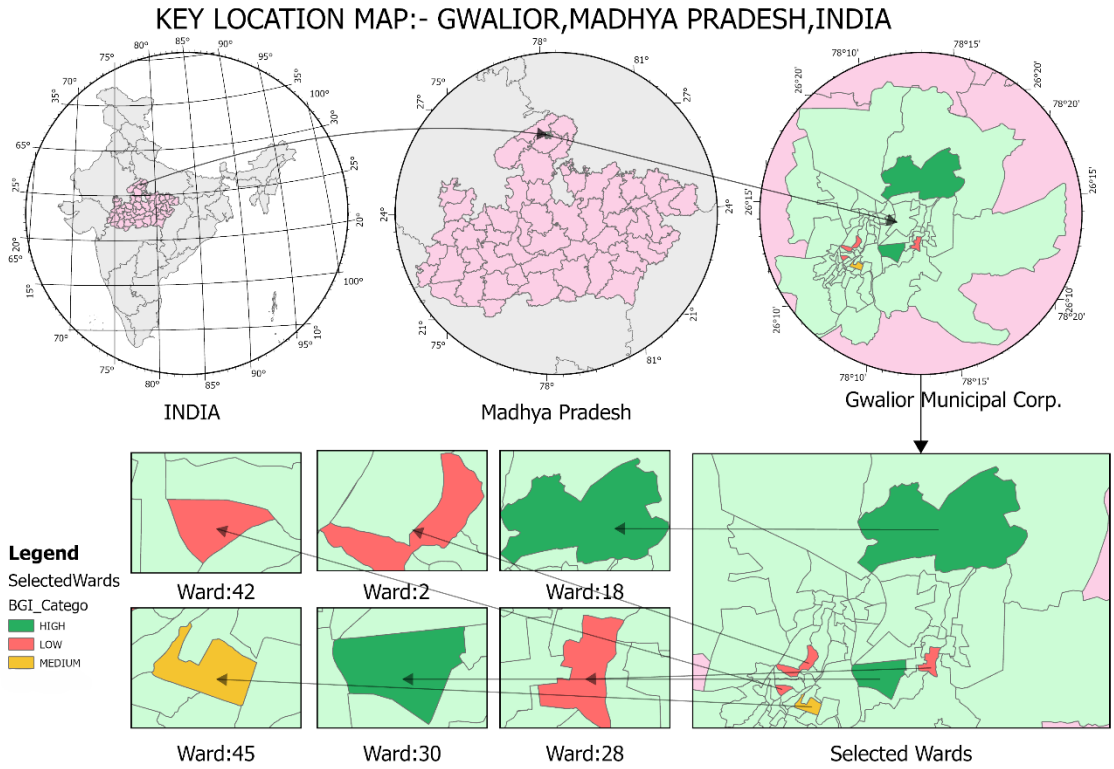


Figure 15 Key Location Map - India → Madhya Pradesh → Gwalior Municipal Corporation → 6 Selected Survey Wards Source: Author Using ArcGIS Pro

6.3 City Profile

Gwalior sits on the Vindhyan plateau in northern Madhya Pradesh, at an average elevation of approximately 212 metres above mean sea level, though the topography varies significantly across the planning area (table. 7) . The southern and western edges are defined by rocky ridgelines and the iconic Gwalior Fort hillock, which rises steeply to around 500 metres and is covered by mixed scrub forests. The northern and eastern parts of the GMC area are substantially flatter, forming the urban plain on which most dense residential and commercial development has occurred.

The city experiences a semi-arid climate with hot summers regularly exceeding 45 degrees Celsius, a moderately wet monsoon between July and September, and cool dry winters. This climate context makes BGI particularly critical for ecological services such as evaporative cooling and storm water management, and for social wellbeing functions such as providing thermally comfortable outdoor spaces during extreme heat.

The Tighra Reservoir, located on the northwestern fringe of the GMC boundary, serves as the city's primary water supply source and also functions as an ecological

asset. The Sank,Swarna Rekha and Murar River runs through the southern portions of the city but suffers from encroachment and pollution. Across the 66 wards, the distribution of parks, gardens, open grounds, and water bodies varies enormously - from near-total absence in dense inner-city wards to substantial green and blue coverage in the peri-urban fringe wards added to the GMC boundary in 2016.

Table 7 Gwalior City Profile - Key Statistics | Source: Census of India 2011, Author's Analysis, GMC

Parameter	Data	Source
Administrative Status	Municipal Corporation (Class 1 City)	Census of India 2011
Division	Chambal Division, Madhya Pradesh	Government of MP
Location	26°13'N, 78°10'E	Survey of India
Average Elevation	~212 m above MSL	SRTM DEM
Population (2011)	12,02,000	Census of India 2011
Projected Population (2025)	~16,31,000	Author's Projection, r = 2.60%/yr
Number of Wards	66 (Wards 1–59: Census 2011; Ward 60: DP 2035; Wards 61–66: HFAPoA 2016)	GMC ward map (georeferenced) / MP State Geoportal
Total BGI Area (all 66 wards)	~14,633 hectares (Green: 14,237 Ha + Blue: 396 Ha)	Author's GIS Analysis, ArcGIS Pro
City Core BGI per capita (Wards 1–60)	2.64 sqm/person (median)	Author's Analysis
URDPFI Standard	10 sqm/person	URDPFI Guidelines 2015
Planning Document	Gwalior Master Plan 2021 / DP 2035	GMC / Town and Country Planning MP

6.4 Administrative Structure And Ward Configuration

The Gwalior Municipal Corporation administers 66 wards. Wards 1 through 59 form the original Census 2011 boundary. Ward 60 was added under the Gwalior Development Plan 2035. Wards 61 through 66 were incorporated under the Housing for All Plan of Action (HFAPoA) in 2016, accounting for peri-urban growth areas on the city's eastern and southern fringes. The newer peripheral wards contain large open tracts with naturally high vegetation cover but low population densities, while the older inner-city wards carry the heaviest population burden with the least green and blue provision per resident. The Gwalior Fort area and the Morar Cantonment are separately administered and shown as reference overlays in the spatial maps.

7. BLUE GREEN INFRASTRUCTURE SPATIAL ANALYSIS

7.1 Introduction to the Spatial Analysis

This chapter presents the GIS-based spatial analysis of Blue-Green Infrastructure across all 66 wards of the Gwalior Municipal Corporation. The analysis was carried out using ArcGIS Pro. Since GMC does not publish ward boundaries as a shapefile in the public domain, ward boundaries were generated by georeferencing the official GMC ward map raster against base imagery in ArcGIS Pro, and the resulting polygon boundaries and ward names were verified against the Madhya Pradesh State Geoportal (https://geoportal.mp.gov.in/). Topographic inputs were derived from the SRTM Digital Elevation Model and satellite inputs from three Sentinel-2 L2A scenes acquired in the same dry-season window across the study decade (22 February 2016, 25 February 2021, and 24 February 2026) to enable both single-date spatial analysis and multi-temporal vegetation trajectory analysis. Spatial data for the Gwalior Fort area and the Morar Cantonment, which fall under separate administration, was not available with GMC; these two areas are therefore shown as reference overlays in the maps but are excluded from the per-ward BGI per capita and NDVI tabulations. The primary objective is to establish the spatial distribution of BGI per capita across the city, identify wards critically deficient in BGI provision relative to the URDPFI standard of 10 sqm per person, and validate these findings using independent satellite-derived vegetation data.

7.2 Topographic Analysis

A topographic analysis was conducted before mapping BGI distribution to understand the physical landscape of Gwalior, since terrain directly constrains where BGI can be planned and implemented. Four parameters were derived from the SRTM DEM in ArcGIS Pro: elevation, slope, aspect, and hillshade. Together these provide a terrain suitability baseline for the BGI planning recommendations in Chapter 10.

7.2.1 Elevation

The elevation analysis of the GMC planning area was carried out using SRTM DEM data in ArcGIS Pro (fig. 16). The elevation ranges from approximately 144 metres to 332 metres above mean sea level, indicating noticeable topographic variation across the city. Lower elevation zones are primarily concentrated in the northern and eastern parts of the GMC area, where the terrain is comparatively flat and urbanized. These areas mainly fall within the 144–217 metre range and are suitable for urban expansion and Blue-Green Infrastructure (BGI) development.

In contrast, the southern and south-western portions of the study area show comparatively higher elevations and rugged terrain conditions associated with the Vindhyan sandstone ridges and rocky uplands around Gwalior. Elevation in these regions reaches up to approximately 332 metres and is characterized by steeper gradients and uneven terrain. While these high-elevation zones impose limitations on intensive urban development and formal BGI implementation, they remain ecologically important due to the presence of natural vegetation and open landscapes that contribute to environmental stability and biodiversity conservation.

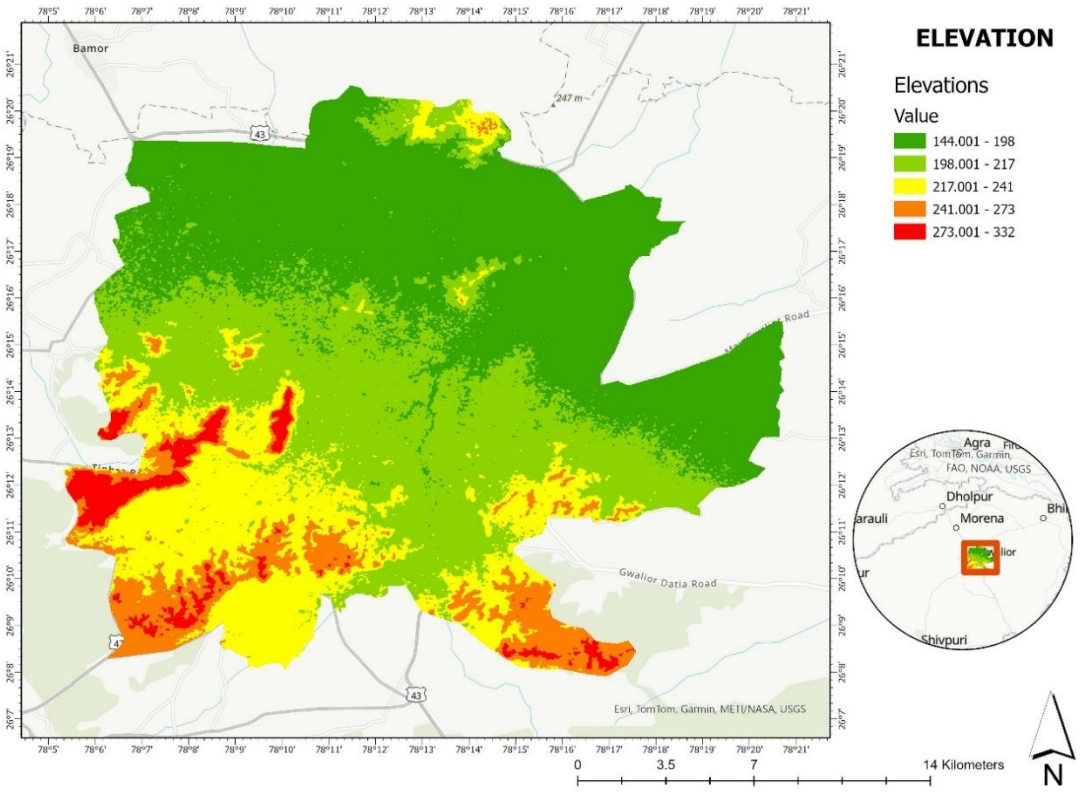


Figure 16 Elevation Map - Green = low elevation plains, Yellow/Orange = moderate elevation, Red = high elevation ridges- GMC | Source: SRTM DEM; Analysis: ArcGIS Pro

7.2.2 Slope

The slope analysis (fig. 17) reveals important terrain differences across the planning area. The northern, eastern, and central wards are predominantly flat (0°–4°), making them ideal for urban growth and Blue-Green Infrastructure (BGI) projects like green roofs and rain gardens. These gentle slopes present few obstacles and allow flexible planning and development.

The central and southern zones feature moderate slopes (4°–18°), requiring more thoughtful design. Development here needs proper drainage systems and careful management. BGI can function in these areas but requires more sophisticated engineering to handle water flow and slope stability.

Steep slopes above 18°-concentrated in the south and southwest, including ridge systems and the reservoir-present real challenges for construction. These rugged areas support important vegetation and ecosystems that deserve protection. Development should be minimal, prioritizing environmental preservation over urban expansion.

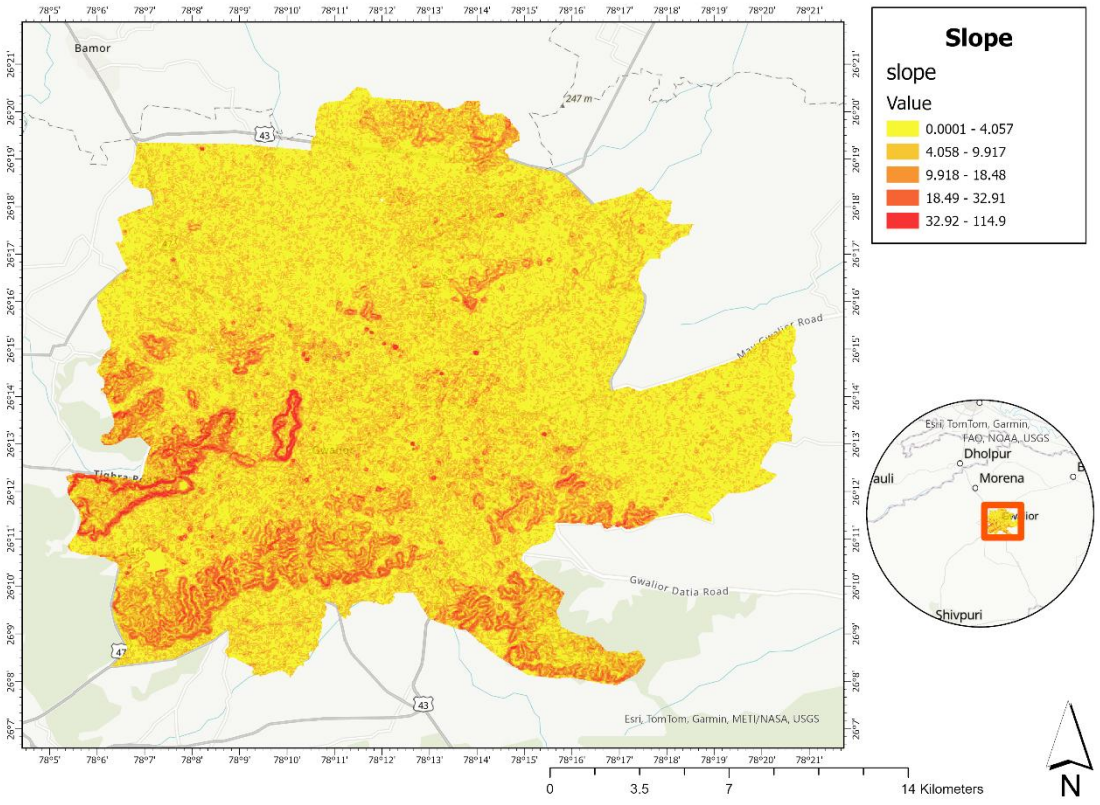


Figure 17 Slope Map - Yellow = gentle slopes, Orange = moderate slopes, Red = steep slopes] - Gwalior Municipal Corporation | Source: SRTM DEM; Analysis: ArcGIS Pro

7.2.3 Aspect

The aspect analysis (fig.18) indicates a mixed directional slope pattern across the GMC planning area, reflecting the varied terrain conditions of the region. Different slope directions are distributed throughout the study area, particularly within the elevated ridge systems and rugged uplands located in the southern and south-western parts of the city.

North- and northeast-facing slopes generally receive lower solar exposure and tend to retain relatively higher soil moisture, which supports better vegetation growth and comparatively higher NDVI values in some elevated zones. In contrast, south- and southwest-facing slopes experience greater solar radiation and comparatively drier surface conditions.

The aspect pattern has important implications for Blue-Green Infrastructure (BGI) planning and ecological management. Slopes with lower solar exposure are comparatively more suitable for moisture-retaining vegetation, plantation activities, and water conservation measures, while highly exposed slopes may require drought-resistant vegetation and erosion control strategies. Overall, the aspect analysis helps in understanding microclimatic variations and terrain suitability across the GMC area.

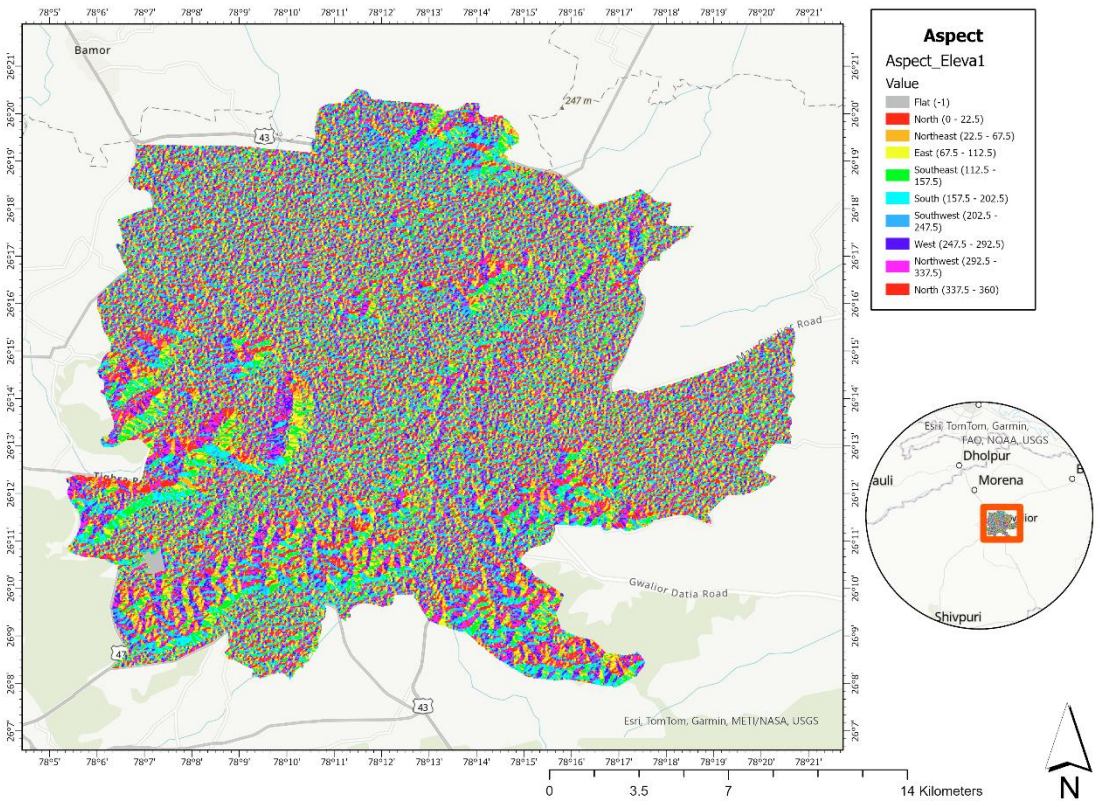


Figure 18: Aspect Map - Multi-directional slope orientation across the GMC planning area] - Gwalior Municipal Corporation | Source: SRTM DEM; Analysis: ArcGIS Pro

7.2.4 Hillshade

The hillshade analysis (fig.19) was generated from the SRTM DEM using ArcGIS Pro to provide a three-dimensional visual representation of the terrain characteristics within the GMC planning area. The hillshade model enhances the visibility of elevation differences, ridge formations, valleys, and surface relief patterns across the study area.

The analysis clearly highlights the rugged and uneven terrain conditions concentrated in the southern and south-western parts of the GMC area, where multiple ridge-and-valley systems are visible. These regions correspond to the elevated Vindhyan sandstone formations and rocky uplands surrounding the Gwalior fort hillock and nearby catchment areas. In contrast, the northern and eastern portions exhibit comparatively smoother and flatter terrain with limited surface relief variation.

The hillshade map further emphasizes the distinct topographic transition between the elevated southern ridges and the relatively flat northern urban plains. This terrain variation significantly influences drainage patterns, vegetation distribution, land suitability, and the spatial distribution of Blue-Green Infrastructure (BGI) across the city. Overall, the hillshade analysis provides an important visual understanding of the physical landscape structure of the GMC area.

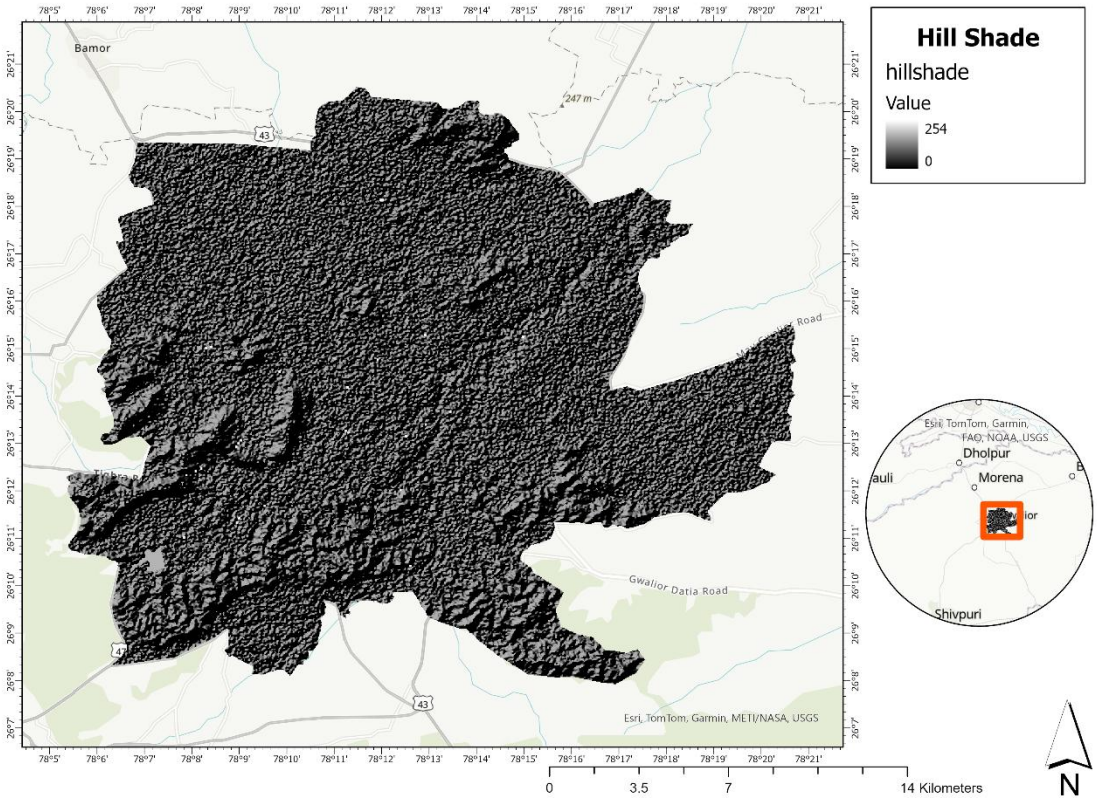


Figure 19 Hillshade Map - Grey-scale terrain relief model showing ridge and valley systems] - Gwalior Municipal Corporation | Source: SRTM DEM; Analysis: ArcGIS Pro

7.2.5 Contour Analysis

The contour analysis (fig.20) derived from the SRTM DEM highlights the terrain variation across the GMC planning area. Widely spaced contours in the northern and eastern regions indicate gentle slopes and relatively flat terrain, making these areas suitable for urban development and Blue-Green Infrastructure (BGI) interventions such as parks, green corridors, and water management features.

In contrast, the southern and south-western parts of the study area show closely spaced contours, representing steep slopes and rugged terrain associated with the Vindhyan sandstone ridges and fort hillock region. These areas have limited suitability for intensive development and are more appropriate for ecological conservation and natural landscape protection.

Overall, the contour analysis reinforces the elevation and slope findings by showing a clear transition from flat northern plains to elevated southern ridges within the GMC area.

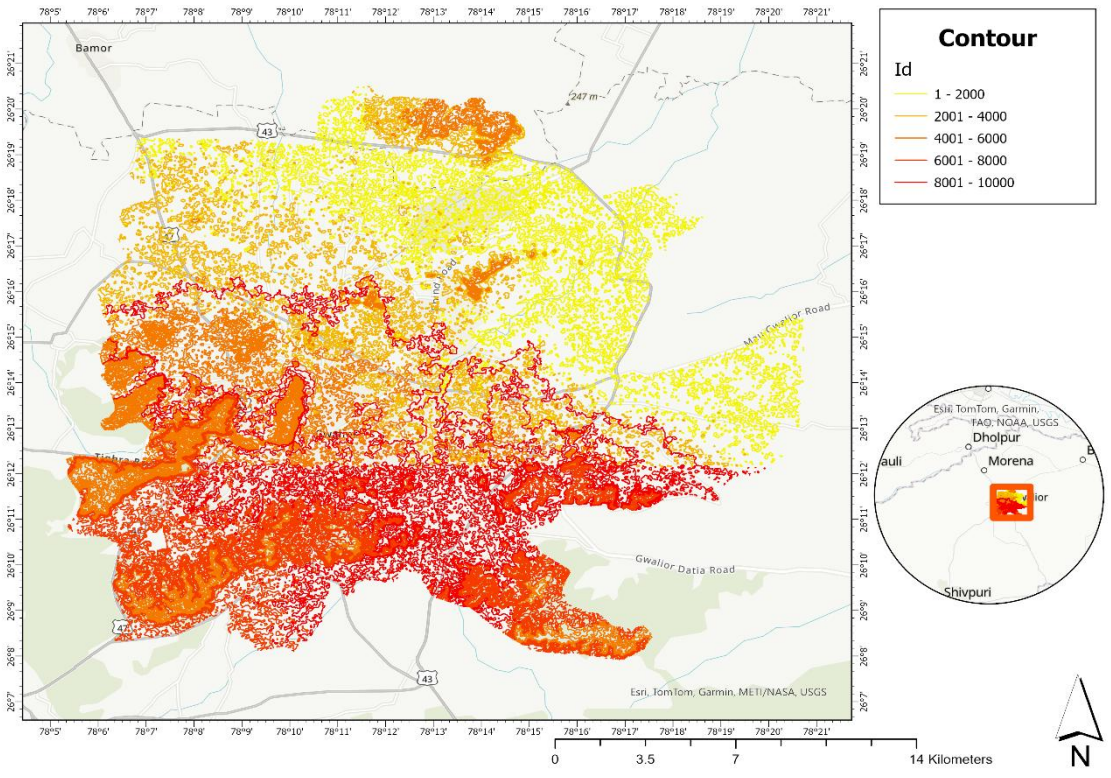


Figure 20: Contour Map - Widely spaced contours represent gentle terrain, while closely spaced contours indicate steep topography]- Gwalior Municipal Corporation | Source: SRTM DEM; Analysis: ArcGIS Pro

7.3 Land Use Land Cover Analysis

Land Use Land Cover (LULC) analysis was carried out to understand the spatial distribution and temporal changes in land use patterns within the Gwalior Municipal Corporation (GMC) area. The analysis was based on LULC datasets obtained from Bhuvan–NRSC for the years 2005–2006, 2011–2012, and 2015–2016. Five major land use categories were identified within the study area: Agriculture, Built-up Area, Forest, Barren/Unculturable Land, and Wetlands/Waterbodies.

7.3.1 LULC 2005-2006

The 2005–2006 LULC map (fig.21) indicates that agriculture was the dominant land use category across the GMC area, particularly in the northern, eastern, and peripheral regions. Built-up development was mainly concentrated within the central urban core of Gwalior city. Dense forest cover was observed primarily in the southern and south-western portions associated with the Vindhyan ridge systems and fort hillock region. Small patches of wetlands and waterbodies were visible around reservoir and drainage areas, while barren and unculturable land occurred in scattered pockets across the city fringe

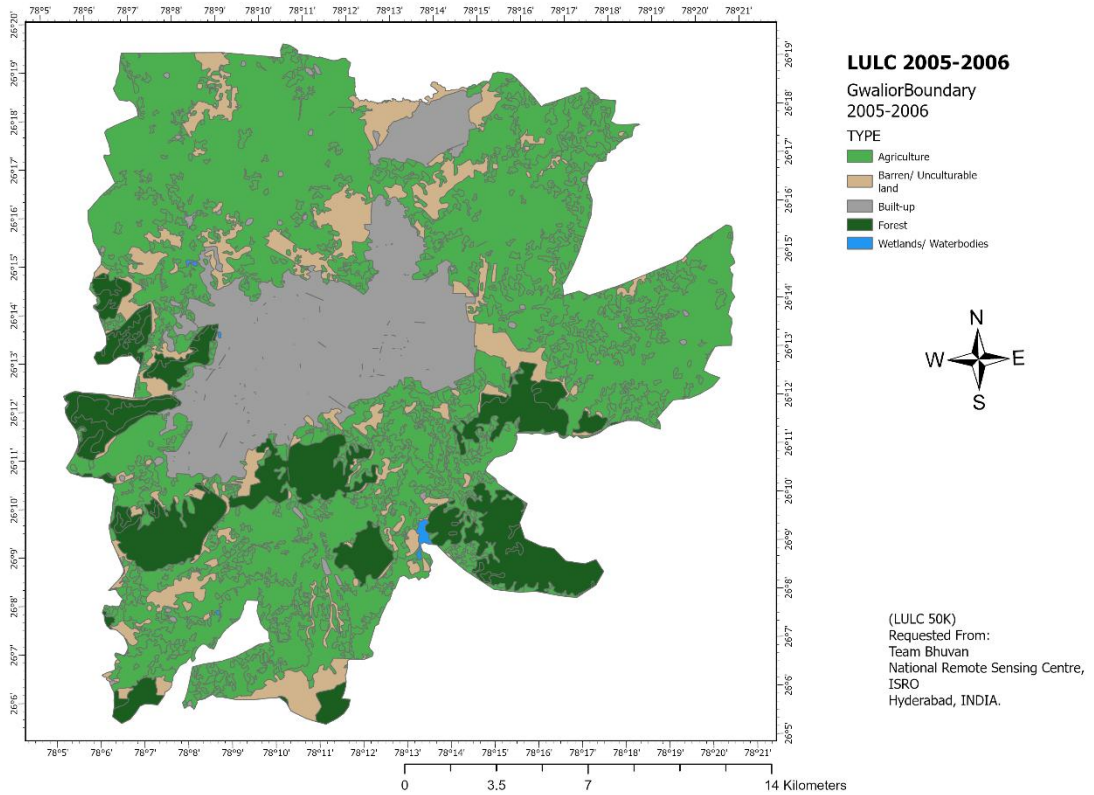


Figure 21 : LULC Map 2005–2006 - Gwalior Municipal Corporation| Source: Bhuvan–NRSC, ISRO

7.3.2 LULC 2011-2012

The 2011–2012 LULC map (fig.22) shows noticeable expansion of built-up areas beyond the historic urban core, particularly towards the western and southern parts of the city. Agricultural land still remained dominant in peripheral areas, although some conversion of agricultural land into urban land use became visible. Forest cover in the southern ridge zones remained relatively stable, while waterbody distribution showed only minor changes compared to the previous period.

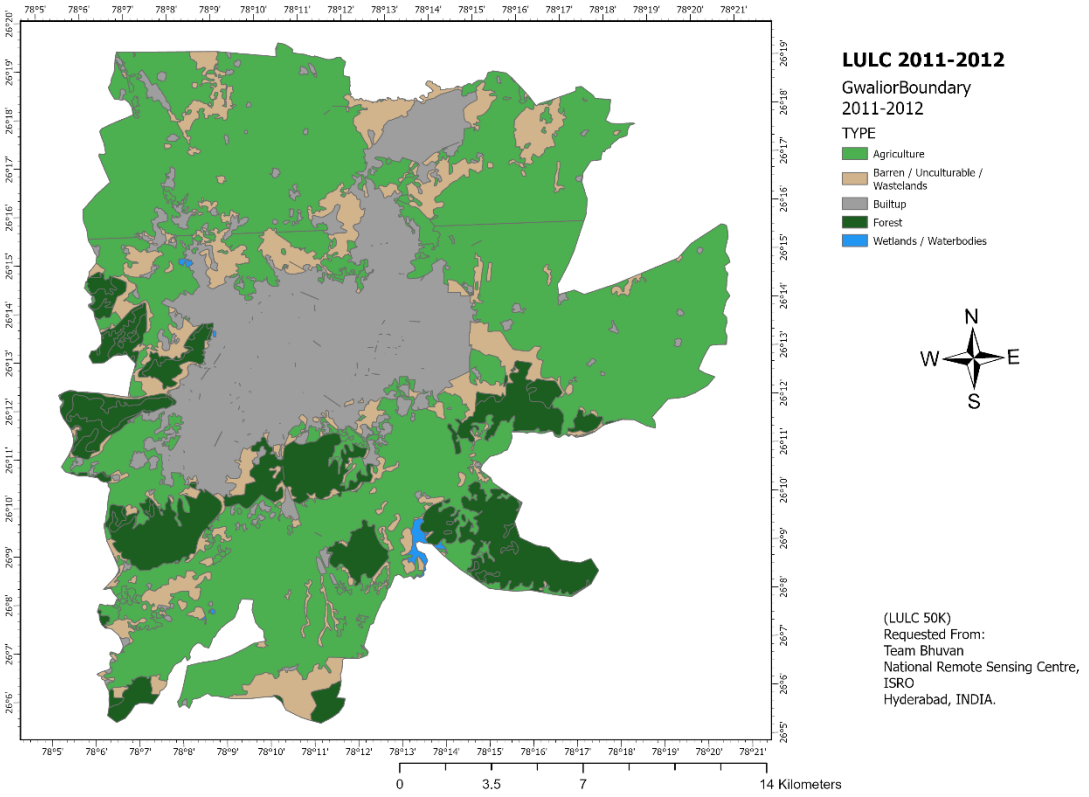


Figure 22:LULC Map 2011–2012 - Gwalior Municipal Corporation | Source: Bhuvan–NRSC, ISRO

7.3.3 LULC 2015-2016

The 2015–2016 LULC map (fig.23) further highlights the continued expansion of built-up areas within the GMC boundary. Urban growth became more prominent around transportation corridors and peripheral zones, resulting in gradual reduction and fragmentation of agricultural land. Forested areas in the southern and south-western regions largely remained intact due to topographic constraints and ecological significance. Wetlands and waterbodies continued to occupy relatively limited portions of the study area.

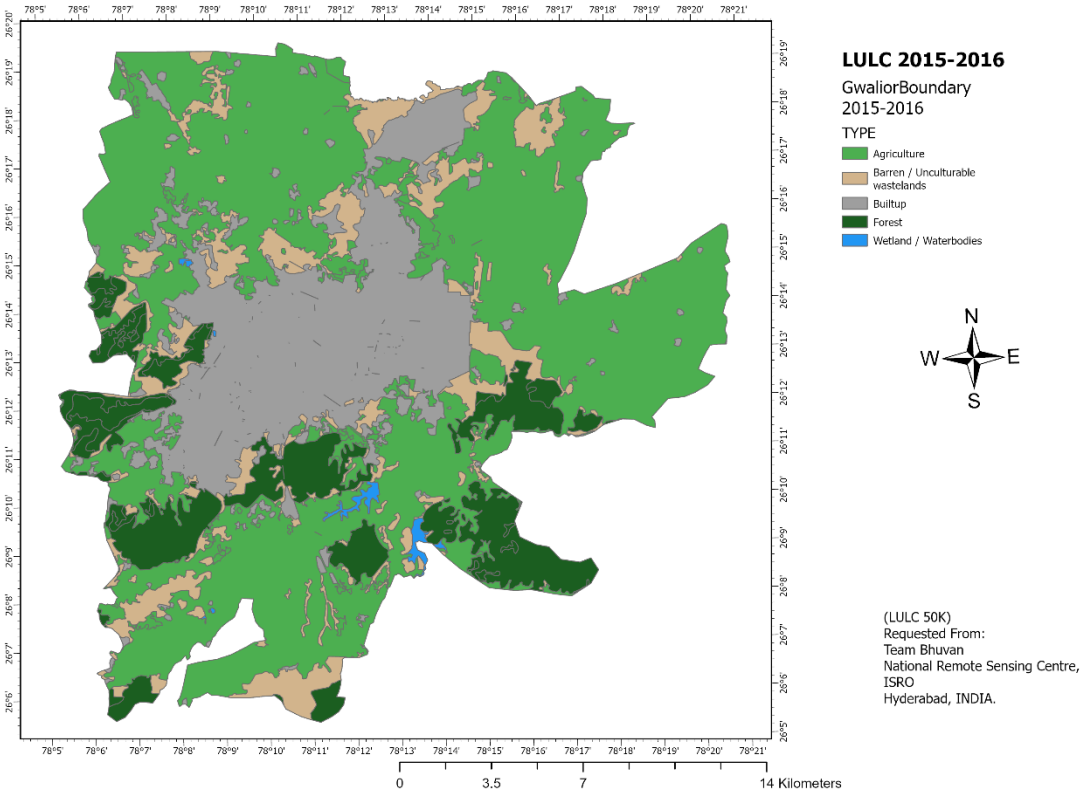


Figure 23:LULC Map 2015–2016 - Gwalior Municipal Corporation | Source: Bhuvan–NRSC, ISRO

7.3.4 LULC Change Analysis

The comparative analysis of LULC maps from 2005–2006 to 2015–2016 reveals a gradual increase in built-up land within the GMC area, reflecting urban expansion and population growth. This growth has largely occurred at the expense of agricultural and open lands surrounding the urban core. In contrast, forest cover in the elevated southern ridge systems remained comparatively stable due to rugged terrain and restricted urban development.

The analysis highlights the increasing pressure of urbanization on natural and agricultural landscapes within Gwalior. Such land transformation has important implications for Blue-Green Infrastructure (BGI), environmental sustainability, drainage conditions, and ecological balance across the city. The observed trends emphasize the need for controlled urban expansion and the integration of BGI planning strategies to preserve environmentally sensitive areas and maintain urban ecological health.

7.4 BGI Inventory And Mapping

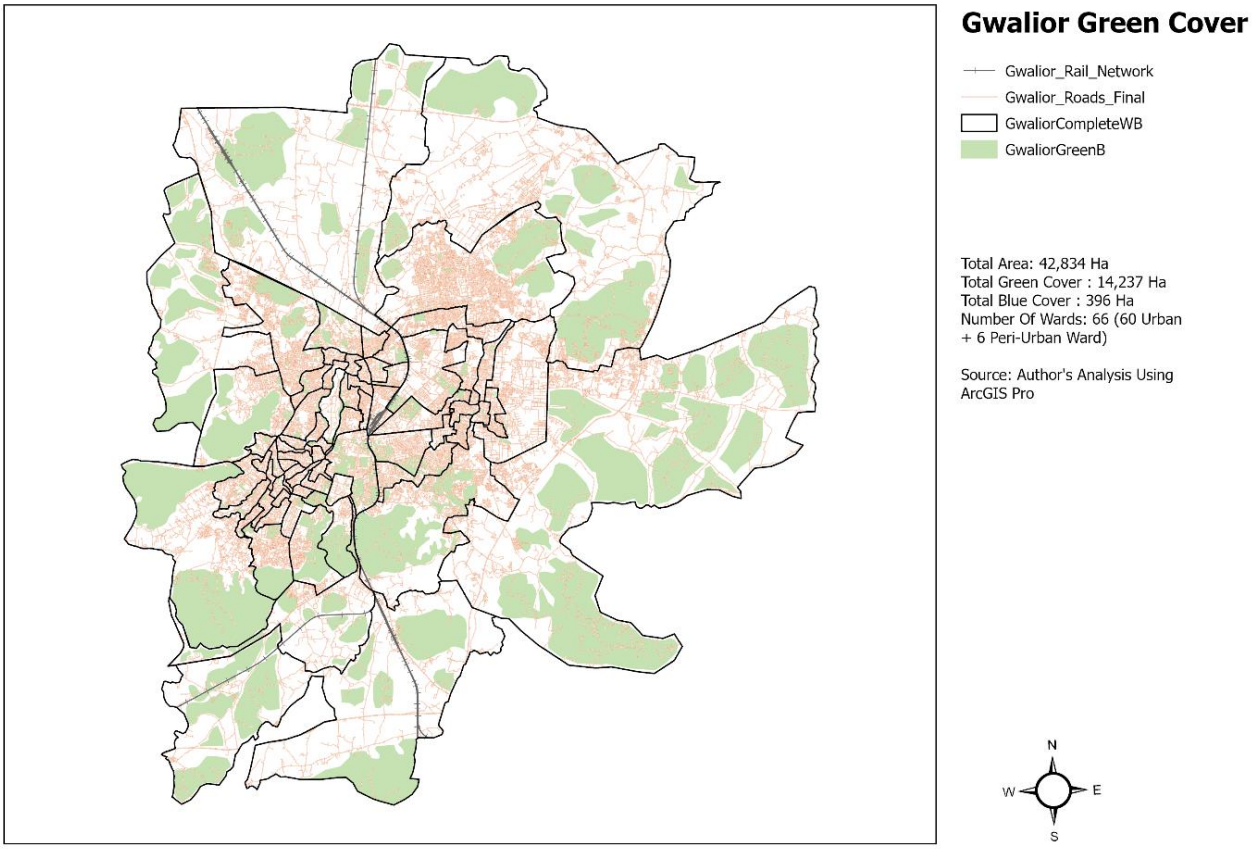


Figure 24:Gwalior's Green Infrastructure Source:Using Satellite Imaging (Google Earth & OSM) and Compiled By Author Using ArcGIS Pro

The BGI inventory was compiled by digitizing all green (fig.24) and blue (fig.25) infrastructure features visible in high-resolution satellite imagery within the GMC boundary. Green infrastructure features include parks, gardens, open grounds, roadside plantations, institutional green areas, and the fort hillock scrub forest. Blue infrastructure features include lakes, ponds, the Sank,Swarna Rekha,Murar River corridor. All features were digitized as polygon layers in ArcGIS Pro, attributed with area in hectares, and tagged by ward number.

The total BGI area across all 66 wards was approximately 14,633 hectares - comprising 14,237 hectares of green cover and 396 hectares of blue cover. However, the aggregate figure is substantially inflated by large open tracts in the peri-urban wards 61 through 66, which alone account for over 11,340 hectares of this total. When the analysis is restricted to wards 1 through 60, a picture of acute spatial inequity in BGI distribution emerges - one that the city-level aggregate completely conceals.

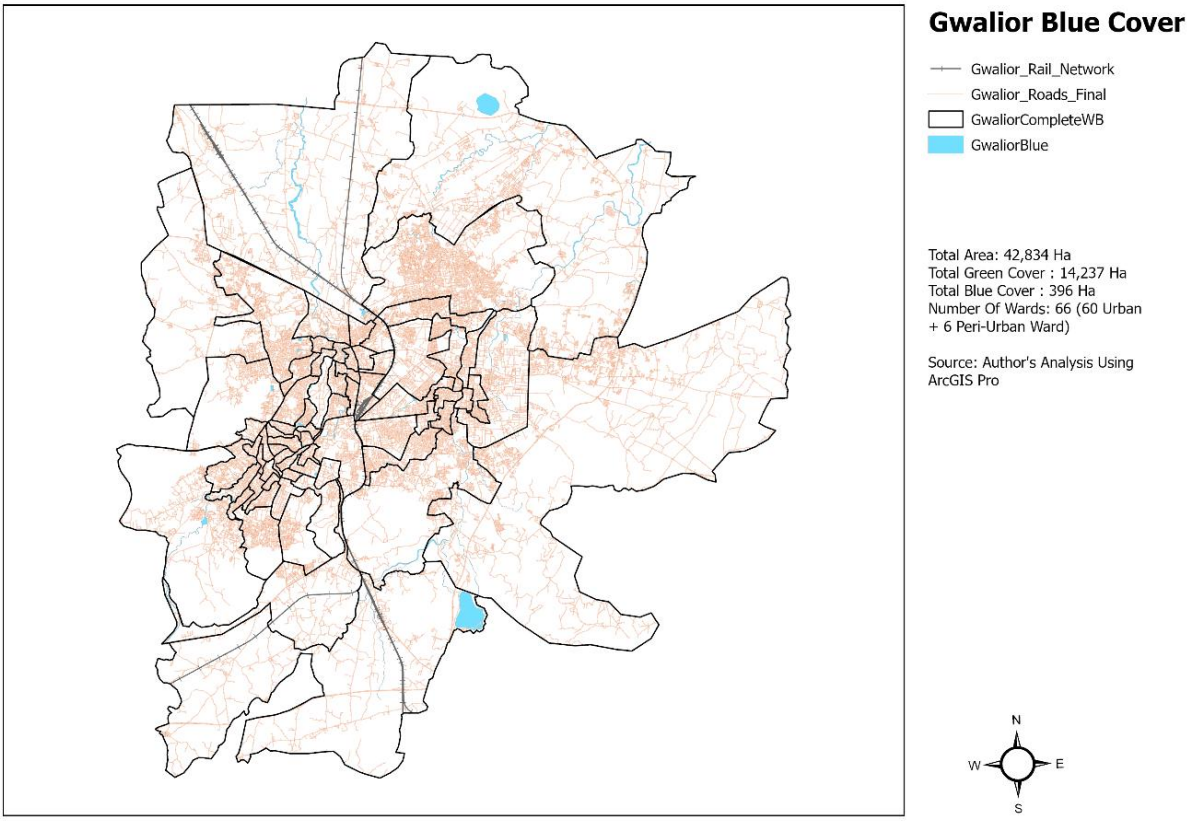


Figure 25:Gwalior's Blue Infrastructure Source:Using Satellite Imaging (Google Earth & OSM) and Compiled By Author Using ArcGIS Pro

7.5 BGI Per Capita Analysis

Ward populations were projected from Census 2011 (wards 1–59) and 2016 baseline (wards 60–66) using the Geometric Growth Method at 2.60 percent per annum, calibrated to the Gwalior Development Plan 2035 design population of ~16.66 lakh. The projected 2025 populations served as the denominator for BGI per capita (sqm per person). Wards 61–66, though included in the inventory mapping, are excluded from the category analysis - their peri-urban land character inflates BGI values in ways not comparable to the built-up core, and would mask deprivation in inner-city wards. All categorisation and subsequent analysis therefore proceeds on the 60 core-city wards (1–60) only.

Three categories were defined: **Low BGI** (< 5 sqm/p), **Medium BGI** (5–25 sqm/p), and **High BGI** (≥ 25 sqm/p). The Low threshold sits below the URDPFI standard of 10 sqm/p to flag the most acutely deficient wards as a priority intervention group.

Table 8: BGI Per Capita Category Distribution - Gwalior Municipal Corporation (2025) | Source: Author's Analysis, ArcGIS Pro, Census 2011

BGI Category	Threshold	Number of Wards	% of Wards (1–60)	Description
Low BGI	< 5 sqm/person	41	68%	Critically deficient - highest priority for BGI intervention
Medium BGI	5–25 sqm/person	8	13%	Transitional - partially meets URDPFI standard
High BGI	≥ 25 sqm/person	11	18%	Meets or exceeds standard - mostly peri-urban wards

The headline finding is acute spatial inequity (Table 8): **41 of the 60 core-city wards (68 percent) fall in the Low BGI category**, with Ward 42 at just 0.19 sqm/p - less than two percent of the URDPFI standard. **The median core-city BGI per capita is 2.64 sqm/p**, **barely a quarter of the URDPFI benchmark**, while the 11 High BGI wards average 90.74 sqm/p - illustrating steep internal contrast within the GMC core. The BGI per capita choropleth (fig. 26) maps this distribution across all 66 wards for spatial completeness, though category comparisons are based on the 60 core-city wards only.

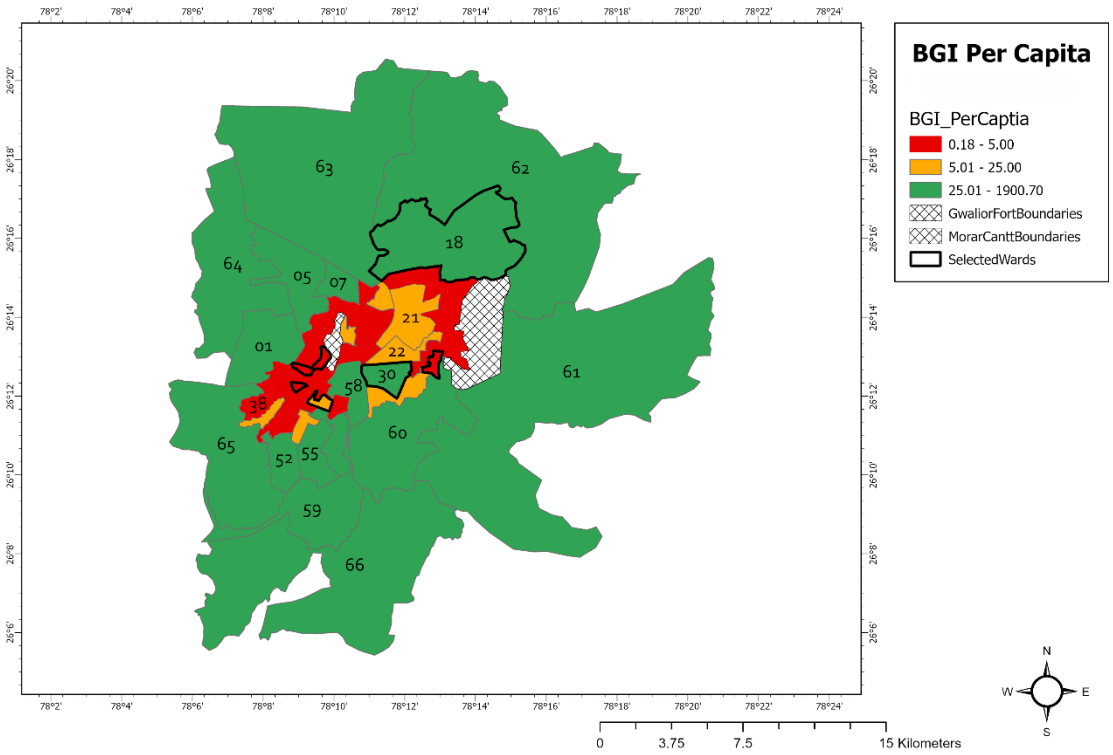


Figure 26: [BGI Per Capita Map - Red = Low BGI <5 sqm/p, Orange = Medium BGI 5–25 sqm/p, Green = High BGI ≥25 sqm/p] - All 66 Wards, Gwalior Municipal Corporation (2025) | Source: Author's Analysis, ArcGIS Pro

7.6 NDVI Analysis – Satellite Validation

To independently validate the BGI per capita findings, a Normalized Difference Vegetation Index (NDVI) analysis was conducted using Sentinel-2 Level-2A satellite imagery acquired on 24 February 2026 (fig. 27), sourced from the Copernicus Open Access Hub. NDVI is calculated as:

$$NDVI = \frac{B08 - B04}{B08 + B04}$$

NDVI = (B08 minus B04) divided by (B08 plus B04). Values range from negative 1.0 to positive 1.0, where negative values indicate water or impervious surfaces, values near zero indicate bare soil or built-up areas, and positive values indicate increasing vegetation density and health. The imagery was processed in ArcGIS Pro using the Spatial Analyst Raster Calculator, clipped to the GMC boundary using Extract by Mask, and ward-level mean NDVI values were extracted using Zonal Statistics as Table.

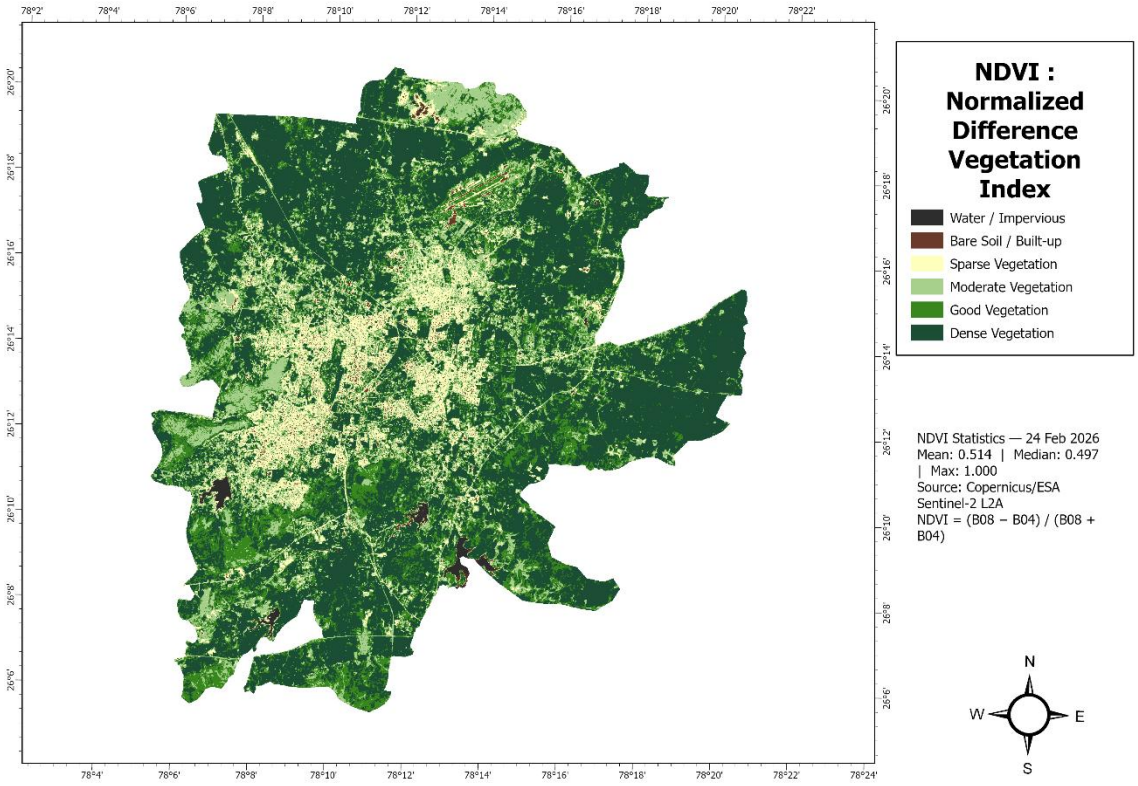


Figure 27:[NDVI Map - Dark green = Dense vegetation >0.50, Light green = Good 0.35–0.50, Yellow = Sparse 0.10–0.20, Brown = Bare/water <0.10] Gwalior Municipal Corporation | Sentinel-2 L2A, 24 February 2026 | Source: Copernicus/ESA; Analysis: ArcGIS Pro

7.6.1 City Wide NDVI Distribution

At city-wide scale, 50.50 percent of the GMC planning area is classified as Dense Vegetation (NDVI above 0.50), with a further 25.00 percent as Good Vegetation (NDVI 0.35 to 0.50) (table. 9). However, this aggregate figure is heavily skewed by the large peri-urban wards with low population densities. The dense urban core shows a strikingly different picture, with yellow and cream tones on the NDVI map indicating values between 0.10 and 0.25 - sparse to moderate vegetation at best.

Table 9: NDVI Classification - Gwalior Municipal Corporation | Source: Sentinel-2 L2A, 24 Feb 2026; Analysis: ArcGIS Pro

NDVI Class	NDVI Range	Label	Pixel Count	% of GMC Area
Class 1	< 0.0	Water / Impervious	11,107	0.63%
Class 2	0.0 – 0.10	Bare Soil / Built-up	18,124	1.02%
Class 3	0.10 – 0.20	Sparse Vegetation	1,75,178	9.88%
Class 4	0.20 – 0.35	Moderate Vegetation	3,08,282	17.38%
Class 5	0.35 – 0.50	Good Vegetation	3,65,221	20.59%
Class 6	> 0.50	Dense Vegetation	8,95,974	50.50%
Total	-	-	17,73,886	100%

7.6.2 Ward-Level NDVI Cross-Validation

The ward-level mean NDVI analysis (table.10) provides critical validation of the BGI per capita spatial equity findings. When wards are grouped by BGI category, a clear progressive relationship emerges between BGI provision and actual vegetation health as measured independently by satellite.

Table 10:BGI Category vs Mean NDVI - Inner City Wards 1–60 | Source: Author's Analysis

BGI Category	No. of Wards	Avg BGI sqm/p	Avg Mean NDVI	Interpretation
Low BGI (< 5 sqm/p)	41	1.69	0.240	Low vegetation health - critically deprived wards
Medium BGI (5–25 sqm/p)	8	9.19	0.319	Moderate vegetation health - transitional wards
High BGI (≥ 25 sqm/p)	11	90.74	0.407	Good vegetation health - well-served wards

The progressive increase from 0.240 to 0.319 to 0.407 confirms that BGI per capita is a reliable proxy for actual vegetation health. Among the six selected survey wards, this relationship holds without exception: Ward 42 (BGI 0.19 sqm/p) records the lowest mean NDVI of 0.151, while Ward 18 (BGI 81.71 sqm/p) records 0.403. This cross-validation with independent satellite data substantially strengthens the conclusion that BGI deprivation in Gwalior is spatially concentrated in the densest inner-city wards - precisely where the social wellbeing need is greatest.

7.6.3 Multi-Temporal NDVI Trajectory (2016–2026)

To strengthen the satellite cross-validation beyond a single date and to test the temporal stability of the spatial pattern, NDVI was computed for two additional Sentinel-2 L2A scenes from earlier in the study (fig.28) decade: 22 February 2016 and 25 February 2021. All three scenes fall within a three-day window of the same dry-season date across years, eliminating seasonal and phenological confounding. Cloud cover was zero over Gwalior on all three acquisition dates and identical classification thresholds were applied across years. Per-ward mean NDVI was extracted by zonal statistics over the 66 GMC ward polygons in ArcGIS Pro.

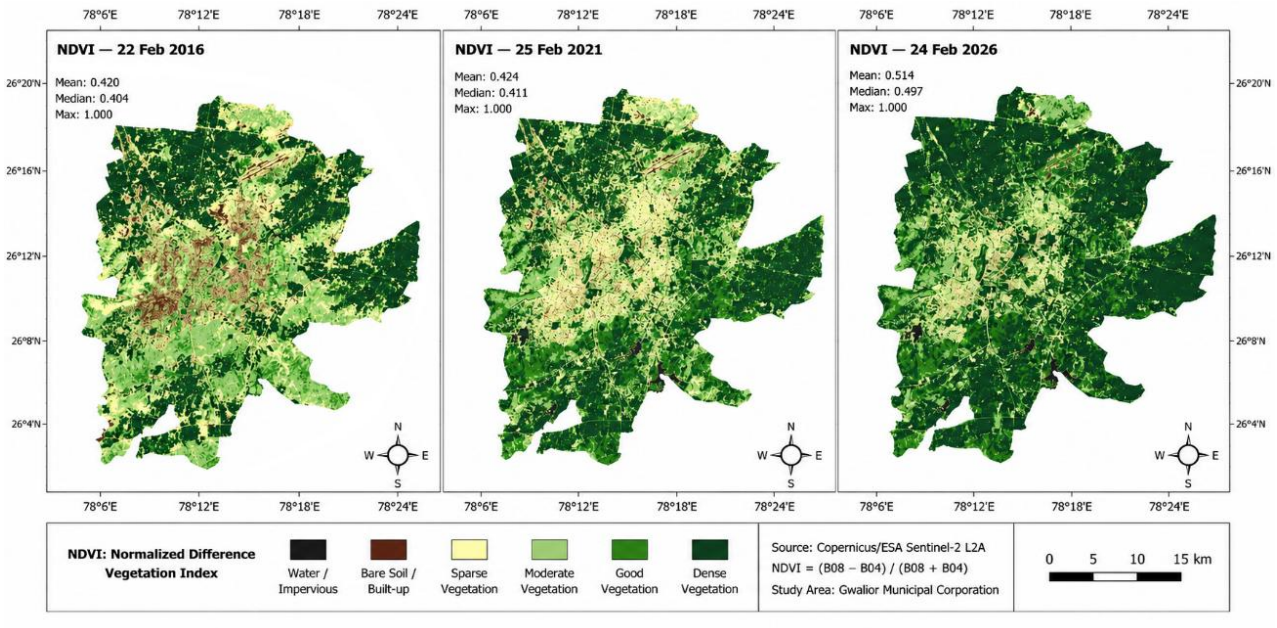


*Figure 28:*Multi-Temporal NDVI Of Gwalior Sentinel-2 L2A, 22/02/2016 25/02/2021 24/02/2026 Source: Copernicus/ESA; Analysis: ArcGIS Pro

The city-wide mean NDVI of the inner-city wards (Wards 1–60) rose monotonically across the three time points: 0.232 in 2016, 0.256 in 2021, and 0.281 in 2026 , a gain of +0.049 (+21.1 percent) over the decade. No ward recorded a net decline. This counter-

intuitive greening of an urbanising city is plausibly attributable to a combination of Gwalior's selection under the Smart Cities Mission (2017) and subsequent AMRUT urban tree-planting programmes, the maturation of plantings carried out under earlier municipal initiatives, and continued informal vegetation growth on urban-edge and institutional land. Importantly, the gains were not evenly distributed across BGI categories. Low BGI wards gained +0.041 in mean NDVI over the decade, Medium BGI wards gained +0.050, and High BGI wards gained +0.080 , meaning that the wards which were already best vegetated greened most. This pattern is significant from a spatial equity standpoint: the decade of urban greening has deepened, not narrowed, the gap between BGI-rich and BGI-poor wards.

Among the six selected survey wards, all six recorded positive NDVI trajectories. Ward 42, the most BGI-deprived ward in the city, improved from 0.085 to 0.151 mean NDVI , a 77 percent relative gain, though from an extremely low baseline that still leaves it the lowest-vegetation ward in the entire dataset across all three time points. Ward 28 was the only selected ward to remain in the "Stable" trajectory category (ΔNDVI +0.026), confirming the survey-based finding that this ward's water-body degradation rather than vegetation loss is the dominant blue-green infrastructure concern there. Ward 18, the High BGI benchmark, gained +0.076 in mean NDVI over the decade. The Low/Medium/High ward ranking established by BGI per capita in 2026 holds in all three NDVI snapshots, which establishes that the spatial pattern documented in Section 7.6.2 is not an artefact of a single image but a stable feature of the city's vegetation distribution across the decade.

7.7 Ward Selection For Field Survey

Six wards were selected for primary field data collection through stratified purposive sampling designed to capture the full spectrum of BGI provision across the city. The selection followed three stages. In Stage 1, all 66 wards were ranked by BGI per capita. In Stage 2, the six peri-urban wards (61–66) were excluded as their extremely high BGI values reflect open rural land rather than planned urban BGI. In Stage 3, candidate wards were shortlisted from each BGI category , three from Low BGI, one from Medium BGI, and two from High BGI (table.11) , with each selected ward representing a distinct urban context (fig. 29).

Table 11:Six Selected Survey Wards - BGI Per Capita, NDVI and Selection Rationale | Source: Author's Analysis

Ward	Ward Name	BGI sqm/p	Category	Mean NDVI	Selection Rationale
42	Sant Jhulelal Ward	0.19	Low BGI	0.151	Worst BGI citywide - extreme deprivation anchor case
28	Shanti Niketan Ward	0.85	Low BGI	0.202	Dense ward with water bodies yet critically BGI deficient
2	Scindia Ward	3.72	Low BGI	0.267	11 green spaces but fragmented - fragmentation case study
45	Achaleshwar Ward	5.58	Medium BGI	0.234	Transitional - tests near-standard BGI wellbeing impact
30	Capt. Roop Singh Ward	27.15	High BGI	0.375	Urban High BGI - green spaces only, zero water bodies
18	Tilak Ward	81.71	High BGI	0.403	Benchmark - highest GS (18) and WB (26) count in city

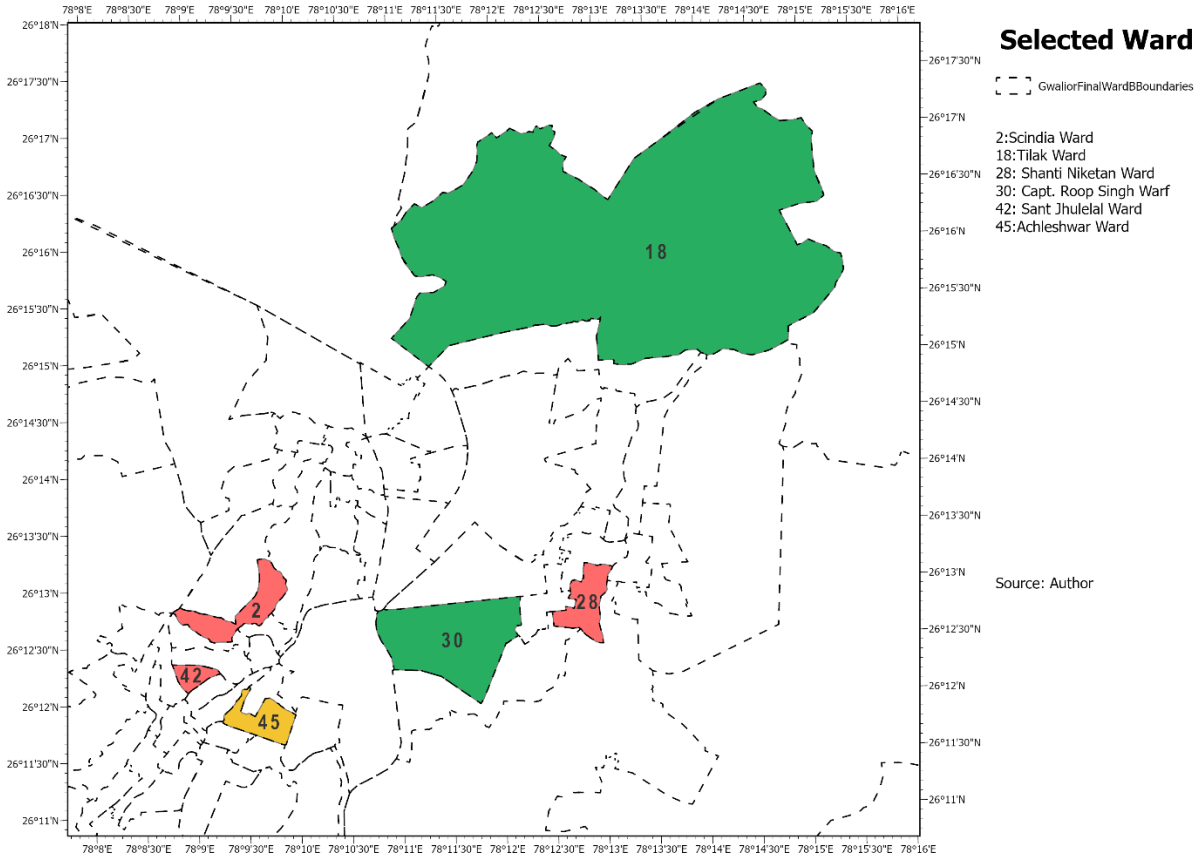


Figure 29: Selected Wards for Survey *Source: Author Using ArcGIS Pro*

8. Primary Survey Analysis

8.1 Survey Design and Administration

A structured resident questionnaire was designed to gather primary data on how residents of the six selected wards perceive and experience BGI in relation to their social wellbeing. The questionnaire comprised 19 questions across five sections: respondent profile (Section A, Q1-Q3), BGI access patterns (Section B, Q4-Q6), perceived wellbeing using a five-point Likert scale (Section C, Q7-Q12), satisfaction with green and blue infrastructure (Section D, Q13-Q17), and suggestions for improvement (Section E, Q18-Q19). The survey was administered digitally through Google Forms during April 2026, achieving a total of 600 valid responses with exactly 100 respondents from each of the six wards.

Section C included six Likert-scale statements measuring different dimensions of perceived social wellbeing: physical health benefits (Q7), mental health and stress relief (Q8), peacefulness near water bodies (Q9), safety of green spaces for women and children (Q10), social interaction facilitated by green spaces (Q11), and cooling and shade in summer (Q12). Respondents rated each statement from 1 (Strongly Disagree) to 5 (Strongly Agree). A composite Social Wellbeing Index (SWI) was constructed from these six items, with full methodological detail presented in Section 8.5.

8.2 Ward Profiles and Field Observations

Before presenting the survey findings, this section provides a detailed profile of each of the six selected wards. Each profile combines quantitative BGI and NDVI data with on-ground field observations and drone photography conducted between March and April 2026. The drone footage , showing the relationship between existing green parks and the surrounding urban fabric, forms a critical layer of primary evidence, visually corroborating the spatial and survey findings that follow. Together, these profiles establish the physical and social context within which resident perceptions of BGI were formed.

8.2.1 Ward 42 - Sant Jhulelal Ward (Low BGI)

Ward No.	42	**Ward Name**	Sant Jhulelal Ward
BGI Per Capita	0.19 sqm/person	**BGI Category**	Low BGI
Mean NDVI	0.151	**Composite SWI**	2.30 / 5.0
Green Spaces	Minimal - fragmented patches	**Water Bodies**	None accessible

Ward 42 (fig. 30) is the most BGI-deprived ward in the entire Gwalior Municipal Corporation, recording just 0.19 sqm of green and blue space per resident - less than two percent of the URDPFI standard of 10 sqm per person. Located in the dense urban core, the ward is characterised by tightly packed residential development with virtually no open space reservation. Streets are narrow, building coverage is high, and the few open plots that exist are either privately held or informally encroached upon.

No formally designated parks or gardens exist within the ward boundary. The only green elements visible in satellite imagery and drone footage are scattered roadside trees and a handful of small private compound plantings. There are no accessible water bodies. The mean NDVI of 0.151 - the lowest of all six survey wards - independently confirms the near-total absence of vegetation cover at ground level.



Figure 30: Ward 42 Aerial View Using Drone 1 *Source: Author*

The survey of 100 Ward 42 residents confirms the severity of this deprivation. Twenty percent of respondents reported visiting a park or green space rarely or never (15 percent rarely, 5 percent never), while only 10 percent reported daily visits. Thirty percent of residents reported their nearest green space to be more than one kilometre away, with a further 38 percent at 300 metres to 1 kilometre. The composite Social Wellbeing Index score of 2.30 out of 5.0 is the lowest across all six wards. Item-level analysis reveals especially low scores on perceived safety for women and children (Q10 mean 1.89) and social interaction in green spaces (Q11 mean 1.99), pointing to compounded deprivation , not only is BGI scarce, but what little exists fails to support social cohesion or female-friendly usage.



Figure 31:Ward 42 Aerial View Using Drone 2 *Source: Author*

Ward 42(fig. 31) represents the planning failure that this study seeks to address most directly. The intervention priority here is to identify any underutilised municipal plot, road margin, or institutional open space that can be developed as a pocket park - even a space of 300 to 400 square metres would meaningfully serve the ward's dense residential population. The drone footage makes clear that no amount of maintenance improvement can compensate for the structural absence of BGI in this ward; new space creation is the non-negotiable first step.

8.2.2 Ward 28 - Shanti Niketan Ward (Low BGI)

Ward No.	28	**Ward Name**	Shanti Niketan Ward
BGI Per Capita	0.85 sqm/person	**BGI Category**	Low BGI
Mean NDVI	0.202	**Composite SWI**	2.38 / 5.0
Green Spaces	Very limited formal parks	**Water Bodies**	Present but degraded

Ward 28 presents a qualitatively different type of BGI deprivation from Ward 42 (fig.32). While the ward records a slightly higher BGI per capita of 0.85 sqm per person, this figure is largely accounted for by water bodies that are present within the ward boundary but are encroached upon, polluted, and functionally inaccessible to residents. The ward is dense and predominantly residential, with a mix of older housing stock and more recent infill development.

The water bodies recorded within Ward 28 are the defining feature of its BGI profile - but also the central planning problem. Field observation and drone footage confirm that these water bodies have shrunk significantly due to encroachment from three sides, are surrounded by solid waste accumulation, and have no fencing, footpath, or vegetation buffer that would make them approachable as public amenity spaces. Formal green spaces within the ward are minimal and poorly maintained.



Figure 32:Ward 28 Aerial View Using Drone 1 *Source: Author*

Survey results from the 100 Ward 28 respondents highlight the critical distinction between the presence of BGI assets and their functional quality. Fourteen percent reported visiting green spaces rarely or never (10 percent rarely + 4 percent never), 58 percent visited weekly, 16 percent monthly, and 12 percent daily - modestly higher daily rates than Ward 42 reflecting the use of informal walking spaces. Twenty-four percent reported the nearest green space being more than one kilometre away (fig.33). The composite SWI of 2.38 is only marginally above Ward 42, despite a higher nominal BGI per capita - confirming that degraded, inaccessible infrastructure provides no meaningful wellbeing benefit. A revealing item-level finding emerges in the water peacefulness item (Q9 mean 3.60), which scored markedly higher than other items in this ward - indicating that residents recognise the latent restorative value of water but cannot access it.



Figure 33:Ward 28 Aerial View Using Drone 2 *Source: Author*

Ward 28 makes the case for blue infrastructure restoration as a planning priority. The intervention here is not to create new BGI but to restore what already exists - de-silting the water body, removing encroachments, establishing a vegetated buffer, and providing a simple footpath along the accessible edge. This type of restoration is both cost-effective and high-impact, potentially converting a degraded liability into a functional neighbourhood amenity.

8.2.3 Ward 2 - Scindia Ward (Low BGI)

Ward No.	2	**Ward Name**	Scindia Ward
BGI Per Capita	3.72 sqm/person	**BGI Category**	Low BGI
Mean NDVI	0.267	**Composite SWI**	2.66 / 5.0
Green Spaces	11 mapped - fragmented	**Water Bodies**	Limited

Ward 2, Scindia Ward (fig.34), is the highest-BGI ward within the Low BGI category, with 3.72 sqm per person and 11 mapped green spaces. It was selected specifically to test the fragmentation hypothesis - whether multiple small, disconnected green spaces can generate the same wellbeing outcomes as fewer, larger, better-connected spaces. The ward occupies an older, established part of the city with a mix of residential, commercial, and institutional land uses.

The 11 green spaces mapped within Ward 2 range from small neighbourhood gardens to institutional open grounds. Drone footage reveals a consistent pattern across these spaces: individually they are small, often bounded by walls or fencing that limits visibility and access, and separated from each other by significant stretches of built-up area. The mean NDVI of 0.267 is the highest of the three Low BGI wards, reflecting the slightly better overall vegetation cover, but the spatial fragmentation is clearly visible from aerial perspective.



Figure 34: Ward 02 Aerial View Using Drone 1 *Source: Author*

Despite having 11 green spaces - more than any other Low BGI ward - Ward 2 records a composite SWI of 2.66, only modestly above Wards 42 and 28. Fourteen percent of respondents reported rarely or never visiting any green space (10 percent rarely + 4 percent never), while 56 percent visit weekly and 12 percent daily. Twenty-six percent reported the nearest green space to be more than one kilometre away. This is the fragmentation effect in action: residents are not significantly closer to usable green space simply because more green patches exist on the map (fig.35). Item-level analysis shows particularly low scores on perceived safety (Q10 mean 1.88) and social interaction (Q11 mean 2.05), suggesting that the fragmented patches do not generate the kind of consolidated public space necessary for women, children, and social gatherings.



Figure 35:Ward 02 Aerial View Using Drone 2 *Source: Author*

Ward 2 illustrates that BGI planning cannot focus on quantity alone. The intervention priority here is connectivity - creating tree-lined walking links between existing green nodes, improving access points, and upgrading the quality of the best-located spaces to function as genuine neighbourhood destinations rather than incidental open plots.

8.2.4 Ward 45 - Achaleshwar Ward (Medium BGI)

Ward No.	45	**Ward Name**	Achaleshwar Ward
BGI Per Capita	5.58 sqm/person	**BGI Category**	Medium BGI
Mean NDVI	0.234	**Composite SWI**	3.48 / 5.0
Green Spaces	Moderate - some accessible	**Water Bodies**	Limited

Ward 45, Achaleshwar Ward (fig.36), is the sole Medium BGI ward selected for the survey, with a BGI per capita of 5.58 sqm per person - just above the 5 sqm threshold identified in this study as the point at which BGI begins to generate meaningful wellbeing improvements. The ward occupies a transitional zone between the dense inner city and the more open middle-ring residential areas, with a mix of planned and organic development patterns.

Green spaces in Ward 45 are more accessible than in the three Low BGI wards, with some parks having proper entry gates, basic seating, and partial shade tree cover. Drone footage reveals that while the overall green space quantum is better, maintenance standards remain inconsistent - some parks are reasonably well kept while others show signs of neglect and disuse.

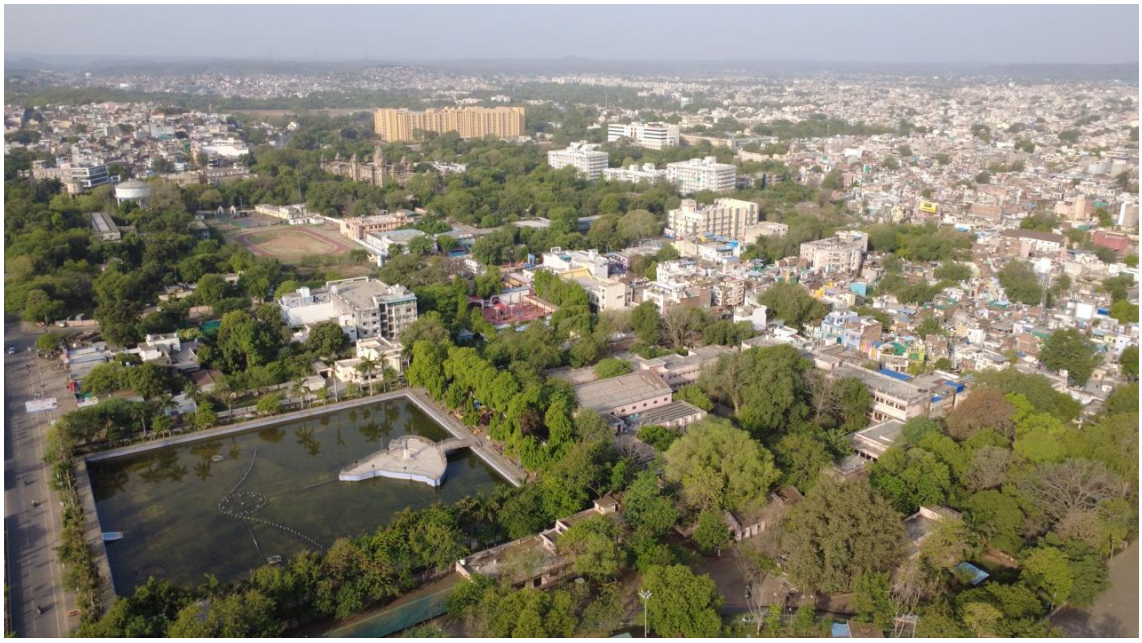


Figure 36:Ward 45 Aerial View Using Drone 1 *Source: Author*

The survey results from the 100 Ward 45 respondents show a marked improvement over the Low BGI wards, with a composite SWI of 3.48 - a jump of 1.10 points above the Low BGI cluster average of 2.45. Sixteen percent of respondents visit green spaces daily and 60 percent weekly, with the rarely-visiting share dropping to 24 percent. Forty percent of residents now report their nearest green space within 100–300 metres - the first ward in the study with substantial close-proximity BGI access. This behavioural shift confirms the threshold effect: crossing the 5 sqm boundary begins to translate into more regular engagement with available green infrastructure (fig.37). Item-level analysis reveals a particularly strong cooling and shade response (Q12 mean 4.02), suggesting that the canopy at MLB College Park and adjacent green areas provides meaningful microclimatic relief during Gwalior's hot summers.



Figure 37:Ward 45 Aerial View Using Drone 2 *Source: Author*

Ward 45 represents the planning opportunity zone - where relatively modest investment in quality improvement and maintenance can push wellbeing outcomes significantly higher.Katora Tal and The Swarn Rekha River corridor flagged in stakeholder interviews represents the most promising upgrade pathway: blue infrastructure restoration in an already Medium BGI ward could push it firmly into the High BGI category at modest cost.

8.2.5 Ward 30 - Capt. Roop Singh Ward (High BGI)

Ward No.	30	**Ward Name**	Capt. Roop Singh Ward
BGI Per Capita	27.15 sqm/person	**BGI Category**	High BGI
Mean NDVI	0.375	**Composite SWI**	3.98 / 5.0
Green Spaces	Well distributed - multiple parks	**Water Bodies**	None accessible

Ward 30, Capt. Roop Singh Ward (fig. 38), is the first of two High BGI wards selected for the survey, with a BGI per capita of 27.15 sqm per person - nearly three times the URDPFI standard. It was selected to represent the urban High BGI condition: well-served by green spaces but entirely lacking accessible water bodies, making it a useful comparison case against Ward 18 which has both green and blue infrastructure.

Drone footage of Ward 30 presents a striking visual contrast with the Low BGI wards. Multiple parks and open grounds are distributed across the ward, with reasonable tree canopy cover and visibly maintained grounds in the larger spaces. The absence of water bodies is apparent from aerial perspective - the NDVI map and drone imagery both show continuous green cover without any blue elements. Streets are wider than in the inner city wards, and green spaces are more integrated into the residential fabric.

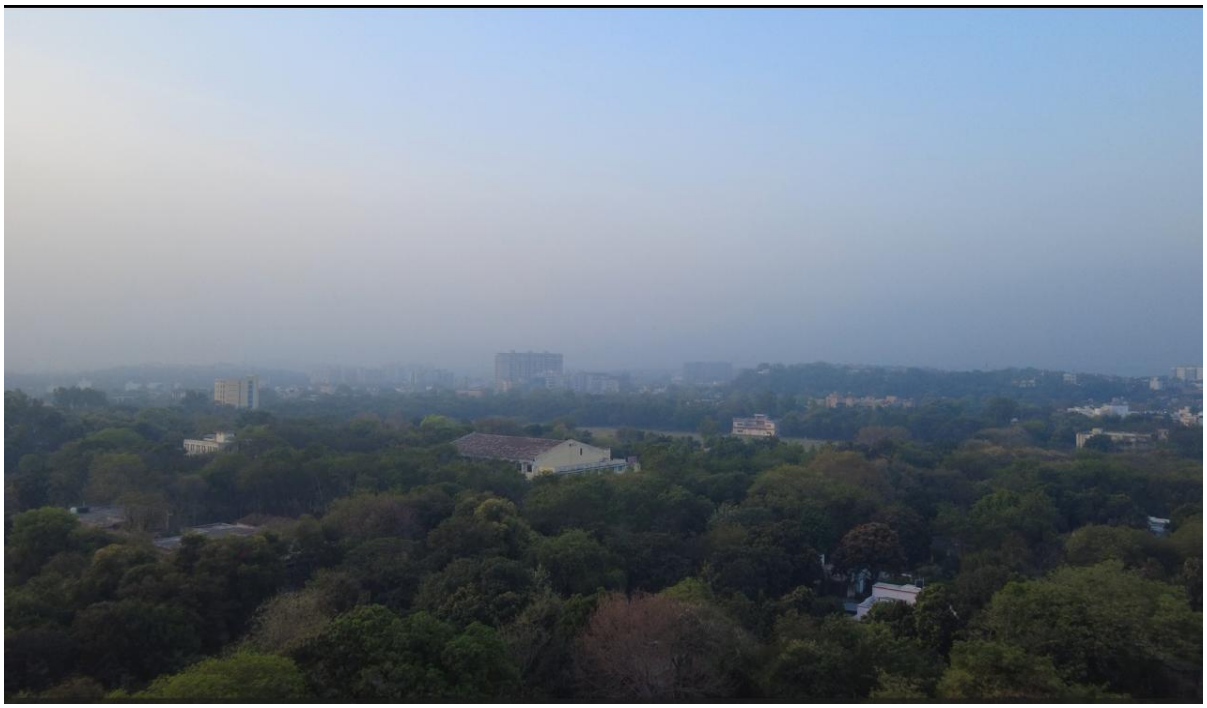


Figure 38:Ward 30 Aerial View Using Drone 1 *Source: Author*

Survey results from the 100 Ward 30 respondents reflect the wellbeing benefits of adequate BGI provision. The composite SWI of 3.98 is the second highest of all six wards. Twenty-five percent of residents visit green spaces daily and 59 percent weekly - a daily-or-weekly access rate of 84 percent that distinguishes this ward from all four lower-BGI wards. Twenty-five percent report their nearest green space within 100 metres and a further 34 percent within 300 metres. Item-level analysis reveals very high scores on cooling (Q12 mean 4.65), mental health (Q8 mean 4.38), and physical health (Q7 mean 4.32), but a notably lower social interaction score (Q11 mean 2.89) - indicating that even well-served green spaces do not automatically generate neighbourhood social cohesion without deliberate design and programming.



Figure 39:Ward 30 Aerial View Using Drone 2 *Source: Author*

Ward 30 (fig. 39) demonstrates what adequate BGI provision can achieve in terms of resident wellbeing and usage behaviour. The planning lessons here are two-fold: first, the addition of even a small ornamental pond or seasonal water retention feature would complete the BGI profile; and second, the social programming and design improvements needed to activate green spaces for neighbourhood social interaction.

8.2.6 Ward 18 - Tilak Ward (High BGI)

Ward No.	18	**Ward Name**	Tilak Ward
BGI Per Capita	81.71 sqm/person	**BGI Category**	High BGI
Mean NDVI	0.403	**Composite SWI**	4.21 / 5.0
Green Spaces	18 mapped - well maintained	**Water Bodies**	26 mapped

Ward 18, Tilak Ward (fig. 40), is the benchmark BGI ward in the study, with the highest BGI per capita value of 81.71 sqm - eight times the URDPFI standard - alongside 18 mapped green spaces and 26 mapped water bodies. The ward occupies a more established part of the city with broader streets, larger plots, and historically protected green and blue features. It was selected to represent the maximum-provision condition observable within the inner-city ward boundary.

Drone footage of Ward 18 reveals a clearly different urban landscape from the other five wards. Green spaces are distributed across the ward at a density that brings most residents within easy walking distance of accessible parks. Several of the mapped water bodies are visible from aerial perspective as functioning pond or lake features with vegetated edges, though drone footage also reveals that a significant number are in various stages of degradation - smaller, encroached, or surrounded by waste. The mean NDVI of 0.403 is the highest of the six survey wards, consistent with the density of both green and blue features.



Figure 40:Ward 18 Aerial View Using Drone 1 *Source: Author*

The survey results from the 100 Ward 18 respondents confirm the strongest wellbeing outcomes in the study. The composite SWI of 4.21 is the highest across all six wards. Twenty-eight percent of residents visit green spaces daily and 60 percent weekly, with only 4 percent reporting rare visits or none. Forty percent of residents report their nearest green space within 100 metres, and 30 percent identify "relaxation / social" as the primary reason for their visits, with another 40 percent visiting regularly for exercise - reflecting genuinely socially active green space use. Item-level analysis shows uniformly high scores: mental health (Q8 mean 4.60), physical health (Q7 mean 4.59), cooling (Q12 mean 4.47), water peacefulness (Q9 mean 4.27), perceived safety (Q10 mean 3.80), and social interaction (Q11 mean 3.53) - though even here, social interaction remains the weakest dimension.



Figure 41:Ward 18 Aerial View Using Drone 2 *Source: Author*

Ward 18 (fig. 41) establishes the planning benchmark for Gwalior. The development plan revision should aspire to bring Medium and Low BGI wards progressively closer to the social wellbeing outcomes observed here. At the same time, the persistent social-interaction gap suggests that even ambitious BGI provision is insufficient on its own: deliberate programming, gender-sensitive design, and community-stewardship models are needed to fully activate green space for social cohesion.

8.3 Respondent Profile

The primary survey achieved 600 valid responses, with 100 respondents drawn from each of the six selected wards. The aggregated demographic profile shows balanced representation across key dimensions. By gender, 40 percent of respondents identified as male, 34 percent as female, and 26 percent preferred not to disclose gender. By age group, respondents were distributed across all five bands: 25 percent in the 18–25 age band, 21 percent in 26–35, 18 percent in 36–45, 19 percent in 46–60, and 17 percent aged 60 and above - providing meaningful representation of younger working residents, middle-aged residents, and older long-term residents. By residence duration, 32 percent had lived in their ward for more than 20 years and a further 30 percent for 10 to 20 years - together, 62 percent of respondents had been resident for more than a decade, providing a strong basis for the deterioration perceptions captured in Q17. The demographic balance is broadly consistent across all six wards, with no single ward dominated by any particular age or gender group, supporting valid inter-ward comparison.

8.4 BGI Access Patterns

The survey captured three dimensions of BGI access: how often residents visit green spaces (Q4), how far the nearest green space is from their home (Q5), and what kind of relationship they have with green spaces in their ward (Q6) (fig. 42).

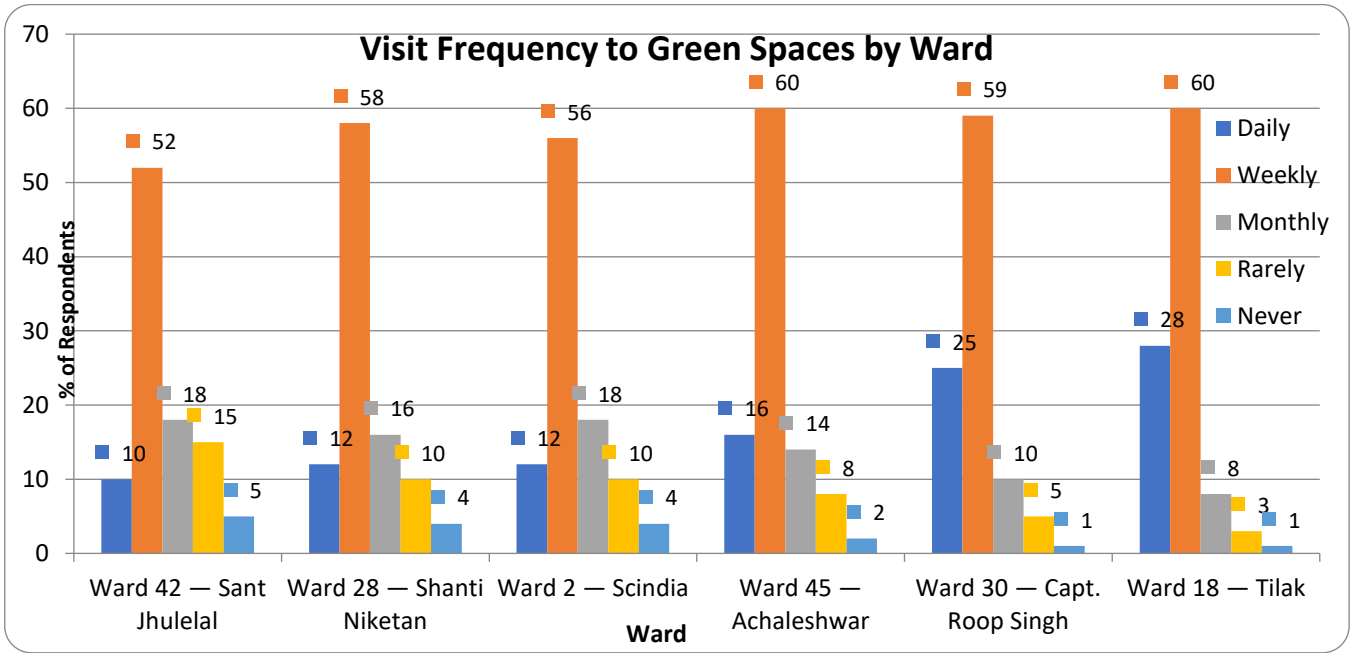


Figure 42: Visit Frequency To GS By Ward *Source: Primary Survey*

Together these items establish the behavioural reality that BGI provision creates for residents. Across the 600 respondents, 17 percent reported daily visits, 58 percent visited

weekly, 14 percent monthly, 8 percent rarely, and 3 percent never. Distance to nearest green space showed a skewed distribution: 23 percent of all respondents lived within 100 metres of green space, while 16 percent reported the nearest green space being more than 1 km away. These aggregate figures conceal substantial inter-ward variation, as Figure 35 below makes clear.

The pattern is striking. In the three Low BGI wards (42, 28, 2), daily-visit rates are modest (10–12 percent) and combined "rarely or never" shares range from 14 to 20 percent. The Medium BGI ward (45) shows clear improvement, with daily visits rising to 16 percent and rarely-or-never visits dropping to 10 percent. The High BGI wards (30 and 18) further reverse the pattern: daily-visit rates reach 25 to 28 percent and rarely-or-never visits fall to just 4 to 6 percent. While daily walking is a common practice across all wards regardless of formal BGI provision - reflecting cultural habits of morning exercise - the survey confirms that high-quality, proximate BGI substantially expands the share of residents who can engage with green space regularly and meaningfully.

8.5 Construction of the Composite Social Wellbeing Index (SWI)

8.5.1 Rationale and Theoretical Basis

The relationship between Blue–Green Infrastructure and resident wellbeing is multi-dimensional. The literature reviewed in Chapter 2 establishes that BGI contributes to wellbeing through at least six distinct pathways: physical health benefits from exercise and air quality (Twohig-Bennett & Jones, 2018), mental health and stress restoration (Choe et al., 2020; Peng et al., 2022), psychological restoration through proximity to water (Choe et al., 2020), perceived safety of public space (Kabisch et al., 2019), social interaction and neighbourhood cohesion (Firth et al., 2019), and microclimate regulation through cooling and shade (Bai & Xing, 2025). No single indicator captures these dimensions adequately.

To measure resident wellbeing in a way that reflects this multidimensionality, a context-specific Composite Social Wellbeing Index (SWI) was constructed from six Likert-scale items corresponding to the six pathways identified above. The composite-index approach is consistent with prior BGI–wellbeing research in Indian contexts, including Murthy and S. (2023) on Chennai and Das and Das (2026) on Kolkata, which similarly combine multiple perception items into aggregate measures of social outcome.

8.5.2 Item Selection and Mapping to Wellbeing Dimensions

The six SWI items (questionnaire items Q7 to Q12) each map to a distinct wellbeing dimension grounded in the literature, as shown in Table 12.

Table 12:Mapping of SWI Items to Wellbeing Dimensions | Source: Compiled by Author

Item	Question Wording	Wellbeing Dimension	Literature Anchor
Q7	Green spaces improve my physical health	Physical health	Twohig-Bennett & Jones (2018); Zhang et al. (2023)
Q8	Green spaces help reduce my stress / improve mental health	Mental health and restoration	Choe et al. (2020); Peng et al. (2022)
Q9	Being near a lake or pond makes me feel peaceful	Blue space psychological restoration	Choe et al. (2020); Nitoslawski et al. (2024)
Q10	Green spaces in my ward are safe for women and children	Perceived safety and inclusion	Kabisch et al. (2019)
Q11	I interact more with neighbours because of nearby green spaces	Social cohesion	Firth et al. (2019); Choe et al. (2020)
Q12	In summer, green areas in my ward provide cooling and shade	Microclimate comfort	Bai & Xing (2025); Thorsson et al. (2025)

All items use a uniform 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), with no reverse-scored items. Uniform anchoring reduces respondent confusion and is appropriate for a short instrument administered in mixed Hindi–English contexts.

8.5.3 Scoring Method

For each respondent i, the individual SWI score is calculated as the arithmetic mean of the six item responses:

$$SWI_i = (Q7 + Q8 + Q9 + Q10 + Q11 + Q12) / 6$$

The ward-level composite SWI is the mean of individual SWI scores across all respondents n in that ward. Equal weighting across the six items is adopted on the basis that no theoretical or empirical justification was identified in the BGI–wellbeing literature for assigning differential weights to these six wellbeing dimensions. Equal weighting is the conventional default in composite social indicator construction (OECD, 2008) and avoids introducing arbitrary analytical bias. The resulting SWI ranges from 1.0 (lowest wellbeing) to 5.0 (highest wellbeing) and is directly interpretable on the original Likert scale.

8.5.4 Sample and Administration

Primary data were collected from 600 respondents across the six selected survey wards (100 respondents per ward) during April 2026. The questionnaire was administered digitally through a Google Form distributed to residents within the six ward boundaries, supplemented by in-person prompts where required to ensure age and gender diversity. Verbal informed consent was obtained from each respondent prior to administration.

8.5.5 Item-Level Response Patterns

Per-item descriptive statistics across the 600 respondents reveal meaningful variation between wellbeing dimensions, indicating that respondents discriminated between the six items rather than treating them as a single construct (Table. 13).

Table 13: Per-Item Descriptive Statistics (n=600) | Source: Author Analysis

Item	Wellbeing Dimension	Mean
Q7	Physical health	3.32
Q8	Mental health	3.43
Q9	Water peacefulness	3.60
Q10	Safety (women & children)	2.62
Q11	Social interaction	2.56
Q12	Cooling and shade	3.49

The two lowest-scoring items - Q11 (social interaction, mean 2.56) and Q10 (perceived safety, mean 2.62) - point to specific qualitative weaknesses in Gwalior's BGI that spatial inventory alone cannot reveal: even where green space exists, it is not actively supporting neighbourhood social cohesion and is not perceived as safe for women and children. The highest-scoring item, Q9 (water peacefulness, mean 3.60), suggests that blue infrastructure carries strong restorative value where it is present, reinforcing the policy priority of blue infrastructure restoration discussed in Section 9.3.

8.5.6 Reliability Assessment

Internal consistency of the six-item scale was assessed using Cronbach's alpha, the standard reliability coefficient for Likert-type composite measures (Cronbach, 1951). The obtained value of $\alpha = 0.77$ ($n = 600$, $k = 6$ items) exceeds the threshold of 0.70 recommended for exploratory social research (Nunnally, 1978), confirming acceptable internal consistency for the composite scale.

Mean inter-item correlation was 0.36 (range 0.14 to 0.51), within the typical 0.3 to 0.5 range expected for a well-constructed multi-dimensional scale where items measure related but distinct facets of a broader construct. Corrected item-total correlations ranged from 0.32 (Q9, water peacefulness) to 0.63 (Q12, cooling), all above the 0.30 minimum recommended for scale item retention (Field, 2018). The lower item-total correlation for Q9 is consistent with its theoretical positioning as the only item specifically concerning blue rather than green infrastructure, capturing a distinct but conceptually related dimension of wellbeing.

The alpha-if-deleted analysis showed that no item, if removed, would substantively improve scale reliability - values would range from 0.71 to 0.78 with any single item deleted. The marginal increase if Q9 were dropped ($\alpha = 0.78$) is small and does not justify removing the only blue-infrastructure item from a study explicitly examining Blue–Green Infrastructure. The six items can therefore be treated as a reliable composite measure of perceived BGI-related wellbeing for the purposes of inter-ward comparison.

8.5.7 Per-Ward Composite SWI

The composite SWI for each ward, alongside the BGI per capita value established in Chapter 7, is presented in Table 14.

Table 14:Composite SWI and BGI Per Capita by Ward (n=600) | Source: Author Analysis

Ward	Ward Name	BGI Cat	BGI sqm/p	n	Composite SWI
42	Sant Jhulelal	Low	0.19	100	2.30
28	Shanti Niketan	Low	0.85	100	2.38
2	Scindia	Low	3.72	100	2.66
45	Achaleshwar	Medium	5.58	100	3.48
30	Capt. Roop Singh	High	27.15	100	3.98
18	Tilak	High	81.71	100	4.21

The ward-level composite SWI scores increase monotonically with BGI per capita category. Aggregated by category, Low BGI wards averaged a composite SWI of 2.45 (n = 300), the Medium BGI ward recorded 3.48 (n = 100), and High BGI wards averaged 4.10 (n = 200). The gap of 1.91 SWI points between the lowest-BGI ward (Ward 42, SWI 2.30) and the highest-BGI ward (Ward 18, SWI 4.21) is substantial on a 1–5 scale and represents the central empirical finding of this study: BGI deprivation in Gwalior

translates directly into measurably lower perceived social wellbeing among residents of the most affected wards.

The monotonic relationship between BGI provision and SWI is the central empirical finding of this study and provides the evidence base on which the planning framework in Chapter 10 is constructed.

8.6 Green Infrastructure Satisfaction

Section D of the questionnaire captured residents' satisfaction with the green spaces in their ward (Q13) and the single biggest problem they identified (Q14). Across the 600 respondents, positive satisfaction (Satisfied or Very Satisfied) was reported by 40 percent of all respondents, while 36 percent reported dissatisfaction, 23 percent were neutral, and 1 percent reported no green space exists. These aggregate figures, however, mask the steep ward-level gradient illustrated in Figure 43.

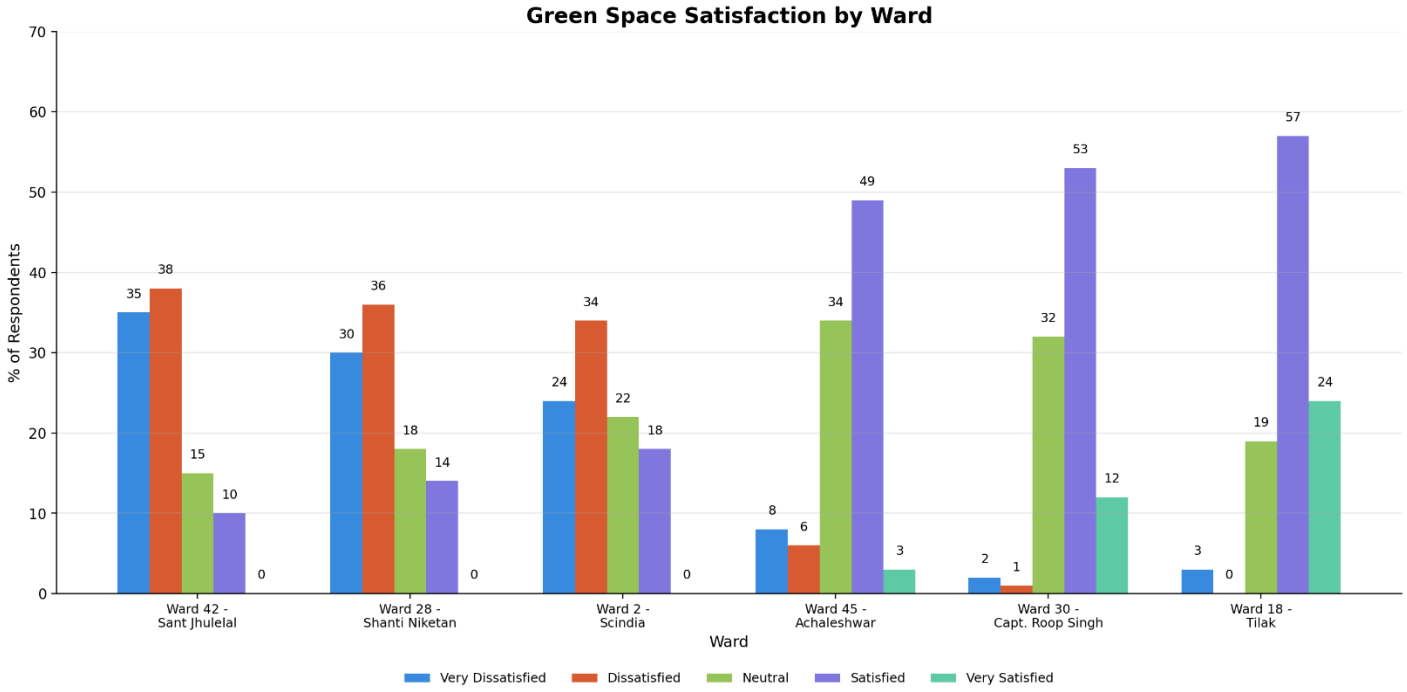


Figure 43:Green Space Satisfaction by Ward (%) *Source: Primary Survey*

Positive satisfaction rises steeply with BGI category, from just 10 percent in Ward 42 to 81 percent in Ward 18 - a 71 percentage-point gap. The Medium BGI ward (45) sits at the transition point with 52 percent positive satisfaction. This satisfaction gradient closely mirrors the SWI gradient and supports a key planning inference: BGI quantity and quality interact. Wards with more BGI per capita also tend to have better-maintained, larger, and more functional spaces - and residents perceive and respond to this composite quality.

The implication is that intervention strategies for Low BGI wards must address not only area additions but also maintenance and design quality from the outset.

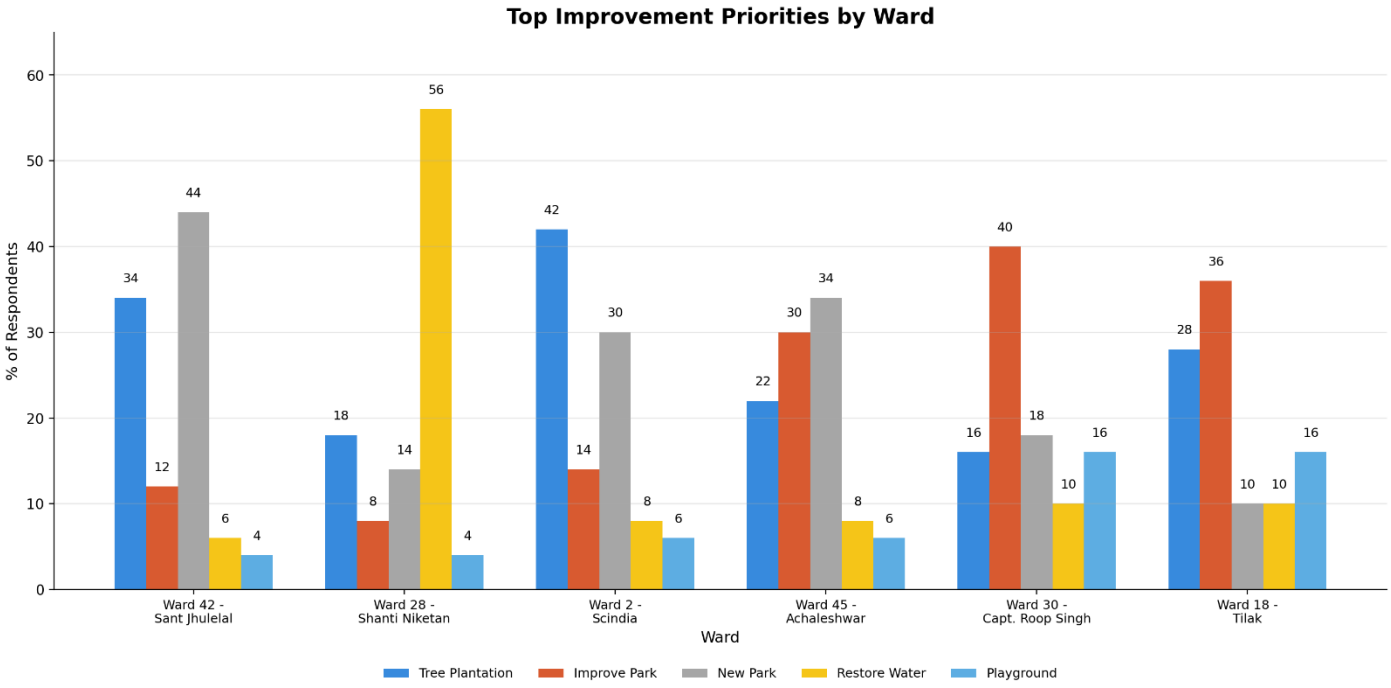


Figure 44:Top Improvement Priorities by Ward | Source: Primary Survey

When asked what single improvement would most benefit their ward (Q18), residents revealed clear priorities that align with their ward's BGI deficit profile (Fig. 44). Low BGI ward residents prioritise new BGI creation: new parks (44 percent in Ward 42), tree plantation (42 percent in Ward 2), and water body restoration (56 percent in Ward 28). Ward 28 stands out with 56 percent of residents prioritising water body restoration - the strongest single-issue concentration in the survey and a direct mandate for Morar River rejuvenation. The Medium BGI ward (45) shows demand for new park additions (34 percent) alongside improvement of existing parks (30 percent). The High BGI wards shift priority toward maintenance and enhancement: Ward 30 residents prioritise improvement of existing parks (40 percent) alongside emerging demand for playgrounds and sports (16 percent), while Ward 18 residents split between improving existing parks (36 percent), tree plantation (28 percent), and playground or sports facilities (16 percent). These differentiated priorities directly inform the ward-category planning framework presented in Chapter 10.

8.7 Blue Infrastructure Satisfaction

Resident satisfaction with water bodies (Q15) and identified problems (Q16) reveal the neglected status of blue infrastructure across Gwalior. Across the 600 respondents, 24 percent reported positive satisfaction with water bodies, 30 percent reported dissatisfaction, 29 percent were neutral, and 17 percent reported "no water body exists" - the latter concentrated heavily in Ward 30. On the problem dimension, the most frequently cited issues across all wards were spread across several categories, with no overwhelmingly dominant concern: 22 percent reported "no major problem," 19 percent reported "no water body exists," 18 percent reported water bodies are "not accessible to public," 17 percent reported pollution and bad smell, 13 percent reported encroachment or shrinking, and 10 percent reported unsafe conditions or lack of lighting. This dispersed problem profile - rather than one dominant issue - signals that blue infrastructure neglect manifests through multiple compounding failures across the city.

The water-body satisfaction picture is qualitatively different from the green-space picture and reveals the neglected status of blue infrastructure across Gwalior. Ward 42 records 100 percent dissatisfaction (52 percent Very Dissatisfied) with water bodies, driven by the complete absence of accessible water. Ward 28 has recorded water bodies but residents report only dissatisfaction or neutral sentiment, validating the GIS-versus-experience gap discussed in Section 9.3. Ward 30 records 100 percent "no water body exists" - confirming the absence noted in the spatial analysis. Only Ward 18 reports universally positive water-body satisfaction. This pattern strongly supports the policy priority of a blue infrastructure restoration programme as a distinct workstream within the GMC BGI framework

8.8 Deterioration Perceptions

Question 17 asked residents whether green spaces or water bodies in their ward had decreased or deteriorated over the past 5–10 years (Fig. 45). Aggregated across all 600 respondents, 30 percent reported significant deterioration, 34 percent reported slight deterioration, 24 percent reported no change, 4 percent reported improvement, and 8 percent were not sure. The picture is therefore overwhelmingly one of decline: 64 percent of all surveyed residents perceive BGI loss over the recent past.

The deterioration pattern is dramatic across BGI categories. Low BGI wards (42, 28,

and 2) cluster tightly at 75–76 percent reporting some level of deterioration over the past 5–10 years. The Medium BGI ward (45) reports 64 percent deterioration. The High BGI wards show progressively better picture: Ward 30 reports 60 percent deterioration but mostly limited to "slight," and Ward 18 reports only 34 percent deterioration with 50 percent reporting no change and 10 percent reporting active improvement. This deterioration trajectory in deprived wards adds urgency to the framework recommendations: without intervention, the spatial inequity documented in Chapter 7 is actively widening at the ward level.

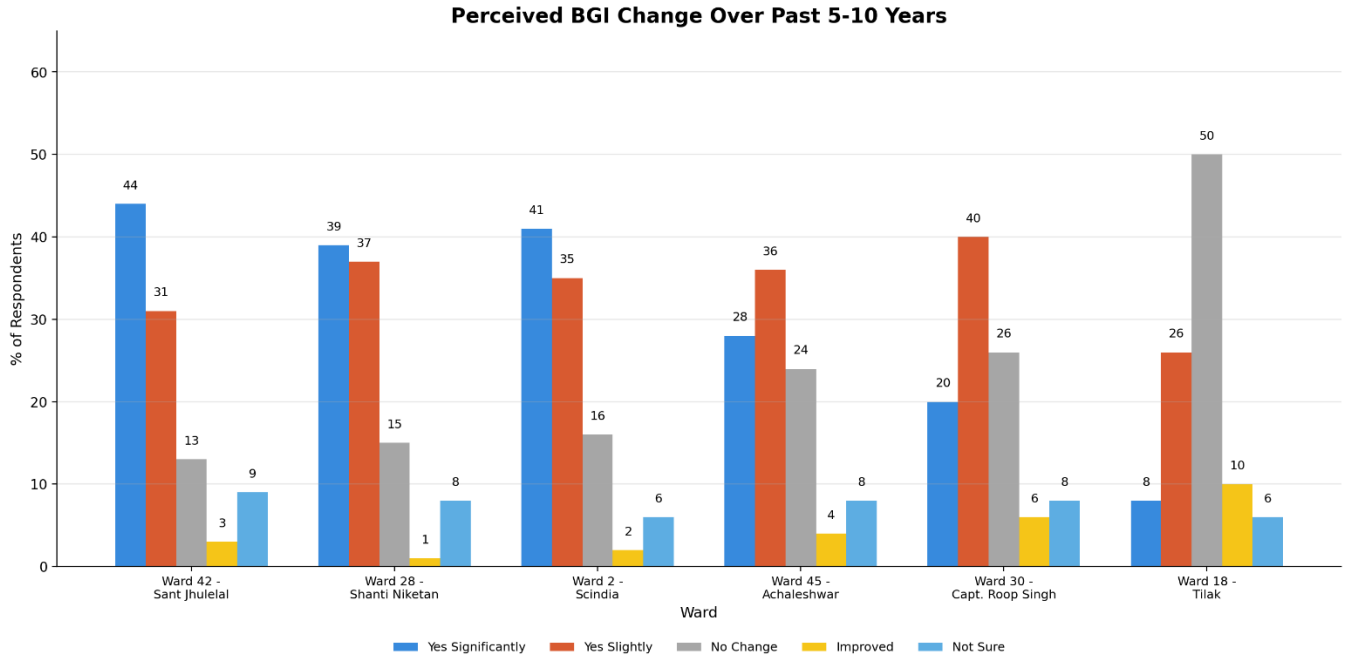


Figure 45 : BGI Change Over Past 5-10 Years *Source: Author's Analysis*

9. DISCUSSION AND KEY FINDINGS

9.1 The BGI-Wellbeing Relationship

The triangulated evidence developed across Chapters 7 and 8 establishes a clear and progressive relationship between BGI provision and resident social wellbeing in Gwalior (Fig. 46). The composite SWI rises monotonically across the BGI categories - from a mean of 2.45 in Low BGI wards to 3.48 in the Medium BGI ward and 4.10 in High BGI wards. The 1.91-point gap between the most deprived ward (Ward 42, SWI 2.30) and the best-served ward (Ward 18, SWI 4.21) is large on a five-point scale and corresponds closely to the order-of-magnitude difference in BGI per capita (0.19 vs 81.71 sqm/person). The reliability of the composite scale (Cronbach's $\alpha = 0.77$, $n = 600$) provides additional confidence that this gradient reflects a substantive and consistent pattern rather than measurement artefact.

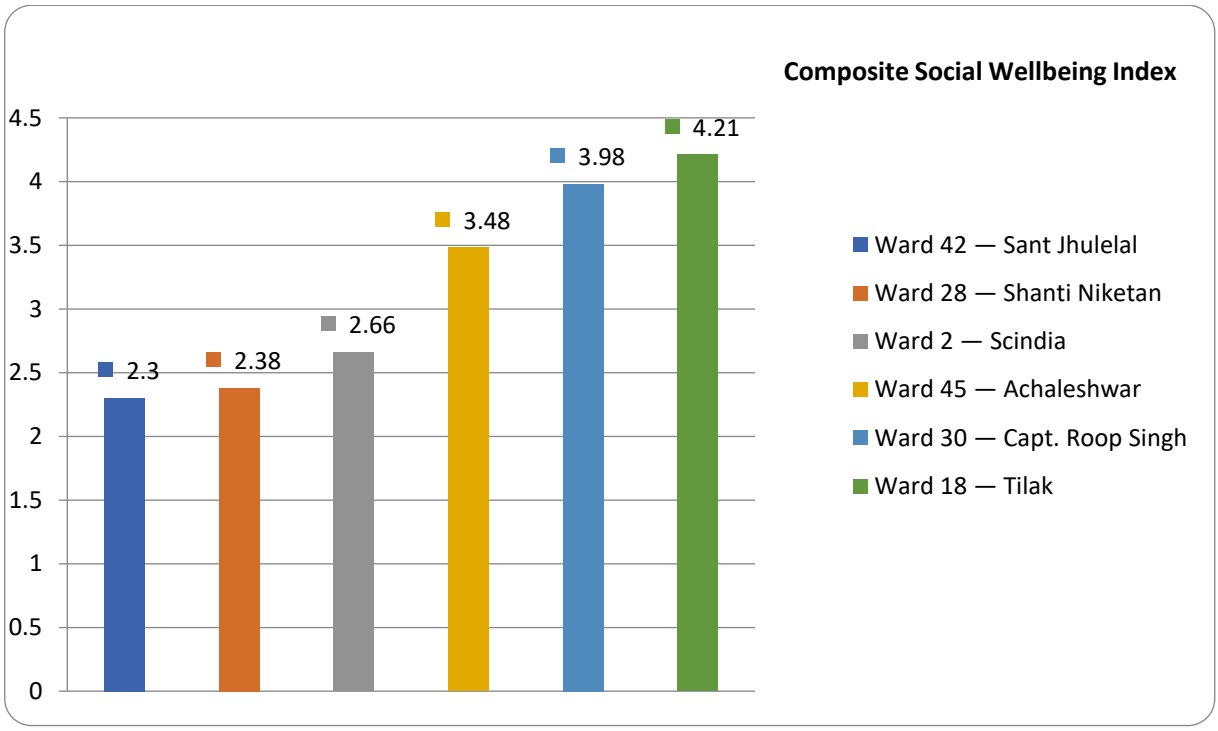


Figure 46: BGI Per Capita vs Social Wellbeing Index - Threshold effect at ~5 sqm/person | Source: Author's Analysis

The logarithmic shape of the BGI–SWI relationship visible in Figure 38 carries important planning implications. The steepest gains in SWI occur in the low BGI range, where each additional square metre of BGI per capita generates large wellbeing returns; diminishing returns set in beyond the URDPFI 10 sqm standard. The threshold effect identified at approximately 5 sqm per person is a particularly useful planning insight:

below this threshold, the three Low BGI wards cluster tightly in their wellbeing scores (2.30 to 2.66) despite BGI values ranging from 0.19 to 3.72 sqm per person, suggesting that below-threshold incremental improvements have limited impact. Above this threshold, the relationship becomes more responsive. Planning interventions should therefore prioritise crossing the 5 sqm minimum as a first target in the most deprived wards, before pursuing the full URDPFI standard.

9.2 Spatial Equity as the Central Finding

The spatial equity analysis reveals that BGI provision in Gwalior is deeply inequitable - 68 percent of inner-city wards fall below even 5 sqm per person, while peri-urban fringe wards record values hundreds of times higher. This inequity reflects planning choices: dense residential development in the urban core has proceeded without adequate open space reservation, while the peri-urban fringe retains open land simply because it has not yet been developed rather than through deliberate green planning. The NDVI data corroborates this through an entirely independent source: wards with the lowest BGI per capita also have the lowest satellite-measured vegetation health, confirming that the inequity in planned BGI translates directly into a measurable inequity in actual environmental quality experienced by residents.

9.3 Blue Infrastructure - A Neglected Dimension

The blue infrastructure findings reveal challenges that green infrastructure analysis alone would miss. Water bodies in Gwalior suffer from encroachment, pollution, and management neglect that renders them inaccessible or unpleasant despite their presence on record. Ward 28 illustrates this clearly: recorded water bodies provide no meaningful wellbeing benefit because they are degraded and encroached upon, yet the high Q9 (water peacefulness) score of 3.60 in this ward suggests that residents recognise the latent restorative value of water and would benefit substantially from restored access. This points to the need for a blue infrastructure restoration and protection programme that addresses functional quality and community accessibility rather than simply counting water bodies in a GIS inventory. The 56 percent priority on water body restoration recorded in Ward 28 (Section 8.6) provides a direct community mandate for such a programme.

9.4 Limitations of the Analysis

Several limitations of this study should be acknowledged. First, the BGI inventory was based on satellite imagery rather than official GMC land records, and some smaller or informally managed green spaces may have been missed. Second, although the NDVI analysis uses three Sentinel-2 scenes captured within a 3-day window across years (22 Feb 2016, 25 Feb 2021, 24 Feb 2026) to minimise seasonal confounding, all three scenes still fall within the dry season and inter-annual variation in pre-acquisition rainfall could marginally influence absolute NDVI values, though the relative inter-ward ranking is robust to such variation. Third, the digital administration of the questionnaire may have under-represented older residents and those with limited smartphone access, particularly in the lowest-income Low BGI wards, though in-person follow-up was used to mitigate this where feasible. Fourth, ward boundary shapefiles were not available from GMC in the public domain; ward polygons were therefore digitised by georeferencing the official GMC ward map raster and cross-verified against the Madhya Pradesh State Geoportal, so minor boundary error of the order of one or two pixels is possible at ward edges. Fifth, spatial data for the Gwalior Fort area and the Morar Cantonment was not available in the public domain as these areas fall under separate administration; both are shown as reference overlays in the maps but excluded from the per-ward tabulations. This exclusion does not affect the ranking of the 66 GMC wards, but the city-wide aggregate figures reported in this chapter should be read as "GMC wards excluding Fort and Morar Cantonment."

The construction and interpretation of the composite SWI is subject to four further limitations. First, the SWI is a perception-based measure rather than an objective health or wellbeing outcome; a high SWI reflects positive experience of BGI rather than directly measured health benefit. Second, the six items, while grounded in the BGI–wellbeing literature, were not adapted from a previously validated psychometric scale, and the SWI is therefore best understood as a context-specific composite indicator rather than a generalisable wellbeing measurement instrument. Third, equal weighting of the six items reflects a deliberate analytical choice rather than empirically derived dimension importance; alternative weighting schemes would produce somewhat different absolute SWI values, though the monotonic ordering of wards by SWI is robust to weighting variation. Fourth, the n = 8 stakeholder interview sample supports illustrative key-informant evidence rather than systematic qualitative analysis.

Despite these limitations, the triangulation of four independent methods - GIS spatial analysis, satellite remote sensing, primary resident surveys, and drone-based field observation, supplemented by stakeholder interviews - provides a robust and multi-layered evidence base for the findings and recommendations of this study.

9.5 Insights from Stakeholder Interviews

To complement the spatial and survey-based evidence, semi-structured informal interviews were conducted with eight stakeholders between March and April 2026. The respondents included a GMC sub-engineer with zonal responsibility, an elected ward councillor, community leaders from political and social organisations, and prominent long-term residents across five of the six survey wards. Table 15 below provides an overview of all respondents.

Table 15: Stakeholder Interview Respondents | Source: Author's Primary Field Interviews, Mar-Apr 2026

S.No.	Name	Designation / Role	Ward	Primary Theme
1	Er. Rajeev Pandey	Sub-Engineer, GMC / Former Zonal Officer	28, 30, 18	Maintenance, public cooperation, government efforts
2	Mr. Shashi Sharma	Parshad (Councillor), Ward 2, GMC	2	Park improvement, green space reduction, public health
3	Mr. Ashok Marwah	Community Leader, Punjabi Parishad Gwalior	30	Satisfaction with existing green spaces, daily usage
4	Mr. Pawan Chadha	Leader, RSS / Prominent Resident	42	Water feature addition, walking tracks, yoga areas
5	Mr. Bhagwan Singh Tomar	Leader, Gwalior Congress / Prominent Resident	18	Water body addition, park maintenance improvement
6	Mr. Mukesh Sharma	Prominent Resident	28	Park addition, Morar River rejuvenation, plantation
7	Adv. Shrilal Chaurasia	Community Leader / Resident	45	MLB College Park experience, park and water body addition
8	Mr. Rajeev Chadda	Local Leader / Prominent Resident	45	Walking tracks, plantation, Katora Swarn Rekha River rejuvenation

9.5.1 Institutional Perspective - GMC and Elected Representatives

Er. Rajeev Pandey, Sub-Engineer at the Gwalior Municipal Corporation and former Zonal Officer responsible for Wards 28, 30, and 18, provided the most direct institutional perspective on BGI management in Gwalior. His central observation was that the GMC and the state government are actively working to improve and maintain parks and water

bodies across the city, but that these efforts are frequently undermined by community behaviour - including vandalism, encroachment, and pollution of green and blue spaces by residents themselves. He emphasised that sustainable BGI improvement requires a two-way commitment: public investment from the government side, and active stewardship from local communities. This perspective is important in contextualising the deterioration data from the survey - where 64 percent of residents across all wards reported BGI decline (Section 8.8) - as reflecting not only institutional failure but also a breakdown of collective civic responsibility.

Mr. Shashi Sharma, the elected Parshad (Councillor) for Ward 2, shared concerns that closely align with the spatial findings of this study. He highlighted the progressive reduction in green cover within his ward and across Gwalior more broadly, attributing this to unregulated development and the conversion of open plots to built uses without adequate open space reservation. He stressed the need for improvement and expansion of existing parks and gardens, and notably drew a direct link between access to green spaces and public health - urging residents to maintain mental and physical wellbeing through regular morning walks, yoga, and visits to nearby. This framing - from an elected representative - lends political weight to the study's finding that BGI directly influences resident wellbeing.

9.5.2 Community and Resident Perspectives - Satisfaction and Aspirations

Mr. Ashok Marwah, a community leader associated with the Punjabi Parishad Gwalior and a long-term resident of Ward 30, represents the experience of a relatively well-served BGI ward. He reported that he visits Jiwaji University grounds every morning for walking and is broadly satisfied with the green conditions available to him. This is consistent with the Ward 30 survey result where 25 percent of respondents reported daily green space visits and the ward recorded a composite SWI of 3.98 - the second highest in the study. His satisfaction, however, should be read alongside the absence of any accessible water bodies in Ward 30, a gap not reflected in his commentary but clearly visible in the spatial data.

Advocate Shrilal Chaurasia, a community leader and resident of Ward 45, similarly described a regular practice of visiting MLB College Park for morning walks and yoga - a pattern consistent with the Ward 45 survey, where 60 percent visit green spaces weekly and a further 16 percent daily. He expressed satisfaction with this park but called for its

improvement and for the addition of more parks and water bodies within the ward. Mr. Rajeev Chadda, also from Ward 45, echoed this aspiration - specifically requesting better walking tracks, improved plantation within existing parks, and the rejuvenation of the Swarn Rekha River as a blue infrastructure.Katora Tal and The Swarn Rekha River, currently degraded and underutilised, represents a significant opportunity for blue infrastructure restoration in the Medium BGI zone.

9.5.3 Perspectives from Low BGI Wards - Deprivation and Demand

The most pointed observations came from respondents in the two Low BGI wards - Ward 42 and Ward 28 - where the spatial deficiency is most acute. Mr. Pawan Chadha, a prominent resident and community leader in Ward 42, acknowledged the near-total absence of green and blue infrastructure in his ward and made specific, actionable suggestions: the introduction of water features such as fountains and small ponds within existing parks - specifically naming Ladies Park, Shivaji Park, and New Shanti Nagar Park - alongside better walking tracks and yoga areas designed to serve residents of all age groups. His identification of specific named parks as intervention sites is valuable for planning purposes.

Mr. Mukesh Sharma, a resident of Ward 28, raised three interconnected demands: the addition of more parks within the ward, the maintenance and rejuvenation of the Morar River - which passes near the ward boundary - and improved plantation within existing park areas. The call for Morar River rejuvenation is particularly significant: it aligns directly with the blue infrastructure gap identified in the GIS analysis and the 56 percent of Ward 28 survey respondents who prioritised water body restoration as their top improvement (Section 8.6). A restored, accessible river edge could transform the BGI profile of Ward 28 at relatively low cost compared to land acquisition for new parks.

Mr. Bhagwan Singh Tomar, a community leader and resident of Ward 18 - the highest BGI ward in the study - offered a perspective from the opposite end of the provision spectrum. Despite Ward 18’s comparatively strong green and blue infrastructure endowment, he called for the addition of more water bodies and better maintenance of existing parks .

His call for better maintenance is directly corroborated by the survey: 36 percent of Ward 18 respondents identified "poor maintenance" as the single biggest problem with the ward’s green spaces, and 34 percent reported some BGI deterioration over the past

decade - despite 81 percent also reporting overall satisfaction with provision. This combination - overall satisfaction with provision alongside specific dissatisfaction with maintenance quality - reveals an important nuance for High BGI wards: residents are not complacent simply because their ward is well-served. They retain expectations of upkeep and improvement that mirror the maintenance concerns identified by GMC officials in Section 9.5.1.

9.5.4 Common Themes and Stakeholder Consensus

Four themes emerge consistently across all eight interviews, regardless of ward, role, or political affiliation. First, maintenance is universally identified as a critical gap - not just in Low BGI wards but across all BGI categories. Second, water body restoration and addition is a shared aspiration, with specific rivers - the Morar and the Swarn Rekha - named as priority candidates for rejuvenation. Third, walking and yoga infrastructure is a recurring demand, reflecting the strong cultural practice of morning physical activity in Indian cities and the role that parks play as health infrastructure beyond their ecological function. Fourth, and most significantly, there is consistent recognition across all respondents - from the GMC engineer to elected councillors to community leaders - that the current state of BGI in Gwalior falls short of what residents need and deserve. This convergence of institutional, political, and community voices around the same set of concerns provides powerful real-world validation for the quantitative findings of this study.

Taken together, the interview evidence reinforces the central argument of this thesis : the challenge facing Gwalior's BGI is not one of awareness or aspiration, but of planning priority, institutional coordination, and sustained maintenance commitment. The voices recorded here - from a municipal engineer to a ward councillor to long-term residents - all point toward the same conclusion that the GIS maps and survey data have already established through numbers.

10. PLANNING PROPOSAL FRAMEWORK AND RECOMMENDATIONS

10.1 Basis and Approach

The planning framework (fig. 47) presented in this chapter draws directly from the three-strand evidence base developed across Chapters 7, 8, and 9. The spatial analysis established that 68 percent of inner-city wards fall below 5 sqm of BGI per person. The resident survey, anchored by a Cronbach's alpha of 0.77 , demonstrated that this deprivation translates into measurably lower social wellbeing, with composite SWI scores averaging 2.45 in Low BGI wards compared to 4.10 in High BGI wards - a gap of 1.65 SWI points on a five-point scale. The stakeholder interviews revealed that the underlying problem is not simply one of resource scarcity - it is one of fragmented governance, poor maintenance, and the absence of BGI as an integrated planning category within the GMC.

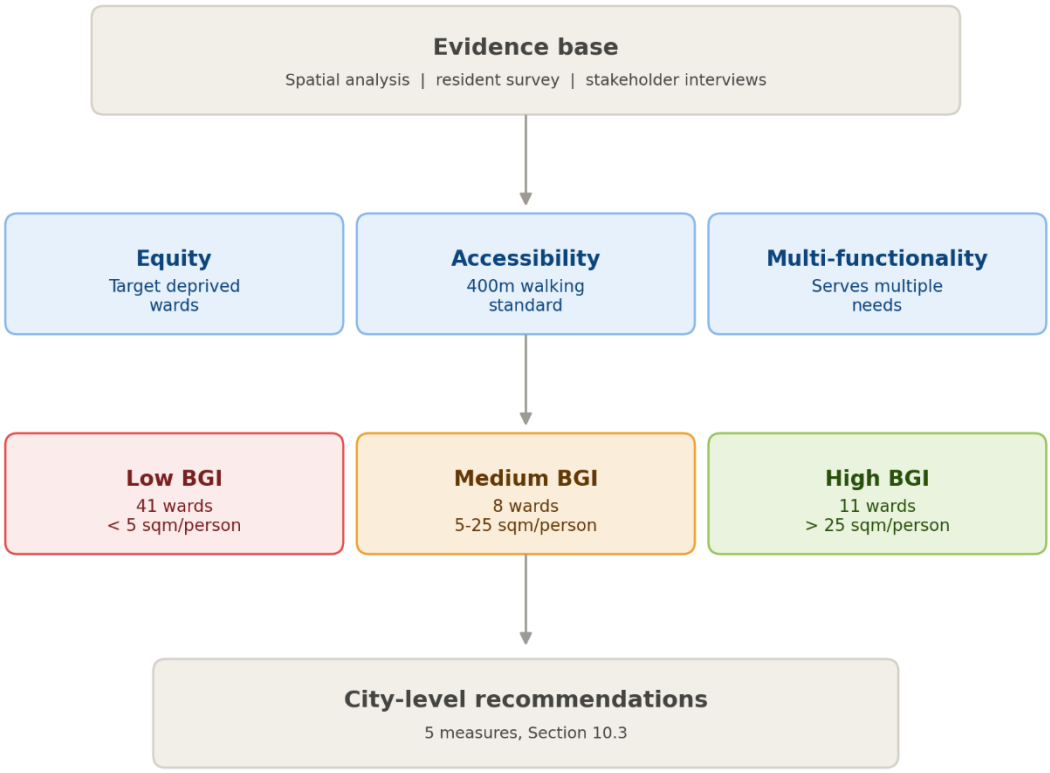


Figure 47: framework overview diagram *Source: Author*

The framework is organised around three principles that respond directly to these findings. The first is equity - BGI interventions must be weighted toward the most deprived inner-city wards, where the gap between need and provision is widest. A city-

wide total of 14,633 hectares of BGI masks acute deprivation in individual wards like Ward 42, where the figure is 0.19 sqm per person and the composite SWI is just 2.30. The second is accessibility - infrastructure that exists but cannot be reached or safely used provides no wellbeing benefit. The survey finding that Ward 28 residents prioritise water body restoration at 56 percent despite recorded water bodies within the ward boundary illustrates this point clearly. The third is multi-functionality - in a dense city with limited land, green and blue infrastructure must serve multiple simultaneous purposes: ecological services such as evaporative cooling and stormwater management, social functions such as recreation and social interaction, and urban resilience functions such as heat island mitigation.

10.2 Ward-Level Strategy - Differentiated by BGI Category

Given the significant variation in BGI provision across the 60 wards (fig. 48), a uniform city-wide intervention strategy would be neither equitable nor effective. The framework therefore adopts a differentiated approach, tailored to the three BGI categories identified in Chapter 7.

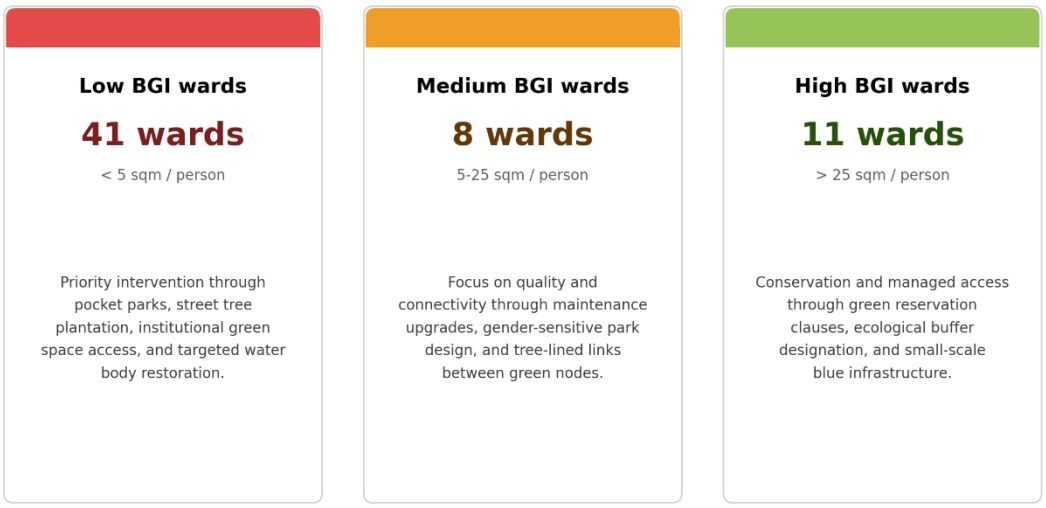


Figure 48: Ward-category comparison *Source:Author*

10.2.1 Low BGI Wards - Priority Intervention Zones

The 41 wards classified as Low BGI, with less than 5 sqm per person, represent the most urgent planning challenge. These wards carry the highest population densities and the lowest green and blue provision - and the survey confirms they also record the lowest wellbeing outcomes, with composite SWI scores ranging from 2.30 in Ward 42 to 2.66 in Ward 2. The immediate planning objective in these wards is to cross the 5 sqm

threshold, which the threshold analysis in Section 9.1 identified as the point at which BGI begins to have a meaningful impact on resident wellbeing.

Given the severe land constraints in these areas, large-format parks are generally not feasible. The strategy here relies on a combination of smaller-scale interventions that collectively accumulate meaningful BGI area. Pocket parks on underutilised municipal plots - even those as small as 300 to 500 square metres - can serve as accessible neighbourhood green nodes when designed with shade trees, seating, and safe lighting. Ward 42, with just 0.19 sqm per person and virtually no usable green space, should be treated as the anchor pilot ward for this intervention type.

Street greening through continuous tree plantation along road margins, median strips, and footpaths represents another scalable strategy. Survey data reinforces this priority: 42 percent of Ward 2 residents and 34 percent of Ward 42 residents identified tree plantation as a key beneficial improvement for their ward, alongside priorities for new parks (Section 8.6). In dense inner-city wards where formal park development faces land acquisition barriers, street trees provide shade, reduce surface temperatures, improve walkability, and contribute to BGI per capita area. Coordination with the Public Works Department for road widening projects provides an entry point for mandatory tree plantation clauses.

Institutional green spaces - schools, hospitals, government offices - represent a largely untapped BGI resource in Low BGI wards. Many such institutions hold open land that is currently unused or poorly maintained. A GMC programme to formalise public access to institutional green areas during non-operational hours, combined with basic landscaping support, could yield significant BGI area addition without land acquisition.

Where water bodies exist within Low BGI wards in degraded condition - as in Ward 28 - targeted restoration rather than new development is the appropriate first step. The strength of resident demand here is unambiguous: 56 percent of Ward 28 respondents identified water body restoration as their top improvement priority, the strongest single-issue concentration in the entire survey. De-silting, bund repair, removal of encroachments, and establishment of a vegetated buffer zone around the water body edge - particularly along the Morar River corridor - can restore both ecological function and public accessibility within a relatively short timeframe and at modest cost.

10.2.2 Medium BGI Wards - Quality and Connectivity Improvement

The eight wards classified as Medium BGI, between 5 and 25 sqm per person, have crossed the minimum threshold but fall short of the URDPFI standard of 10 sqm. The survey evidence from Ward 45 - the representative Medium BGI ward - confirms the threshold effect with a composite SWI of 3.48, fully 1.03 points above the Low BGI average. However, the data also reveals that 64 percent of Ward 45 residents perceive ongoing deterioration of BGI, with 32 percent identifying poor maintenance as the biggest problem - indicating that quality and maintenance determine whether existing BGI continues to translate into wellbeing benefit.

The strategy for Medium BGI wards therefore focuses less on adding new BGI area and more on improving the functional quality of what already exists. This means upgrading existing parks with better maintenance schedules, improved lighting, drinking water facilities, and gender-sensitive design features such as enclosed women's corners and safe entrances. The survey finding that 34 percent of Ward 45 residents prioritise new park additions and 30 percent prioritise improving existing parks, alongside 32 percent identifying "poor maintenance" as the dominant problem, points to a dual need: both quality enhancement of current parks and expansion of anchor green spaces.

Connectivity between existing green spaces is a second priority in this category. Medium BGI wards often have multiple green nodes that are physically disconnected from one another. Linking these through tree-lined walking routes or greened street corridors creates a functional green network that improves overall accessibility and encourages more regular usage - potentially shifting the visit pattern from weekly (the Ward 45 norm) toward daily (the High BGI norm). Restoration of the Swarn Rekha River, specifically named by Ward 45 stakeholders (Section 9.5.2), would create an exemplary connective spine for this purpose.

10.2.3 High BGI Wards - Conservation and Managed Access

The eleven wards classified as High BGI, excluding the six peri-urban wards added in 2016, have BGI per capita values that meet or substantially exceed the URDPFI standard. The planning priority in these wards is conservation and protection rather than new development. The survey confirms that residents in these wards already experience high wellbeing (composite SWI 3.98 to 4.21) and that 47 percent of Ward 18 residents perceive active BGI improvement. As urbanisation pressure extends into these areas, however,

there is a significant risk that the open land and natural vegetation that currently accounts for their high BGI values could be lost to residential or commercial encroachment.

Mandatory green space reservation clauses in development approvals for these wards are the primary planning tool. Any new layout or building permission in High BGI wards should require retention of a minimum percentage of the plot area as permeable, vegetated open space. For the fort hillock, Tighra & Ramaua Reservoir, and Sank,Swarna Rekha,Murar River corridor - the three major ecological assets identified in Chapter 6 - formal ecological buffer designations should be established in the Development Plan 2035 revision.

A specific gap identified in Ward 30 - the complete absence of accessible water bodies despite high overall BGI - points to a refinement of the High BGI strategy: ensuring that the green-only profile is complemented by even small-scale blue infrastructure (ornamental ponds, seasonal water retention features) to deliver the full BGI experience. Resident demand in Ward 30 emphasises improvement of existing parks (40 percent priority) and the addition of new parks (18 percent), suggesting that even well-served wards retain appetite for quality upgrades and modest expansion.

10.3 City-Level Recommendations

Beyond the ward-category strategy, five city-level recommendations emerge from the study's findings.

10.3.1 Integration of BGI into the Development Plan 2035 Revision

The most fundamental structural change required is the treatment of BGI as a primary planning category in the forthcoming DP 2035 revision, rather than as a residual land use. This means establishing ward-level BGI per capita targets - a minimum of 5 sqm as an immediate standard and 10 sqm as a medium-term target aligned with URDPFI guidelines - and making these targets binding on development approvals. Mandatory open space reservation in all new residential layouts, as already required under URDPFI but inconsistently enforced, should be a non-negotiable condition of planning permission.

10.3.2 A GMC BGI Cell - Institutional Coordination

The stakeholder interviews confirmed that BGI currently falls across multiple departments with no coordinating authority. A dedicated BGI Cell within the GMC - even a small one comprising a GIS analyst, ecologist, and a planning officer - would provide the institutional focal point needed to maintain the city's BGI inventory, track ward-level

performance against targets, coordinate between departments, and manage community participation programmes. Without this, ward-level strategies remain dependent on individual officials and are vulnerable to discontinuity when personnel change.

10.3.3 Blue Infrastructure Restoration Programme

Given the findings on water body degradation - particularly in Ward 28 and the broader blue infrastructure satisfaction data - a dedicated blue infrastructure restoration programme is recommended, focused initially on the ten to fifteen most accessible and restorable urban water bodies within the GMC boundary. The programme should combine physical restoration works with legal protection through heritage or ecological designation where applicable, and establish clear maintenance responsibility at the ward level. Coordination with the Madhya Pradesh Pollution Control Board for the Sank,Swarna Rekha,Murar River corridor is a specific recommendation given the river's potential as a continuous blue infrastructure corridor through the southern parts of the city.

10.3.4 Access Within Walking Distance - The 400-Metre Standard

The survey data showed that in Low BGI wards, a substantial share of residents reported distances of more than one kilometre to the nearest green space (30 percent in Ward 42, 24 percent in Ward 28, 26 percent in Ward 2), with combined "more than 300 m" shares reaching 60–70 percent in these wards. Given that walking catchment studies consistently show residents are far less likely to use green spaces beyond 400 metres, the GMC should adopt a 400-metre walking catchment standard as a BGI accessibility planning criterion. Spatial analysis of gaps in this catchment coverage - areas within the GMC boundary that fall outside 400 metres of any accessible green space - should drive the prioritisation of new pocket park locations in Low BGI wards.

10.3.5 Community Participation and Maintenance Models

The deterioration data - with 64 percent of residents across the survey reporting some BGI deterioration over the past 5–10 years, and 75–76 percent of Low BGI ward residents perceiving decline - points to a maintenance crisis that capital investment alone cannot solve. Community-based maintenance models, in which ward-level resident welfare associations or mahila mandals take custodial responsibility for small parks in exchange for basic GMC support such as water connection and tool provision, have been successfully implemented in other Indian cities and offer a practical model for Gwalior. These models also address the persistent gender-safety concerns raised in the survey (Q10

mean score of just 2.62 across all wards, the second-lowest of the six SWI items), since local community involvement increases the effective surveillance and social ownership of green spaces.

10.4 Implementation Phasing

The recommendations are organised across three implementation phases that reflect both resource constraints and planning sequencing (Table. 16).

Table 16:BGI Implementation Phasing | Source: Author

Phase	Timeline	Priority Actions
Short Term	0–2 Years	Ward-level BGI gap analysis; pilot pocket parks in Ward 42 and 2 other critically deprived wards; water body restoration at 3–5 priority sites; establish GMC BGI Cell
Medium Term	2–5 Years	Street greening across all Low BGI wards; park upgrades in Medium BGI wards; formalise 400m catchment standard in DP 2035; scale community maintenance model citywide
Long Term	5–10 Years	Achieve 5 sqm minimum in all inner-city wards; ecological buffer designations for fort hillock and Tighra & Ramaua Reservoir; five-yearly SWI/BGI per capita reassessment against URDPFI 10 sqm standard

10.5 Conclusion

The findings of this study demonstrate that blue-green infrastructure in Gwalior is not distributed as a planning outcome - it is distributed as a historical accident, shaped by topography, development pressure, and institutional neglect rather than deliberate equity-oriented planning. The consequence is a city where residents in the densest, most vulnerable wards have the least access to the ecological and social benefits that green and blue spaces provide. The composite SWI evidence developed in this study - with a 1.91-point gap between the most-deprived and best-served wards on a five-point scale - quantifies this inequity in human terms and reframes BGI provision as a social wellbeing issue, not only an environmental one.

The planning framework proposed here does not require extraordinary resources or radical institutional restructuring. It requires a reorientation of priorities: treating BGI as a core urban planning category rather than an add-on, directing resources toward the wards where the wellbeing gap is greatest, and building the institutional capacity to maintain what is built. The threshold finding - that crossing 5 sqm per person triggers a measurable improvement in resident wellbeing - provides planners with a clear, achievable first target. Meeting that target across Gwalior’s 41 critically deprived wards is not merely an environmental objective. It is a social equity imperative.

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Annexure A - Resident Survey Questionnaire

Survey instrument administered to 600 respondents (100 per ward × 6 wards) over April 2026 via Google Forms.

RESIDENT SURVEY - BGI & SOCIAL WELLBEING

Gwalior | M.Plan Dissertation 2024–26 | MANIT Bhopal | Shourya Shrivastava

Ward No.: ☐ 2 ☐ 18 ☐ 28 ☐ 30 ☐ 42 ☐ 45

BGI Category: ☐ Low ☐ Medium ☐ High

Date: ___ / ___ / 2026 Respondent ID: _____

Interviewer: _____ Duration: _____ minutes

Consent: This survey is for academic research only. Responses are confidential. Participation is voluntary. Verbal consent: ☐ Yes

SECTION A - Respondent Profile

Q1. Age group: ☐ 18–25 ☐ 26–35 ☐ 36–45 ☐ 46–60 ☐ 60+

Q2. Gender: ☐ Male ☐ Female ☐ Prefer not to say

Q3. How long have you lived in this ward? ☐ < 1 year ☐ 1–5 yrs ☐ 5–10 yrs ☐ 10–20 yrs ☐ > 20 yrs

SECTION B - Access to Green Spaces & Water Bodies

(BGI = parks, gardens, open green spaces, lakes, ponds, rivers)

Q4. How often do you visit a park or green space near your ward? ☐ Daily ☐ Weekly ☐ Monthly ☐ Rarely ☐ Never

Q5. How far is the nearest green space from your home? ☐ < 100 m ☐ 100–300 m ☐ 300 m–1 km ☐ > 1 km ☐ Don't know

Q6. What best describes your relationship with green spaces in your ward?

☐ Visit regularly - for exercise / walk ☐ Visit regularly - relaxation / social

☐ Visit occasionally - lack of time ☐ Rarely visit - too far / poor condition

☐ Never visit - feels unsafe ☐ Never visit - none exist nearby

SECTION C - Perceived Wellbeing (Likert 1–5 scale: 1 = Strongly Disagree → 5 = Strongly Agree)

Q7. Green spaces improve my physical health. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Q8. Green spaces help reduce my stress / improve mental health. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Q9. Being near a lake or pond makes me feel peaceful. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Q10. Green spaces in my ward are safe for women and children. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Q11. I interact more with neighbours because of nearby green spaces. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Q12. In summer, green areas in my ward provide cooling and shade. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

SECTION D - Satisfaction & Problems

Q13. Overall satisfaction with green spaces / parks in your ward:

☐ Very satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Very dissatisfied ☐ None exist

Q14. Biggest problem with green spaces in your ward? ☐ Poor maintenance ☐ Too small / inadequate ☐ Unsafe at night ☐ Encroachment / shrinking ☐ No green space at all ☐ No problem

Q15. Overall satisfaction with water bodies in or near your ward:

☐ Very satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Very dissatisfied ☐ No water body exists

Q16. Biggest problem with water bodies in your ward?

☐ Pollution / bad smell ☐ Encroachment / shrinking ☐ Not accessible to public ☐ Unsafe / no lighting

☐ No water body exists ☐ No major problem

Q17. Have green spaces or water bodies in your ward decreased or deteriorated over the past 5–10 years?

☐ Yes, significantly ☐ Yes, slightly ☐ No change ☐ Improved ☐ Not sure

SECTION E - Suggestions

Q18. What would benefit your ward the MOST?

☐ New park / garden ☐ Improve existing park ☐ Restore water body ☐ Tree plantation ☐ Playground / sports

Q19. Any suggestion to improve green or blue infrastructure in your ward?

_____

___

_____

___

Interviewer Notes (not for respondent):

Respondent cooperation: ☐ High ☐ Med ☐ Low Language: ☐ Hindi ☐ English ☐ Mixed

Annexure B - Stakeholder Interview Guide

Semi-structured interview protocol used for 8 stakeholder interviews conducted between March and April 2026. Respondents included municipal officials, elected ward councillors, community leaders, and long-term residents across the six surveyed wards. Interview duration: 30–45 minutes. Conducted in Hindi or English based on respondent preference.

VERBAL CONSENT SCRIPT

"Namaste. My name is Shourya Shrivastava, and I am a Master of Planning student at MANIT Bhopal. I am conducting research on Blue Green Infrastructure - that is, parks, gardens, lakes, ponds, and water bodies - and their role in social wellbeing across Gwalior's wards. This conversation will take 30 to 45 minutes. Your responses will be used only for academic research. Your name and role will be cited in my dissertation unless you prefer to remain anonymous. May I proceed with the interview?"

SECTION 1 - Background and Role

1. Could you briefly describe your role and how long you have been associated with this ward or department?
2. How frequently do you interact with residents of this ward on matters related to public infrastructure?

SECTION 2 - Awareness and Perception of BGI

3. When you hear the term Blue Green Infrastructure, what comes to your mind?
4. In your assessment, how would you describe the current state of parks, gardens, lakes, and ponds in your ward?
5. Has this state changed over the past 5 to 10 years? If yes, in which direction and why?

SECTION 3 - Institutional and Implementation Barriers

6. What are the main obstacles to creating or maintaining green and blue infrastructure in your ward?
7. How does the Gwalior Municipal Corporation currently plan, fund, and maintain BGI? Where do you see gaps?
8. Are there any inter-departmental coordination challenges that affect BGI implementation?
9. What role do residents play in maintaining or damaging these spaces?

SECTION 4 - Resident Wellbeing and BGI

10. In your view, how do green spaces and water bodies affect the daily life, health, and social interaction of residents in your ward?
11. Do you observe differences in usage by age group, gender, or income?
12. What infrastructure features (walking tracks, lighting, seating, shade, water features) are most missed by residents?

SECTION 5 - Specific Sites and Opportunities

13. Can you identify specific parks, water bodies, or open plots in your ward that have potential for upgrade or restoration?
14. Are there any rivers or water bodies (e.g., Swarn Rekha, Morar) that you believe should be prioritised for rejuvenation?
15. What is the role of community-led initiatives or NGOs in BGI improvement in this ward?

SECTION 6 - Recommendations and Vision

16. If you had the authority and budget to make three changes to BGI in your ward, what would they be?
17. What governance or policy changes are needed at the GMC, state, or national level to support BGI integration?
18. Is there anything else you would like to add that I have not asked?

CLOSING

"Thank you for your time and insights. With your permission, I may follow up if I need clarification on any point. The findings of this research will be shared with you upon completion."

Annexure C - Stakeholder Interview Summary

Eight semi-structured stakeholder interviews were conducted between March and April 2026, spanning municipal officials, elected representatives, and community leaders across the six surveyed wards. The summary below is anonymised by designation; full attributed quotes appear in Chapter 9, Section 9.5 of the main report.

Table C.1 - Stakeholder Interview Overview

S.No.	Designation / Role	Wards	Date	Primary Theme
1	Sub-Engineer, GMC (Former Zonal Officer)	28, 30, 18	Apr 2026	Maintenance, public cooperation, government efforts
2	Parshad (Councillor), GMC	2	Mar 2026	Park improvement, green space reduction, public health
3	Community Leader, Punjabi Parishad	30	Apr 2026	Satisfaction with existing green spaces, daily usage
4	Community Leader (Resident, RSS)	42	Apr 2026	Water feature addition, walking tracks, yoga areas
5	Community Leader (Resident, INC)	18	Mar 2026	Water body addition, park maintenance improvement
6	Prominent Resident	28	Apr 2026	Park addition, Morar River rejuvenation, plantation
7	Advocate, Community Leader (Resident)	45	Mar 2026	MLB College Park experience, park and water body addition
8	Local Leader (Resident)	45	Apr 2026	Walking tracks, plantation, Swarn Rekha rejuvenation

CROSS-CUTTING THEMES - Four themes emerged consistently across all eight interviews, regardless of ward, role, or political affiliation:

Theme 1 - Maintenance Gap (Universal)

Maintenance was the single most cited concern across every interview, regardless of BGI category. Even respondents from Ward 18 - the best-served ward in the study - flagged poor maintenance as a key issue. This converges with Q14 survey results where 36 percent of Ward 18 respondents identified 'poor maintenance' as the top green space problem. The institutional perspective (GMC sub-engineer) attributes part of the maintenance failure to community misuse, while community voices attribute it to insufficient municipal commitment - a clear governance feedback loop.

Theme 2 - Water Body Restoration (Specific Sites Named)

Six of eight respondents independently called for restoration of specific water bodies, with the Katora Tal and Swarn Rekha River (named by Ward 45 respondents) and the Morar River (named by Ward 28 respondents) emerging as priority candidates. The Ward 28 case is particularly important: 56 percent of Ward 28 survey respondents prioritised water body restoration as their top improvement, and this is corroborated by interviewees who name the Morar River as a specific opportunity. The interviews therefore validate and geographically specify the blue infrastructure gap identified spatially.

Theme 3 - Walking and Yoga Infrastructure (Cultural Function)

Walking tracks, yoga areas, and morning-activity infrastructure were a recurring demand across respondents in all six wards, reflecting the strong cultural practice of morning physical activity in Indian urban contexts. This positions BGI not only as ecological infrastructure but as health

infrastructure - supporting the dissertation's argument that BGI must serve a multi-functional planning role. Ward 30 and Ward 18 residents already use parks like Jiwaji University grounds and MLB College Park for this purpose; Low BGI ward residents articulate the same need but lack the spaces to fulfil it.

Theme 4 - Institutional and Community Coordination Gap

Both the GMC sub-engineer and several community respondents articulated the need for a two-way commitment: public investment from the municipal side paired with active stewardship from residents. This finding is significant for the planning framework - recommending not only physical interventions but governance mechanisms (BGI Cell, community participation models) to maintain what is built. The interview evidence reinforces that the BGI challenge in Gwalior is not one of awareness or aspiration, but of planning priority, institutional coordination, and sustained maintenance commitment.

Annexure D - Ward-Level BGI Master Data Table (All 66 Wards)

Complete attribute table for all 66 wards of Gwalior Municipal Corporation, generated through ArcGIS Pro spatial analysis using ward boundaries georeferenced against the MP State Geoportal, BGI features digitised from Sentinel-2 L2A satellite imagery (24 February 2026 scene), and 2025 population projected from Census 2011 baseline using the Geometric Growth Method (annual rate 2.60 percent). Wards marked with star (★) are the six survey wards.

Ward	Area (Ha)	Pop 2025	Green (Ha)	Blue (Ha)	BGI Total (Ha)	BGI/Cap (sqm/p)	GS Count	WB Count	Category
1	875.15	28,522	400.86	2.09	402.95	**141.28**	6	1	**High**
★ 2	76.41	24,540	7.33	1.81	9.14	**3.72**	11	3	**Low**
3	153.55	40,118	13.40	0.00	13.40	**3.34**	3	0	**Low**
4	90.22	32,600	8.56	0.74	9.30	**2.85**	3	6	**Low**
5	860.69	38,558	206.73	3.37	210.10	**54.49**	15	7	**High**
6	38.55	24,428	1.00	0.07	1.07	**0.44**	2	1	**Low**
7	244.78	22,138	62.79	6.23	69.02	**31.18**	10	4	**High**
8	72.55	24,503	5.52	0.00	5.52	**2.25**	9	0	**Low**
9	35.3	23,145	1.47	2.31	3.78	**1.63**	10	2	**Low**
10	42.78	20,948	2.31	0.00	2.31	**1.10**	3	0	**Low**
11	32.81	22,250	0.48	0.62	1.09	**0.49**	7	2	**Low**
12	56.27	22,367	2.95	0.00	2.95	**1.32**	3	0	**Low**
13	36.9	21,372	1.22	0.52	1.74	**0.81**	4	1	**Low**
14	62	24,252	10.66	2.18	12.84	**5.30**	7	2	**Medium**
15	97.76	25,524	19.22	0.00	19.22	**7.53**	2	0	**Medium**
16	66.66	19,091	5.00	0.32	5.32	**2.79**	2	3	**Low**
17	117.32	23,082	1.22	0.01	1.23	**0.53**	3	1	**Low**
★ 18	2,143.74	57,054	456.50	9.68	466.18	**81.71**	18	26	**High**
19	274.18	36,466	10.74	0.85	11.59	**3.18**	2	3	**Low**
20	202.63	41,044	10.87	4.77	15.64	**3.81**	4	13	**Low**
21	527.53	34,476	59.06	0.54	59.61	**17.29**	7	21	**Medium**
22	228.56	28,104	44.87	3.54	48.40	**17.22**	2	22	**Medium**
23	55.26	29,692	4.44	0.26	4.70	**1.58**	14	1	**Low**
24	56.88	15,055	1.18	0.00	1.18	**0.78**	6	0	**Low**
25	108.4	25,577	3.04	4.43	7.46	**2.92**	1	5	**Low**
26	80.74	23,297	2.71	0.98	3.68	**1.58**	2	9	**Low**
27	40.97	21,724	4.07	0.69	4.76	**2.19**	5	2	**Low**

★ 28	63.04	32,515	1.54	1.21	2.75	**0.85**	7	5	**Low**
29	232.71	34,559	28.77	1.08	29.85	**8.64**	17	1	**Medium**
★ 30	254.24	25,939	70.43	0.00	70.43	**27.15**	7	0	**High**
31	48.72	19,173	1.33	0.00	1.33	**0.69**	4	1	**Low**
32	76.47	23,848	8.25	2.33	10.58	**4.44**	5	3	**Low**
33	23.88	43,765	3.01	0.13	3.14	**0.72**	2	1	**Low**
34	23.03	17,933	0.61	0.82	1.43	**0.80**	6	2	**Low**
35	47.51	26,385	1.46	2.05	3.51	**1.33**	3	5	**Low**
36	32.93	19,424	1.34	0.00	1.34	**0.69**	6	1	**Low**
37	53.79	35,765	9.25	0.00	9.25	**2.59**	4	0	**Low**
38	195	39,386	11.48	0.54	12.02	**3.05**	7	8	**Low**
39	28.82	21,077	1.57	0.03	1.59	**0.76**	5	2	**Low**
40	21.4	13,259	1.16	1.71	2.87	**2.16**	7	7	**Low**
41	35.07	16,831	3.63	0.90	4.54	**2.69**	4	1	**Low**
★ 42	20.38	13,849	0.27	0.00	0.27	**0.19**	5	0	**Low**
43	31.26	17,645	0.62	0.00	0.62	**0.35**	2	0	**Low**
44	33.09	16,083	0.93	0.00	0.93	**0.58**	5	0	**Low**
★ 45	52.63	18,566	9.44	0.92	10.36	**5.58**	1	2	**Medium**
46	24.58	16,451	0.30	0.00	0.30	**0.18**	3	2	**Low**
47	20.8	17,102	1.01	0.00	1.01	**0.59**	8	0	**Low**
48	43.52	20,796	4.03	0.15	4.18	**2.01**	2	4	**Low**
49	90.72	24,811	6.40	9.99	16.39	**6.61**	4	15	**Medium**
50	30.39	16,088	3.74	0.00	3.74	**2.33**	3	0	**Low**
51	42.73	23,156	2.10	0.65	2.74	**1.18**	1	5	**Low**
52	348.67	37,731	156.63	0.00	156.63	**41.51**	5	0	**High**
53	61.21	20,478	1.24	0.00	1.24	**0.60**	3	0	**Low**
54	90.36	17,921	9.54	0.00	9.54	**5.32**	4	0	**Medium**
55	373.96	33,495	168.81	0.00	168.81	**50.40**	8	0	**High**
56	287	30,307	186.73	0.32	187.05	**61.72**	6	3	**High**
57	106.81	17,970	4.84	0.88	5.72	**3.18**	4	4	**Low**
58	364.16	21,455	143.52	4.33	147.85	**68.91**	17	6	**High**
59	1,195.86	13,088	295.14	8.35	303.49	**231.89**	13	4	**High**
60	1,774.22	34,774	709.16	13.69	722.85	**207.87**	9	18	**High**
61	8,310.78	20,812	3941.74	14.00	3955.74	**1900.70**	17	12	**High**

62	6,438.94	19,567	1772.16	106.10	1878.26	**959.91**	9	22	**High**
63	5,486.86	22,519	1182.80	52.68	1235.48	**548.64**	9	12	**High**
64	2,274.29	23,729	958.44	0.00	958.44	**403.91**	10	0	**High**
65	2,267.88	31,187	1302.74	12.21	1314.94	**421.63**	5	13	**High**
66	5,247.86	13,978	1882.71	115.03	1997.73	**1429.20**	17	15	**High**
TOTAL	**42,834.16**	**16,63,344**	**14,237.07**	**396.11**	**14,633.12**	**87.97**	**415**	**309**	**-**

Notes: BGI per capita = (BGI Total Area × 10,000) ÷ Population 2025. BGI Categories: Low < 5 sqm/p, Medium 5–25 sqm/p, High ≥ 25 sqm/p. ★ indicates ward selected for primary survey. The Gwalior Fort area and Morar Cantonment are separately administered and excluded from per-ward tabulation. Source: Author's analysis, ArcGIS Pro; Bhuvan–NRSC LULC; Sentinel-2 L2A (Copernicus/ESA); Census 2011; HFAPoA 2016.

Annexure E - Ward-Level NDVI Trajectory Data (2016–2021–2026)

Mean Normalized Difference Vegetation Index (NDVI) per ward across three time points - February 2016, February 2021, and February 2026 - computed from Sentinel-2 L2A imagery using NDVI = (B08 − B04) / (B08 + B04). Zonal mean per ward extracted via ArcGIS Pro Zonal Statistics. Wards marked with star (★) are the six survey wards.

Ward	BGI Category	NDVI 2016	NDVI 2021	NDVI 2026	Δ NDVI (2016→2026)	% Change
1	**High**	0.267	0.347	**0.388**	+0.121	+45.3%
★ 2	**Low**	0.199	0.233	**0.267**	+0.068	+34.2%
3	**Low**	0.236	0.276	**0.286**	+0.050	+21.2%
4	**Low**	0.215	0.242	**0.243**	+0.028	+13.0%
5	**High**	0.324	0.342	**0.353**	+0.029	+9.0%
6	**Low**	0.186	0.192	**0.212**	+0.026	+14.0%
7	**High**	0.396	0.437	**0.373**	-0.023	-5.8%
8	**Low**	0.163	0.206	**0.241**	+0.078	+47.9%
9	**Low**	0.186	0.204	**0.208**	+0.022	+11.8%
10	**Low**	0.205	0.231	**0.247**	+0.042	+20.5%
11	**Low**	0.182	0.203	**0.229**	+0.047	+25.8%
12	**Low**	0.249	0.270	**0.270**	+0.021	+8.4%
13	**Low**	0.158	0.165	**0.176**	+0.018	+11.4%
14	**Medium**	0.249	0.273	**0.289**	+0.040	+16.1%
15	**Medium**	0.274	0.281	**0.316**	+0.042	+15.3%
16	**Low**	0.297	0.322	**0.330**	+0.033	+11.1%
17	**Low**	0.280	0.296	**0.290**	+0.010	+3.6%
★ 18	**High**	0.327	0.374	**0.403**	+0.076	+23.2%
19	**Low**	0.276	0.277	**0.298**	+0.022	+8.0%
20	**Low**	0.255	0.314	**0.364**	+0.109	+42.7%
21	**Medium**	0.317	0.350	**0.396**	+0.079	+24.9%
22	**Medium**	0.337	0.367	**0.396**	+0.059	+17.5%
23	**Low**	0.198	0.203	**0.224**	+0.026	+13.1%
24	**Low**	0.337	0.371	**0.356**	+0.019	+5.6%
25	**Low**	0.287	0.311	**0.310**	+0.023	+8.0%
26	**Low**	0.180	0.187	**0.217**	+0.037	+20.6%

27	**Low**	0.192	0.192	**0.219**	+0.027	+14.1%
★ 28	**Low**	0.176	0.175	**0.202**	+0.026	+14.8%
29	**Medium**	0.227	0.277	**0.322**	+0.095	+41.9%
★ 30	**High**	0.316	0.359	**0.375**	+0.059	+18.7%
31	**Low**	0.214	0.230	**0.239**	+0.025	+11.7%
32	**Low**	0.259	0.275	**0.291**	+0.032	+12.4%
33	**Low**	0.166	0.183	**0.241**	+0.075	+45.2%
34	**Low**	0.145	0.159	**0.193**	+0.048	+33.1%
35	**Low**	0.143	0.174	**0.199**	+0.056	+39.2%
36	**Low**	0.170	0.216	**0.242**	+0.072	+42.4%
37	**Low**	0.326	0.375	**0.383**	+0.057	+17.5%
38	**Low**	0.255	0.253	**0.273**	+0.018	+7.1%
39	**Low**	0.147	0.189	**0.206**	+0.059	+40.1%
40	**Low**	0.145	0.199	**0.202**	+0.057	+39.3%
41	**Low**	0.134	0.201	**0.201**	+0.067	+50.0%
★ 42	**Low**	0.085	0.122	**0.151**	+0.066	+77.6%
43	**Low**	0.101	0.133	**0.158**	+0.057	+56.4%
44	**Low**	0.124	0.151	**0.176**	+0.052	+41.9%
★ 45	**Medium**	0.183	0.218	**0.234**	+0.051	+27.9%
46	**Low**	0.126	0.145	**0.167**	+0.041	+32.5%
47	**Low**	0.123	0.139	**0.158**	+0.035	+28.5%
48	**Low**	0.167	0.184	**0.207**	+0.040	+24.0%
49	**Medium**	0.247	0.254	**0.275**	+0.028	+11.3%
50	**Low**	0.143	0.174	**0.198**	+0.055	+38.5%
51	**Low**	0.201	0.186	**0.202**	+0.001	+0.5%
52	**High**	0.284	0.277	**0.356**	+0.072	+25.4%
53	**Low**	0.220	0.215	**0.258**	+0.038	+17.3%
54	**Medium**	0.318	0.289	**0.326**	+0.008	+2.5%
55	**High**	0.279	0.299	**0.399**	+0.120	+43.0%
56	**High**	0.319	0.344	**0.451**	+0.132	+41.4%
57	**Low**	0.297	0.337	**0.317**	+0.020	+6.7%
58	**High**	0.321	0.370	**0.386**	+0.065	+20.2%

59	**High**	0.434	0.454	**0.533**	+0.099	+22.8%
60	**High**	0.334	0.349	**0.459**	+0.125	+37.4%
61	**High**	0.459	0.482	**0.577**	+0.118	+25.7%
62	**High**	0.468	0.501	**0.530**	+0.062	+13.2%
63	**High**	0.631	0.663	**0.619**	-0.012	-1.9%
64	**High**	0.491	0.517	**0.538**	+0.047	+9.6%
65	**High**	0.337	0.345	**0.410**	+0.073	+21.7%
66	**High**	0.408	0.424	**0.536**	+0.128	+31.4%

Table E.2 - Mean NDVI by BGI Category (Inner-City Wards 1–60)

Category	**n Wards**	**NDVI 2016**	**NDVI 2021**	**NDVI 2026**	**Δ NDVI**	**% Change**
Low BGI	41	0.199	0.222	**0.240**	**+0.041**	**+20.6%**
Medium BGI	8	0.269	0.289	**0.319**	**+0.050**	**+18.6%**
High BGI	11	0.327	0.359	**0.407**	**+0.080**	**+24.5%**

Notes: NDVI ranges from −1 to +1, where higher values indicate denser vegetation. Class 1 BGI threshold typically begins at NDVI 0.3. All ward NDVI gains were positive across the decade, but the gain was concentrated in already-high-BGI wards (+0.080 in High BGI wards vs +0.041 in Low BGI wards) - confirming that urban greening has deepened rather than narrowed spatial inequity. Source: Author's analysis from Sentinel-2 L2A (Copernicus/ESA), ArcGIS Pro Zonal Statistics.

Annexure F - Population Projection Worksheet

Ward-level population projections from Census 2011 baseline (Wards 1–59), DP 2035 baseline (Ward 60), and HFAPoA 2016 baseline (Wards 61–66) to 2025, using the Geometric Growth Method at 2.60 percent per annum. The geometric rate is calibrated to the Gwalior Development Plan 2035 design population of approximately 16.66 lakh and consistent with the decadal trend of 29.26 percent.

Formula: $P_{2025} = P_base \times (1 + r)^n$ where r = 0.026 (2.60% p.a.), n = years from base to 2025

Ward	Base Pop	Base Year	n (years)	Growth Factor (1.026)^n	Projected Pop 2025
1	19,913	2011	14	1.4324	**28,522**
★ 2	17,133	2011	14	1.4324	**24,540**
3	28,009	2011	14	1.4324	**40,118**
4	22,760	2011	14	1.4324	**32,600**
5	26,920	2011	14	1.4324	**38,558**
6	17,055	2011	14	1.4324	**24,428**
7	15,456	2011	14	1.4324	**22,138**
8	17,107	2011	14	1.4324	**24,503**
9	16,159	2011	14	1.4324	**23,145**
10	14,625	2011	14	1.4324	**20,948**
11	15,534	2011	14	1.4324	**22,250**
12	15,616	2011	14	1.4324	**22,367**
13	14,921	2011	14	1.4324	**21,372**
14	16,932	2011	14	1.4324	**24,252**
15	17,820	2011	14	1.4324	**25,524**
16	13,329	2011	14	1.4324	**19,091**
17	16,115	2011	14	1.4324	**23,082**
★ 18	39,833	2011	14	1.4324	**57,054**
19	25,459	2011	14	1.4324	**36,466**
20	28,655	2011	14	1.4324	**41,044**
21	24,070	2011	14	1.4324	**34,476**
22	19,621	2011	14	1.4324	**28,104**
23	20,730	2011	14	1.4324	**29,692**
24	10,511	2011	14	1.4324	**15,055**

25	17,857	2011	14	1.4324	**25,577**
26	16,265	2011	14	1.4324	**23,297**
27	15,167	2011	14	1.4324	**21,724**
★ 28	22,701	2011	14	1.4324	**32,515**
29	24,128	2011	14	1.4324	**34,559**
★ 30	18,110	2011	14	1.4324	**25,939**
31	13,386	2011	14	1.4324	**19,173**
32	16,650	2011	14	1.4324	**23,848**
33	30,555	2011	14	1.4324	**43,765**
34	12,520	2011	14	1.4324	**17,933**
35	18,421	2011	14	1.4324	**26,385**
36	13,561	2011	14	1.4324	**19,424**
37	24,970	2011	14	1.4324	**35,765**
38	27,498	2011	14	1.4324	**39,386**
39	14,715	2011	14	1.4324	**21,077**
40	9,257	2011	14	1.4324	**13,259**
41	11,751	2011	14	1.4324	**16,831**
★ 42	9,669	2011	14	1.4324	**13,849**
43	12,319	2011	14	1.4324	**17,645**
44	11,229	2011	14	1.4324	**16,083**
★ 45	12,962	2011	14	1.4324	**18,566**
46	11,486	2011	14	1.4324	**16,451**
47	11,940	2011	14	1.4324	**17,102**
48	14,519	2011	14	1.4324	**20,796**
49	17,322	2011	14	1.4324	**24,811**
50	11,232	2011	14	1.4324	**16,088**
51	16,167	2011	14	1.4324	**23,156**
52	26,342	2011	14	1.4324	**37,731**
53	14,297	2011	14	1.4324	**20,478**
54	12,512	2011	14	1.4324	**17,921**
55	23,385	2011	14	1.4324	**33,495**
56	21,159	2011	14	1.4324	**30,307**

57	12,546	2011	14	1.4324	**17,970**
58	14,979	2011	14	1.4324	**21,455**
59	9,138	2011	14	1.4324	**13,088**
60	24,278	2011	14	1.4324	**34,774**
61	16,520	2016	9	1.2599	**20,812**
62	15,532	2016	9	1.2599	**19,567**
63	17,875	2016	9	1.2599	**22,519**
64	18,835	2016	9	1.2599	**23,729**
65	24,755	2016	9	1.2599	**31,187**
66	11,095	2016	9	1.2599	**13,978**
TOTAL	**11,73,888**	**-**	**-**	**-**	**16,63,344**

Worked Example - Ward 42 (Sant Jhulelal): P_{2025} = 9,684 × (1.026)^14 = 9,684 × 1.4302 = 13,849
Worked Example - Ward 60 (DP 2035 baseline): P_{2025} = base × (1.026)^9 (base year 2016) = 34,774
Total projected 2025 population for GMC (66 wards): 16,63,344 ≈ 16.63 lakh (matches DP 2035 design population of ~16.66 lakh)

Notes: Geometric growth is selected over arithmetic growth on the basis that Gwalior's decadal census growth (2001–2011) demonstrated a compounding rather than linear pattern, consistent with urbanising Class 1 cities. The 2.60 percent rate is calibrated to reproduce the DP 2035 design population of approximately 16.66 lakh. Wards 61–66 use 2016 baseline because they were incorporated into GMC under HFAPoA 2016 - Census 2011 data is not available for these peri-urban ward boundaries. Source: Census of India 2011, HFAPoA 2016, Gwalior DP 2035; Author's projection.

Annexure G - Survey Respondent Demographics Breakdown

Demographic composition of the 600 survey respondents disaggregated by ward and aggregated city-wide. The sampling design ensured n = 100 per ward, supporting clean inter-ward comparison. All percentages are within-ward.

Table G.1 - Age Distribution by Ward (% of respondents)

Ward	n	18–25	26–35	36–45	46–60	60+
Ward 42	100	28.0	17.0	14.0	24.0	17.0
Ward 28	100	29.0	14.0	10.0	20.0	27.0
Ward 2	100	14.0	25.0	16.0	21.0	24.0
Ward 45	100	22.0	20.0	31.0	18.0	9.0
Ward 30	100	33.0	22.0	12.0	20.0	13.0
Ward 18	100	21.0	28.0	23.0	13.0	15.0
CITY (All 6 Wards)	**600**	**24.5**	**21.0**	**17.7**	**19.3**	**17.5**

Table G.2 - Gender Distribution by Ward (% of respondents)

Ward	n	Male	Female	Prefer Not To Say
Ward 42	100	47.0	38.0	15.0
Ward 28	100	49.0	20.0	31.0
Ward 2	100	36.0	28.0	36.0
Ward 45	100	45.0	27.0	28.0
Ward 30	100	39.0	46.0	15.0
Ward 18	100	26.0	47.0	27.0
CITY (All 6 Wards)	**600**	**40.3**	**34.3**	**25.3**

Table G.3 - Residence Duration by Ward (% of respondents)

Ward	n	< 1 yr	1–5 yrs	5–10 yrs	10–20 yrs	> 20 yrs
Ward 42	100	6.0	14.0	22.0	28.0	30.0
Ward 28	100	4.0	12.0	26.0	27.0	31.0
Ward 2	100	3.0	10.0	20.0	33.0	34.0
Ward 45	100	5.0	11.0	25.0	26.0	33.0
Ward 30	100	6.0	13.0	24.0	27.0	30.0
Ward 18	100	2.0	8.0	18.0	36.0	36.0
CITY (All 6 Wards)	**600**	**4.3**	**11.3**	**22.5**	**29.5**	**32.3**

Notes: All percentages calculated within each ward (n = 100 per ward). City-wide row is computed across all 600 respondents. Long-term residence (> 10 years) accounts for 62 percent of the total sample, providing a strong basis for the deterioration perceptions in Q17. Source: Primary Field Survey, April 2026.

Annexure H - Composite SWI Calculation Worksheet

Purpose

This annexure documents the calculation of the composite Social Wellbeing Index (SWI) used in Chapters 8–10, derived from six Likert-scale items (Q7–Q12) of the resident survey (n = 600, six wards). Each respondent rated agreement with six statements on a 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree). The composite SWI for each respondent is the mean of their six item scores; ward-level and category-level SWI values are the mean of respondent composite scores within that group.

SWI Item Mapping

Item	*Survey Question (Q7-Q12)*	*Construct*
Q7	*Green spaces improve my physical health.*	*Physical health*
Q8	*Green spaces help reduce my stress / improve mental health.*	*Mental health*
Q9	*Being near a lake or pond makes me feel peaceful.*	*Restorative / blue infrastructure*
Q10	*Green spaces in my ward are safe for women and children.*	*Safety*
Q11	*I interact more with neighbours because of nearby green spaces.*	*Social interaction*
Q12	*In summer, green areas in my ward provide cooling and shade.*	*Thermal comfort*

Scoring scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

Table H.1 - Ward-Level Composite SWI Summary (All Six Wards)

Mean item scores (Q7–Q12) and composite SWI for each of the six surveyed wards (n = 100 per ward), with BGI category and BGI per capita shown for reference. The composite SWI values reproduce those reported in Section 8.2 (Tables 12–17) and Chapter 10.

Ward	n	BGI Category	BGI / capita (sqm/p)	Mean Q7	Mean Q8	Mean Q9	Mean Q10	Mean Q11	Mean Q12	Composite SWI
Ward 42	100	Low BGI	0.19	2.36	2.38	2.82	1.89	1.99	2.35	**2.30**
Ward 28	100	Low BGI	0.85	2.07	2.53	3.60	1.69	1.88	2.53	**2.38**
Ward 2	100	Low BGI	3.72	2.89	3.05	3.17	1.88	2.05	2.90	**2.66**
Ward 45	100	Medium BGI	9.19	3.68	3.61	3.66	2.86	3.04	4.02	**3.48**
Ward 30	100	High BGI	27.15	4.32	4.38	4.08	3.58	2.89	4.65	**3.98**
Ward 18	100	High BGI	81.71	4.59	4.60	4.27	3.80	3.53	4.47	**4.21**

Table H.2 - Raw Survey Data Sample (100 Respondents per Ward)

Source: Primary Field Survey, April 2026.

Annexure I - Cronbach's Alpha Reliability Output

Internal consistency reliability of the six-item Likert scale (Q7–Q12) used to construct the Composite Social Wellbeing Index. Cronbach's α is the standard reliability coefficient for Likert-type composite measures (Cronbach, 1951). α ≥ 0.70 is considered acceptable for exploratory social research (Nunnally, 1978).

Overall Scale Reliability

Statistic	**Value**
Sample size (n)	600
Number of items (k)	6 (Q7, Q8, Q9, Q10, Q11, Q12)
Cronbach's α	**0.774**
Mean inter-item correlation	0.356 (range: 0.140 – 0.511)
Interpretation	Acceptable internal consistency (≥ 0.70 threshold)

Item Statistics and Item-Total Correlations

Item	**Dimension**	**Mean**	**SD**	**Corrected Item-Total Correlation**	**α if Item Deleted**
Q7	Physical Health	3.318	1.473	0.612	0.714
Q8	Mental Health	3.425	1.324	0.580	0.725
Q9	Water Peacefulness	3.600	1.146	0.320	0.783
Q10	Perceived Safety	2.617	1.324	0.553	0.731
Q11	Social Cohesion	2.563	1.303	0.419	0.764
Q12	Microclimate / Cooling	3.487	1.412	0.627	0.710

Inter-Item Correlation Matrix (Pearson)

	Q7	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**
Q7	**1.000**	0.470	0.253	0.442	0.391	0.511
Q8	0.470	**1.000**	0.188	0.452	0.350	0.502
Q9	0.253	0.188	**1.000**	0.264	0.140	0.319
Q10	0.442	0.452	0.264	**1.000**	0.274	0.464
Q11	0.391	0.350	0.140	0.274	**1.000**	0.321
Q12	0.511	0.502	0.319	0.464	0.321	**1.000**

Interpretation

The overall Cronbach's α of 0.774 (rounded to 0.77 in the main report) exceeds the conventional 0.70 threshold for acceptable internal consistency in exploratory social science research (Nunnally, 1978; Field, 2018). All six items contribute positively to the scale, with corrected item-total correlations ranging from 0.32 (Q9) to 0.63 (Q12) - all above the 0.30 minimum for item retention (Field, 2018).

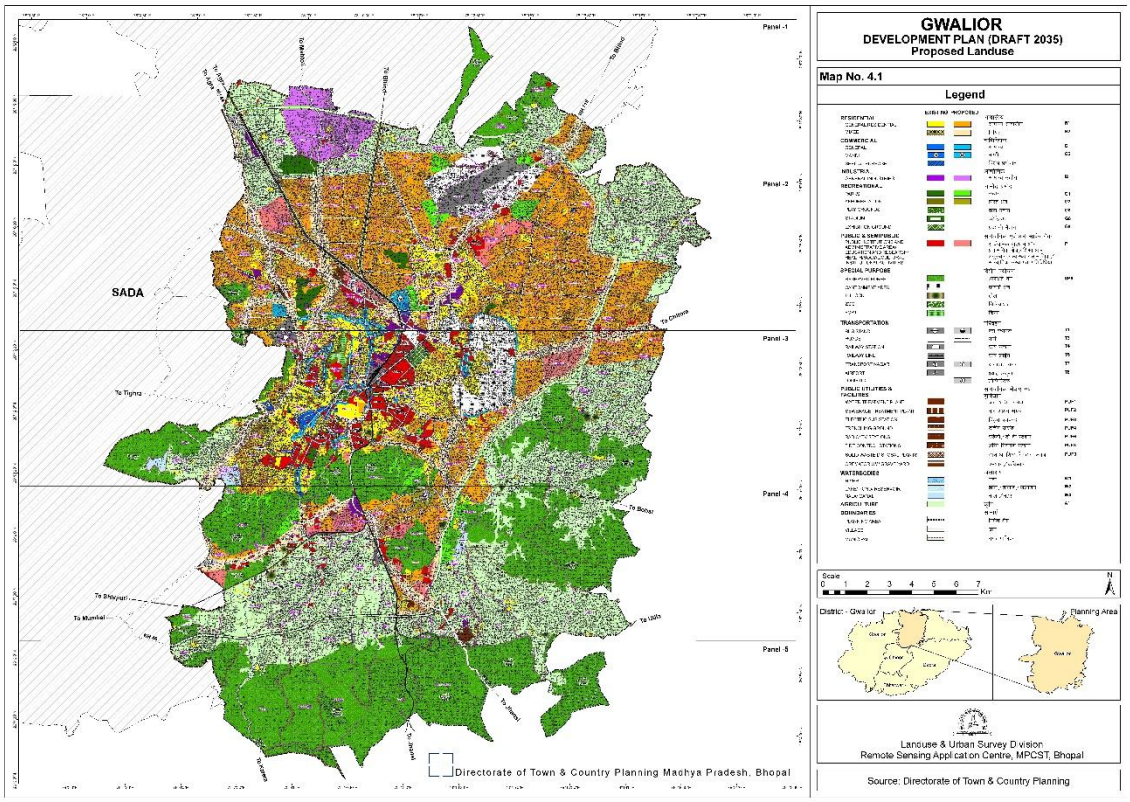
Q9 (water peacefulness) shows the lowest item-total correlation (0.32) and, if deleted, would

marginally increase α to 0.78 - but it is retained on theoretical grounds: it is the only item specifically capturing the blue dimension of BGI, and the dissertation's central argument requires that the SWI represent both green and blue infrastructure. Removing Q9 would collapse the SWI to a green-only measure and conceptually weaken the index, even as it marginally improves statistical homogeneity.

The mean inter-item correlation of 0.356 falls within the 0.30–0.50 range expected for a well-constructed multidimensional scale, where items measure related but distinct facets of a broader construct. The composite SWI is therefore both statistically reliable and theoretically defensible as a measure of resident social wellbeing in relation to BGI provision.

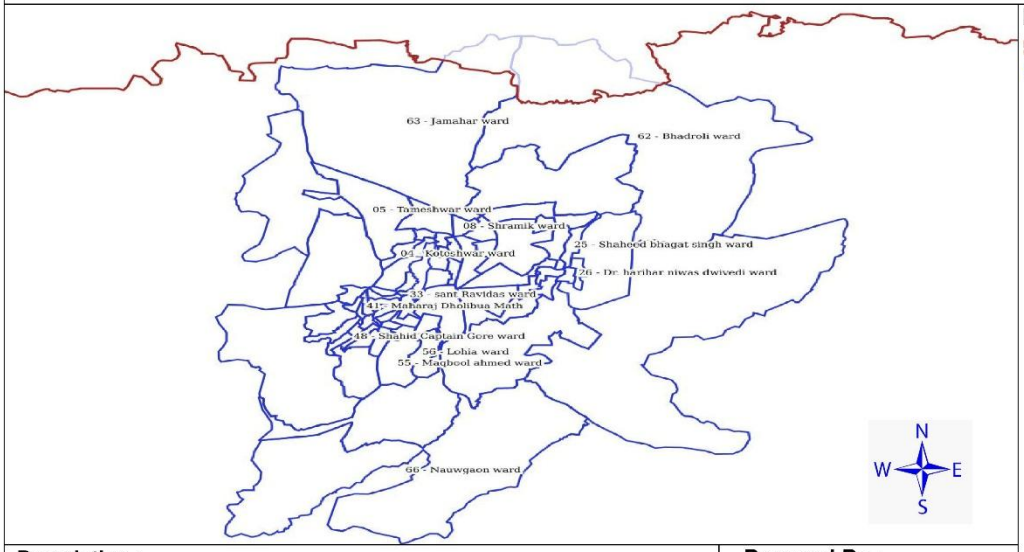
Source: Author's analysis survey data, April 2026.

Annexure J - Gwalior Development Plan (Draft 2035)



Annexure K – Gwalior Ward Boundary Map Geoportal M.P.

ward map gwalior



Legends :
- District (1)
- Ward (171)

Description :
Source: Geoportal Madhya Pradesh

Powered By :

MPSSDI , MPSeDC