Urban Metamorphosis: Navigating the Interplay of Morphology and Ecology in Bengaluru's Water Network

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Abstract: *This study investigates the intricate relationship between urban morphology and urban ecology, focusing on the water networks within Bengaluru's Koramangala Challaghatta Valley. The research addresses the need to understand how urbanization has altered these historically significant water systems and their impact on urban ecology. Despite their critical role, these water networks have experienced significant transformations due to land reclamation and buffer zone creation, highlighting a gap in current urban planning practices. To bridge this gap, the study used a combination of field reconnaissance, including systematic site observations and un structured stakeholder interviews at 20 strategically selected sites along the water network. The analysis involved mapping and evaluating the land-water interface to identify specific typologies of transformation and their implications for urban ecology. The results reveal that urbanization and planning regulations have considerably disrupted the water network. The study found that the primary transformations include land reclamation and land use along the water network, which have altered the ecological functions and spatial configuration of the water systems. Based on these findings, the study recommends the adoption of targeted planning tools and policy adjustments that consider the ecological carrying capacity of sensitive zones. Specifically, it suggests policies for improved collective management of urban commons and more precise regulations to integrate and protect water networks in urban development. These recommendations aim to address the gaps in the current urban planning policies and enhance the sustainability and effectiveness of urban planning in rapidly expanding cities.*

Keywords: *Urbanization, Urban Morphology, Water Network, Bengaluru, Urban Planning Law, Urban Ecology.*

Kentsel Metamorfoz: Bengaluru'nun Su Ağı'ndaki Morfoloji ve Ekoloji Etkileşimini Keşfetmek

Özet: *Bu çalışma, Bengaluru'nun Koramangala Challaghatta Vadisi'ndeki su ağlarını odaklanarak, kentsel morfoloji ile kentsel ekoloji arasındaki karmaşık ilişkiyi araştırmaktadır. Araştırma, kentleşmenin bu tarihsel olarak önemli su sistemlerini nasıl değiştirdiğini ve bunların kentsel ekoloji üzerindeki etkilerini anlamanın gerekliliğini ele almaktadır. Kritik rolüne rağmen, bu su ağları, arazi kazanımı ve tampon bölgelerin oluşturulması nedeniyle önemli dönüşümler geçirmiştir ve bu durum mevcut kentsel planlama uygulamalarında bir boşluğu ortaya koymaktadır. Bu boşluğu kapatmak amacıyla, çalışma, su ağı boyunca stratejik olarak seçilen 20 alanda sistematik saha gözlemleri ve yapılandırılmamış paydaş mülakatlarını içeren bir saha keşfi kombinasyonu kullanmıştır. Analiz, dönüşümün belirli tipolojilerini ve bunların kentsel ekoloji üzerindeki etkilerini tanımlamak için arazi-su arayüzünün haritalanmasını ve değerlendirilmesini içermektedir. Sonuçlar, kentleşme ve planlama düzenlemelerinin su ağını önemli ölçüde bozduğunu ortaya koymaktadır. Çalışma, birincil dönüşümlerin su ağı boyunca arazi kazanımı ve arazi kullanımı olduğunu ve bunların su sistemlerinin ekolojik işlevlerini ve mekansal yapılarını değiştirdiğini bulmuştur. Bu bulgulara dayanarak, çalışma, hassas bölgelerin ekolojik taşıma kapasitesini dikkate alan hedeflenmiş planlama araçlarının ve politika ayarlamalarının benimsenmesini önermektedir. Özellikle, kentsel ortak kullanım alanlarının daha iyi kolektif yönetimi ve su ağlarını kentsel gelişimde entegre ve korumaya yönelik daha kesin düzenlemeler için politikalar önermektedir. Bu öneriler, mevcut kentsel planlama politikalarındaki boşlukları gidermeyi ve hızla genişleyen şehirlerde kentsel planlamanın sürdürülebilirliğini ve etkinliğini artırmayı amaçlamaktadır.*

Anahtar Kelimeler: *Kentleşme, Kentsel Morfoloji, Su Ağı, Bengaluru, Kentsel Planlama Hukuku; Kentsel Ekoloji.*

1. INTRODUCTION

Bengaluru's water network exemplifies the dynamic interplay between urban morphology and ecology, shaped by the city's evolving geography and urban planning processes. Initially developed in the 16th century as a small trade city with a footprint of 2.7 sq km, Bengaluru has expanded into a sprawling metropolitan area of over 1200 sq. km (Figure 1, 2). The city's water network, integral to its historical development, has been fundamentally altered by urbanization.

Figure 1. Map of India indicating the location of Bengaluru. Source: Wikipedia. Open Source (OS).

Figure 2. Pete, Kote, and Thota- Survey of the boundaries of purgunna of Bengaluru in1800. Source: Mythic Society, Bengaluru. OS.

This study focuses on the Koramangala Challaghatta Valley, a key component of Bengaluru's water system. The valley is part of a larger hydrological network that includes three primary watersheds—Hebbal, Koramangala Challaghatta, and Vrishabavathi—each featuring a series of interconnected tanks and

rajakaluveys (Figure 3,4). Originally designed to manage stormwater, collect runoff, [1] and support agrarian settlements [2], this network has transitioned from a vital ecological system to a series of underutilized and often polluted backyards [3].

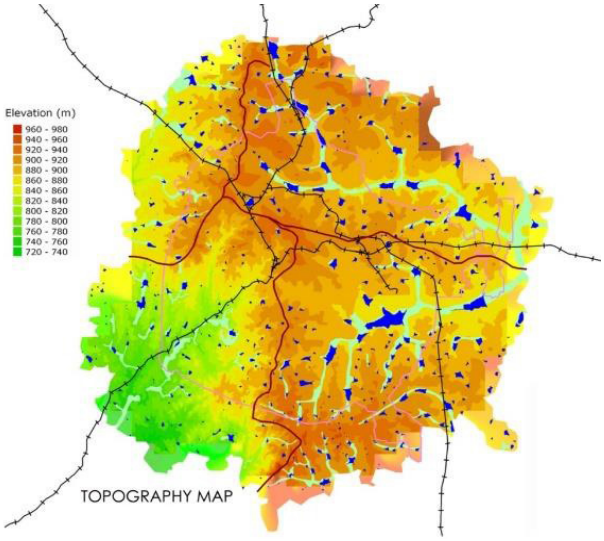


Figure 3. Topography of Bengaluru. Source: BBMP, Bengaluru. OS.

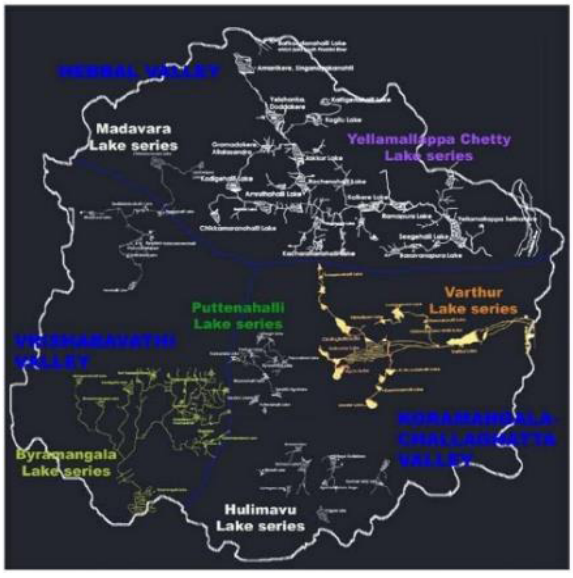


Figure 4. Watershed with tank series of Bengaluru Source: BBMP, Bengaluru. OS.

The research focuses on how formal urban planning and governance processes have impacted this water network, particularly emphasizing the Varthur tank series in the Koramangala Challaghatta Valley. Field studies, spanning from the city core to its peri-urban areas, involved mapping the interface between land and water to analyze transformations in morphology and ecology. A critical problem addressed by this study is the disconnect between urban planning laws and the ecological importance of water networks. Historical planning frameworks, such as the Outline Development Plan (ODP) 1972 and the Comprehensive Development Plan (CDP) 1984, overlooked ecological considerations [3]. Although the

Revised Master Plan (RMP) 2015 introduced non-buildable buffer zones and sensitive areas, centralization of governance has undermined local management practices that traditionally maintained these water systems [4].

This research aims to highlight how formal processes have reshaped the water network and to advocate for policy reforms that better integrate ecological considerations into urban planning. The paper is structured into six sections: the first outlines the historical and ecological context, the second describes the research methodology and study area, the third presents field observations, the fourth analyses these findings, the fifth concludes the study, and the sixth offers policy recommendations for improved integration of ecological aspects into urban governance.

1.1. Exploring the Ecology Layer

The ecology layer is vital for the health of the city, and the Government of Karnataka (GoK) has launched a project to reclaim the interlinked water network, inspired by similar efforts in Chengyachone, Seoul. The "Daylighting" projects across the USA and UK, as well as the Slum Networking Project in India, serve as other notable examples of water network reclamation. Citizen and judicial activism have drawn attention to the water network issues in Bengaluru. In response to the National Green Tribunal's (NGT) directive for the rejuvenation of Bellandur and Varthur lakes, the Karnataka State Pollution Control Board (KSPCB) and BWSSB carried out a comprehensive survey of the Koramangala and Challaghatta valley to locate buildings discharging untreated sewage. This survey, conducted between Shantinagar and Bellandur within the study area, highlighted the longstanding neglect of this crucial ecological layer. The compact development along the stretch makes installing underground drainage challenging, and sewage pumping into nalas was observed in over 538 residences, underscoring the neglect of the water network.

TV Ramachandran and his team have found that urbanization between 1973 and 2017 led to a significant decline in green spaces (88%) and wetlands (79%) [5]. Construction activities in the valley zone like the special economic zone (SEZ) by KIADB contradict sustainable development principles, as they harm natural resources, leading to ecosystem degradation. These valley zones are designated as 'No Development Zones' per CDP 2015. The Agara-Bellandur Wetland Violation, reported by IISc in 2017, exemplifies the adverse impacts of topography alterations and wetland encroachment, which cause flooding, property damage, and health issues.

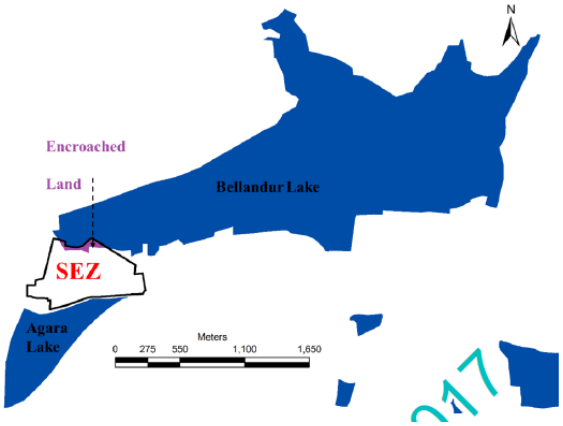


Figure 5. SEZ and encroached land – Agara Bellendur wetland violation as mapped by IISC. Source: Indian Institute of Science. OS.

In Civil Appeal Number 1132/2011 at SLP (C) 3109/2011, the Honourable Supreme Court of India on January 28, 2011 raised concerns regarding the encroachment on common property resources, especially lakes and rajakaluves. The Court directed state governments to remove encroachments from all community lands. Eviction of encroachments is provided for under the Karnataka Public Premises (Eviction of Unauthorized Occupants) Act 1974 and the Karnataka Land Revenue Act 1964.

The Honourable High Court of Karnataka (W.P No. 817/2008) issued a directive for the protection of lakes that included:

- "Lake protection across the State of Karnataka
- Prohibiting the dumping of garbage and sewage in lakes
- Surveying and fencing lake areas and declaring them as no development zones
- Removing encroachments
- Forest development to plant trees around lakes and watershed regions in consultation with experts
- Setting up district lake protection committees
- The monitoring of implementation of these measures to be overseen by the member secretary of the State Legal Services Authority in coordination with the Revenue and Forest Departments."

Judicial intervention to protect eco-sensitive zones highlights the narrow framework within urban planning laws for planning, implementing, monitoring, and protecting these areas.

2. RESEARCH METHOD

The study employed an empirical approach to investigate the intersection of urban morphology and ecology, with a particular focus on the land-water interface. This approach utilized a combination of surveys and observational techniques to map and analyze morphological patterns along the water's edge. Building upon the foundational work of Bostancı [6], which highlights both descriptive and analytical methods in urban research, this study integrated these methods with targeted field observations. Initially, the research identified and categorized 20 distinct hotspots along the land-water interface into 10 typologies, as detailed in Table 1. This classification was based on the unique characteristics of each hotspot and their responses to the surrounding geography and ecology. Data were systematically gathered and assessed, including observations of the water network transformation and its impact on urban morphology and planning regulations. The research used qualitative, constructivist techniques to explore these issues, providing a comprehensive view of how urban morphology interacts with ecological factors along the water interface. This methodology emphasizes the contextual understanding of the phenomena and contributes to the broader urban design and planning knowledge.

2.1. Research Design

The research design included sampling, data collection, documentation, and analysis.

Sampling

The study focused on the water network from the urban core to the peri-urban area to evaluate urban planning law's impact on land water interface. Using representative random sampling, 20 locations along the water network were selected for morphology studies. Preliminary field studies guided the selection of samples to examine the transformation of the water network and land-water edge during urbanization.

Data Collection and Documentation

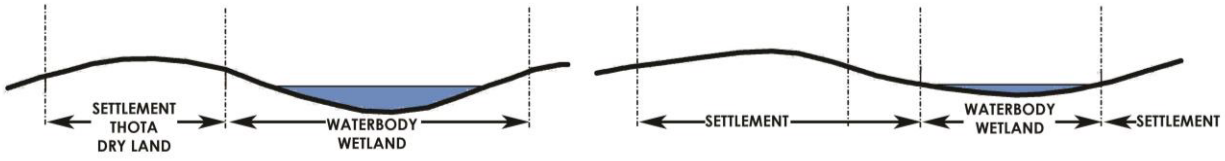
Field studies and observations mapped transformations in the water network and land-water edge. A base map was created using preliminary field data, Google Maps, and revenue maps. Detailed studies and unstructured interviews with residents supported the findings. Data from field studies were cross-verified

with maps, and morphology data of the built form along the water-land interface was collected. The study also referred to master plans and conducted unstructured interviews with authorities to analyze regulations governing the water network. Twenty hotspots were identified along the water network for documentation and analysis.

Data Documentation
Observations and interviews were documented with diagrams, photos, Google Maps, and land use maps. Sketches and photographs documented the morphology of built forms along the water edge. Information from informal discussions with locals was integrated, and land use data from master plans was overlaid on sketches to analyze the impact of land use regulations.

Data Analysis
Documented data was compiled, compared, and grouped into typologies. The impact of formal processes on each typology was analyzed using interpretation as the analytical tool.

2.2. Study Area Identification
Preliminary field observations indicate the condition of the water network and land interface (Figure 6), This reflects urban metamorphosis in the process of urbanization and varies along this stretch Additionally, the interface between the water network and the land also varies. To map the intersection of morphology and ecology, the research examined both the existing conditions of the water network and the water-land interface. The core of the city was formed in 1570 AD and the city has grown periodically around the core. The study area indicated in a Google map (Figure 7), spans a 20 km stretch across the city from the core through the urban zone into the agrarian zone.



a - Agrarian land use **b – Urban land use**

Figure 6. Schematic representation of the land water interface pattern in agrarian (a) and urban (b) land use. Source: Conceptualized from preliminary field observations.

The study focused on the Koramangala Challaghatta valley in Bengaluru's South East, featuring a water network comprising the Varthur, Puttenahalli, and Hulimavu lake series. This network, with over 800 km of tanks and rajakaluveys, is crucial to Bengaluru's ecology. The Varthur lake series, originating in the city's core and extending to the periphery, connects to the Kalavarapalli reservoir and eventually the Cauvery River, illustrating the impact of urban planning on ecology and morphology. Bellandur tank, the largest in the Varthur series, covers about 1000 acres with a 280 sq km catchment area. Its watershed is formed by three main streams-Eastern (from Ulsoor tank), Central (from the core), and Western (from Madivala). Field observations indicated that the rajakaluve connecting the core to Bellandur tank had been narrowed to 30 meters, half its original width, contributing to flooding as reported by an IISc study. Despite RMP 2015 regulations for rajakaluveys, development often occurred before these regulations were enforced. For instance, KIADB developed wetland between Agara and Bellandur tanks without a carrying capacity study, despite RMP 2015 designating it for a sewage treatment plan (STP).

The Koramangala Challaghatta valley, particularly the Varthur tank series, has faced significant environmental concerns. An extensive 2009 report by IISc on urban floods in Bengaluru, presented to the Ministry of Home Affairs and Bruhat Bengaluru Mahanagara Palike (BBMP), highlighted severe flooding issues in south Bengaluru due to overflowing stormwater drains and inundated roads and houses [7]. Buffer zones, areas of land adjacent to water bodies like lakes, tanks, ponds, or rivers, act as flood plains. These zones experience flooding or stagnation during periods of precipitation. The delineation of buffer zones depends on factors like the size of the water body, catchment shape and size, and rainfall intensity. They are delineated using topographic contours from Survey of India Topographic maps [5]. Buffer zones and wetlands are designated as no-development zones with regulations outlined in RMP 2015. TV Ramachandran and his team emphasized the need to preserve buffer zones around water bodies. Frequent flooding, even with normal rainfall, is attributed to increased impervious surfaces from high-density urban development and the loss of wetlands and vegetation [8].

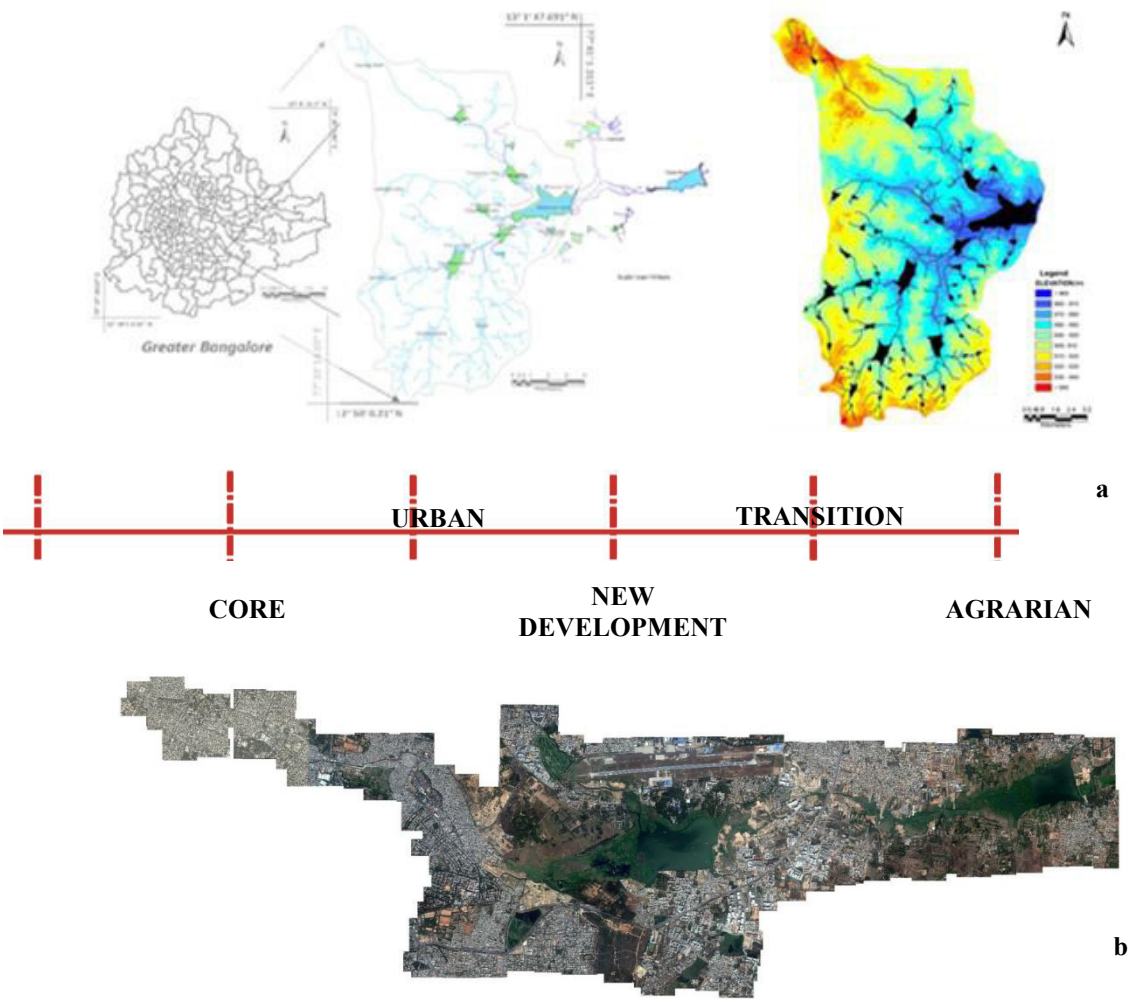


Figure 7a. Location and topography of Varthur tank series in context of Bengaluru. Source: Indian Institute of Science. OS.
Figure 7b. Site identified for the study- Koramangala Challaghatta valley. Source: Google Maps.

3. OBSERVATIONS

The research identified 20 hotspots in the study area and categorized them into 10 distinct typologies based on the morphology and water-land interface, as documented in image 6. This categorization highlights the transformation of the water network and the ecological aspects of settlements in response to their geographical contexts. Additionally, the research mapped the morphology along the land-water interface to study the built form's response to the land-water interface. Observations for each of the typologies identified were documented with the corresponding governance and urban planning regulation and strategies that impact the existing condition as detailed in Table 1. Urban morphology resulted from urban planning laws regulating city development. The primary study revealed that these laws do not recognize the water network or the land-water intersection, leading to their exclusion. Consequently, the water network has become the city's "backyard," with the urban planning law influencing this neglect. The current morphology and land-water interface patterns reflect this oversight, manifesting in the city's disregard for its water network.

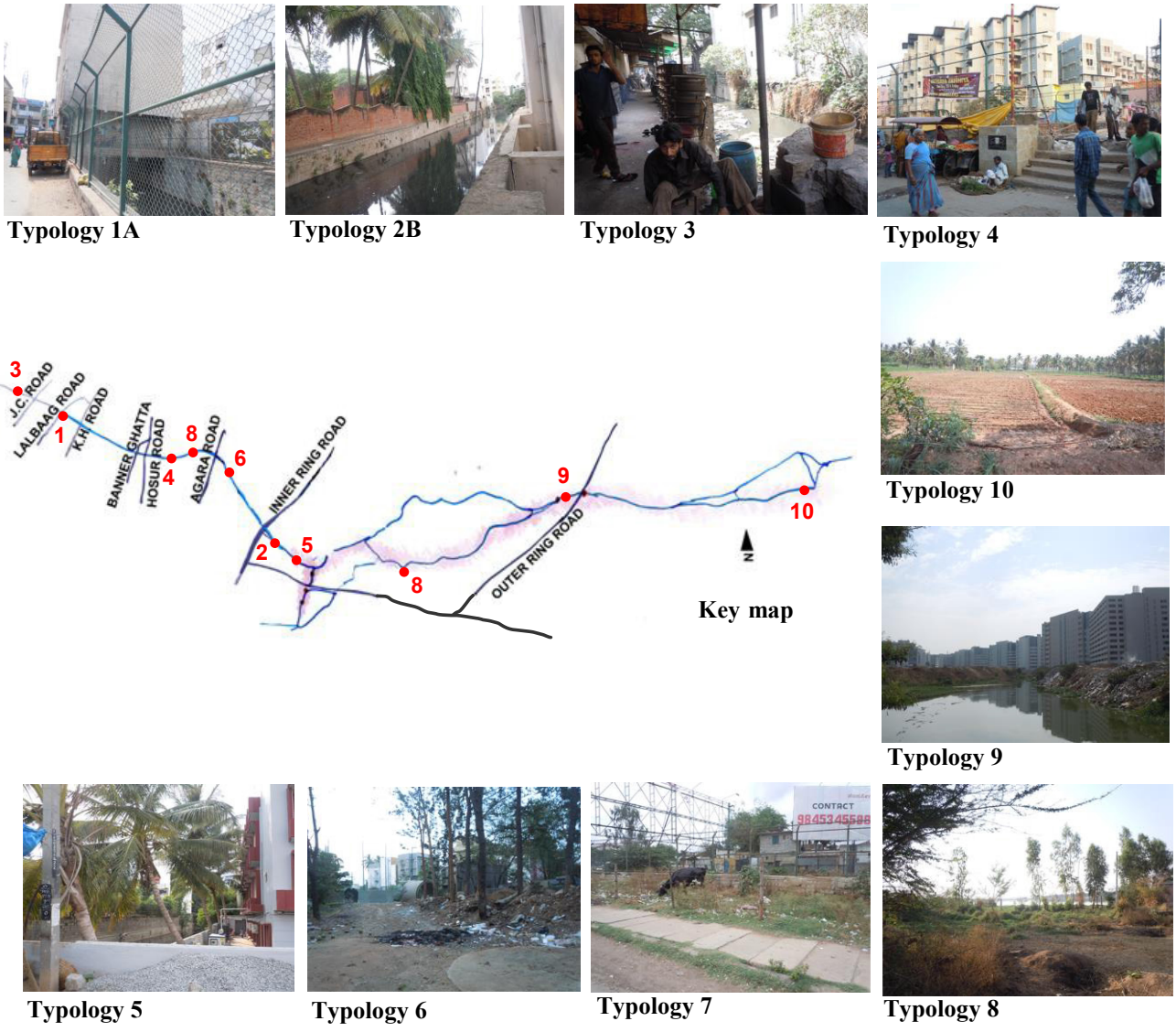


Figure 8. Pictorial representation of the Typologies as observed from the field study
Source: Photographed during the field study.

Table 1. Observations from the field study

Typology	Observation	Impact Due To
Typology 1a	Land Creation over the water network. Accessibility is restricted to one side sides of the blue network.	Government regulations - 30-year lease period and ownership pattern- Corporation
Typology 1 B	Land Creation over the water network. Accessibility on both sides of the blue network	Government regulations - 30-year lease period and ownership pattern- Corporation
Typology 2 A	Backyard formation	Land use policy and Settlement Pattern.
Typology 2 B	Backyard formation	Urban Planning and Government Regulations
Typology 3	Visual and olfactory experience is far from desirable. Accessibility is restricted to one side sides of the blue network.	Existing land use policy which is Industrial Land use.
Typology 4	Visual and olfactory experience is far from desirable. Accessibility on both sides of the blue network.	Existing land use policy which is Industrial Land use.
Typology 5	Buffer space on one side of the blue network	Planning at the project scale as a response to landform.
Typology 6	Buffer space on one side of the blue network	Ownership pattern, settlement pattern, and Government regulations,
Typology 7	Buffer space on one side of the blue network	Ownership pattern and settlement pattern.
Typology 8	Tank and land interface	Formation of backyards in the process of development on land.
Typology 9	Setback acts as the buffer space	Ownership on either side of the blue network and Government regulations,
Typology 10	Rural inclusion of the Blue Network	Existing land use.

The study reveals that government regulations permitting 30-year building leases over water networks have resulted in significant alterations to these areas. These regulations ignored the water network and land interface. The typology study highlighted the impact of land use regulations on land water interface, revealing that Typologies 1A and 1B involve land creation over the water network due to government regulations allowing 30-year building leases which is long over, as informed by the BBMP. Despite the High Court's orders for building removal, non-compliance persists, reflecting an ongoing neglect of the water network in urban planning. The data shows a clear disjunction between legal provisions and their enforcement, which reinforces the water network's non-recognition in urban development.

Typologies 2A and 2B illustrate how land use policies and planning principles allowed settlements to encroach and abut the water network, creating backyards. The inability to desilt the rajakaluve results from these principles which permitted construction along the water's edge. The Koramangala tank bed became a settlement for the urban poor, as seen in Typology 2A, with residences built under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM)[1] urban policy. This project transformed the water network into a backyard instead of integrating it with the settlement. The regulations allowing this construction did not recognize the water network or land water intersection and failed to protect tank beds, which is classified as no-development and ecologically sensitive zones by RMP 2015. Typology 2A underlines how land use regulations fail to integrate water networks, leading to the degradation of these ecological zones. The findings align with studies on urban planning neglecting ecological infrastructure, such as works by [9] on the impact of urban sprawl on natural systems. The exclusion of water networks in planning laws echoes critiques from the literature on the failure of regulatory frameworks to account for ecological considerations in urban growth [10].

Typology 3 in Bamboo Bazaar and Typology 4 on Marble Road feature industrial land use are highlighted due to their significant impact on pollution and the environment causing pollution by discharging untreated waste into the rajakaluve and creating undesirable visual and olfactory experiences. The discharge of untreated waste into the rajakaluve represents a severe case of environmental degradation directly linked to land use policies and industrial activities. Typology 5 includes a buffer space next to the water network, which is an unplanned residual space turned into a park. Known as ST Bed, this tank bed was converted into a housing layout and is prone to flooding during rains. The lack of urban planning regulations for these low-lying, sensitive zones is a significant concern, as these areas are not recognized by existing urban planning laws.

Typology 6, from the 1997 National Games Village (NGV) site formed under CDP 1995, featured a planned buffer space, providing safety from flooding for one side of the housing cluster, while the other side has revenue development abutting the water network. Typology 7 showed undeveloped Defense land on one side of the rajakaluve and Ejipura, a low-rise, high-density settlement and notified slum on the other. Ejipura settlement has been in the news for evictions due to part of the land being leased for a mall and housing for the displaced.

Typology 8 is unique as it features the interface between private land and Bellandur tank, resulting in the development turning its back to the tank. The Shantinagar tank is now a bus terminal, and the Koramangala tank houses the National Dairy Research Institute (NDRI). This stretch, from Shantinagar bus terminal to ST Bed, is prone to flooding. Urbanization and the transformation of tanks and tank beds into land have led to surface runoff flooding these former water bodies. This highlights the failure of formal urban planning and governance processes in recognizing the ecology layer of the settlements.

Typology 9 reflects RMP 2015, which mandates buffer spaces on both sides of the rajakaluveys. In the Hi-tech zone, corporate developments have used these buffers as private landscaped areas, making them gated and inaccessible. The narrowing of rajakaluveys has reduced their carrying capacity and shrunk the buffer zones. Although the RMP 2015 designates sensitive zones and recognizes the water network, it lacks specific recommendations based on carrying capacity and defining buffer spaces as commons. The interpretation of buffer zone regulations has left to landowners, developers, and authorities in a contested space. Additionally, primary, secondary, and tertiary nalas are neither clearly mapped nor defined, leading to varied interpretations by citizens and authorities.

Typology 10 represents agrarian land use where land, water networks, and settlements are interconnected. Agriculture, horticulture, and dairy farming are practiced, necessitating access to the water network.

However, the water quality within this network is polluted and unsuitable for domestic use. Farmers utilize this polluted water for cultivating vegetables and greens, which are then sold in city markets, establishing a concerning food chain where the city provides polluted water for rural production, which is then consumed by urban residents. A farmer while acknowledging this practice, cultivates vegetables for their own consumption using clean water. This situation underscores the unsustainable reliance on polluted water for urban food production, as articulated by the farmer stating, "You give us polluted water for us to grow your food".

The study identified and analyzed unique hotspots within the area, each influenced by factors like ownership, plot size, plot division, and regulations such as land use and buffer spaces. These elements impact the intersection of ecology and morphology along water networks. Ownership patterns, particularly in buffer zones delineated by RMP 2015, vary, with privately owned land parcels in both urban and agrarian zones. In urban areas, roads often serve as buffer spaces, though they may not meet the prescribed buffer space widths. The city's older sections, planned before RMP 2015, often turn their backs on water networks, as documented in typology studies. Discussions with Bangalore Development Authority (BDA) officials revealed that no new layouts have been formed by BDA post RMP 2015, though private layouts with BDA sanctions exist. Downstream agrarian zones show built forms responding to water networks, but the primary land use is Hi-tech, with secondary residential use, lacking density guidelines for environmentally sensitive areas. The study highlighted that the water network is not well-integrated into the urban fabric, with roads and built forms acting as barriers. Where accessible, the water network is in poor condition, reflecting the city's health. While the master plan recommends buffer zones along water networks, a concept introduced in RMP 2015, this has been contentious. Local area plans, essential for macro-scale planning, are missing, as neither BDA nor BBMP formulate them, despite the 74th Constitutional Amendment Act (CAA)[2] enabling municipal governments to do so. Additionally, there is a lack of specific regulations for sensitive zones, defining carrying capacity, and land use compatible with the land's sensitive nature.

4. RESULTS

The study revealed several key findings:

Typology Analysis: The research uncovered how urban planning laws have led to a disregard for the water network and land-water interface. For instance, Typologies 1A and 1B demonstrated how land creation over water networks was permitted due to outdated regulations. Similarly, Typologies 2A and 2B highlighted the adverse effects of land use policies that allowed settlements to encroach upon and pollute water bodies. Typologies 3 and 4, which focus on industrial land use, are highlighted due to their significant impact on pollution and the environment. The discharge of untreated waste into the rajakaluve represents a severe case of environmental degradation directly linked to land use policies and industrial activities. Typologies 5 and 8 are emphasized because they demonstrate the inadequacies of planning regulations in addressing flood risks and the transformation of water bodies into urban spaces.

Impact of Regulations: The analysis showed that current urban planning laws fail to adequately address or protect sensitive ecological areas, contributing to the degradation of the water network and inadequate buffer zones as seen in Typologies 3 through 10. The study also noted the inadequacies in handling polluted water used for agricultural purposes in Typology 10. The analysis reveals that urban planning inadequately addresses the intersection of land and water networks. For instance, Typology 6's planned buffer space mitigates flooding on one side of the housing cluster but fails to address the ecological impact on the other side. This disparity underscores the lack of a holistic approach in urban planning. Typologies 9 and 10 highlight the failure of the RMP 2015 and previous regulations to effectively manage buffer zones and protect sensitive ecological areas. The implementation gaps in these regulations, particularly regarding the

carrying capacity of water bodies and the management of agrarian land use, demonstrate a critical oversight in planning policies.

Field Observations and Interviews: Observations and discussions with local authorities and stakeholders provided insights into the practical challenges and failures of existing urban planning practices. This included the lack of effective implementation of regulations and the need for better integration of ecological considerations into urban planning. Feedback from residents in Typology 5 (ST Bed) highlights dissatisfaction with flooding issues due to the conversion of tank beds into housing layouts. Interviews with these residents reveal concerns about inadequate flood management and lack of maintenance. Discussions with BDA and BBMP officials indicate a recognition of these issues but also reveal the constraints faced in policy implementation and enforcement. The absence of local area plans and the slow adaptation to newer regulations like RMP 2015 are seen as barriers to effective management. In Typology 10, farmers' insights on using polluted water for irrigation reflect a critical issue in the urban-rural interface. Farmers report health concerns and challenges related to water quality, emphasizing the need for improved water management practices. It is estimated that an additional 109 hectares of land will be needed to produce sufficient food for urban populations [11]. Additionally given that by 2050, around 80% of the global population is projected to reside in urban areas, urban agriculture, including edible gardens and vertical and horizontal farming, can be a viable solution, to meet the demand for food. To facilitate the process of connecting land, water, and people, local community actors and stakeholder participation are critical [12].

5. CONCLUSION

Navigating through the intersection of urban morphology and ecology as a manifestation of the formal processes highlighted significant issues in urban planning law's recognition and integration of water network and land interface. Key findings reveal a significant oversight in urban planning laws regarding the recognition and incorporation of these ecological components. Specifically, land use regulations have allowed critical water features to be transformed into urban backyards or built-up areas, disregarding their ecological value. Despite existing legal mandates and court orders aimed at reclaiming these water networks and removing unauthorized structures, enforcement challenges persist, exposing systemic weaknesses in urban planning regulation implementation.

The transformation of tank beds and sensitive ecological zones into urban or industrial areas underscores the failure of current regulations to preserve these critical zones, leading to issues such as increased flooding and pollution. While the introduction of buffer zones was intended to protect these areas, ambiguous interpretations and private land ownership disputes have often rendered these zones ineffective. Moreover, the study uncovers a disconnect between macro-scale planning and detailed local area planning, revealing a critical gap in integrating ecological considerations into urban development strategies. The lack of well-formulated local area plans exacerbates this issue.

Urban planning law's inadequately recognition of these networks, leading to urban morphology that neglects critical ecological features. Land use regulations profoundly shape the inclusion of ecology features, often allowing construction that transforms essential water features into backyards or built-up areas. Despite legal mandates and court orders to reclaim water networks and remove unauthorized constructions, enforcement remains a significant challenge, revealing systemic issues in the implementation of urban planning regulations. Overall, the study underscores the need for urban planning laws to integrate the ecology considerations more comprehensively, prioritizing the recognition and protection of water networks, sensitive zones, and buffer areas to ensure sustainable urban development. These inferences emphasize the urgent need for urban planning and governance to prioritize inclusivity, regulatory enforcement, and strategic integration of water networks and sensitive zones into urban landscapes.

6. RECOMMENDATIONS

The research paper draws out recommendations for the planning and governance of the intersection of ecology and morphology along the water network. Thorough assessments of historical use, transformations, and current needs associated with spaces should be conducted to inform future planning and development decisions.

Specify Density Regulations for Sensitive Zones: Implement zoning regulations that restrict development density in sensitive ecological areas based on their carrying capacity. For example, in Typologies 1A and 2A, where the ecological impact has been significant, density should be limited to a specific ratio (e.g., X persons per hectare) to mitigate environmental degradation. This ensures that development does not exceed the ecological capacity of these areas, thereby preserving their ecological integrity.

Encourage Mixed-Use Developments: Create incentives for mixed-use developments that combine residential, commercial, and recreational spaces along the water network. This could include tax breaks for developers who incorporate green spaces and pedestrian pathways, similar to those seen in Typology 5 and 6. Mixed-use developments enhance urban vitality, reduce vehicle dependency, and foster pedestrian-friendly environments, which are essential for integrating urban morphology with ecological considerations.

Transform Buffer Zones into Urban Agriculture Areas: Convert non-buildable buffer zones into urban agriculture zones where local food production can occur. Develop policies to encourage and facilitate this transformation, such as incentives for urban farming initiatives and community gardening projects, similar to initiatives observed in Typology 10. This approach supports sustainability by integrating ecological preservation with local food production, reducing urban food miles, and promoting green spaces.

Conduct Comprehensive Assessments: Perform detailed assessments of historical land use, recent transformations, and current needs for areas surrounding water networks. This includes mapping changes over time and evaluating current ecological impacts, as demonstrated in the analysis of Typologies 3 and 4. These assessments provide a data-driven basis for informed planning decisions and ensure that future developments align with ecological and urban goals.

Enforce Compliance with Existing Regulations: Strengthen enforcement of the Wetlands (Conservation and Management) Rules 2010 and the Wetlands Regulatory Framework 2008 by enhancing monitoring mechanisms and increasing penalties for non-compliance. This could involve creating a dedicated task force to oversee wetland conservation, addressing the challenges observed in Typology 8. Effective enforcement is crucial to ensure that wetlands are protected and managed sustainably, addressing issues of pollution and unauthorized construction.

Develop Policy Tools for Buffer Zone Compensation: Establish a compensation scheme for landowners who maintain buffer zones in addition to strategies seen in Typology 9. This could include financial incentives, for example, tax reductions, or land-use credits. Compensating landowners encourages the preservation of buffer zones and ensures that they are maintained as effective ecological buffers.

Integrate traditional maintenance systems and local self-governance into urban planning frameworks, as enabled by the 74th CAA[2]. State ownership and community maintenance of buffer spaces should be enabled to ensure their preservation and effective management. This calls for a need to develop community-based management plans for buffer zones and water networks that involve local stakeholders in decision-making processes. Collective management empowers communities, ensures local needs are met, and integrates traditional knowledge into modern planning practices.

Coordinate Multi-Authority Governance: Establish a coordinated governance framework for the management and conservation of tanks and rajakaluveys involving all relevant authorities. Currently, tanks are governed by multiple authorities and rajakaluveys managed by the BBMP This framework should include regular meetings, shared data systems, and joint conservation efforts. Coordinated governance ensures that management strategies are unified, reducing conflicts and improving the effectiveness of conservation efforts.

6.1. Scope for Future Research

Building on the recommendations provided, future research should explore several critical areas to enhance the integration of ecological considerations into urban planning. To assess the impact of implementing density regulations on sensitive ecological areas, detailed case studies and empirical evaluations are needed. Research should also investigate the effectiveness of mixed-use developments along water networks, focusing on their potential to enhance urban vitality and integrate ecological features. Additionally, exploring the feasibility and impacts of converting buffer zones into urban agriculture areas through pilot projects will provide insights into their sustainability and benefits for local food production.
Comprehensive assessments of land use surrounding water networks are crucial, utilizing advanced GIS tools and historical data to inform future planning. Strengthening the enforcement of wetland conservation laws should be examined, including the evaluation of current monitoring mechanisms and the potential for enhanced penalties or dedicated task forces. Research into compensation policies for maintaining buffer zones—such as financial incentives or land-use credits—will help in developing effective strategies for ecological preservation.

Furthermore, integrating traditional and contemporary management practices into urban planning frameworks should be explored, focusing on community-based management of buffer zones and water networks. Finally, developing and testing coordinated governance frameworks for managing water bodies under multiple authorities will be essential to improve conservation and management efforts. These research avenues will contribute significantly to bridging the gaps identified in urban planning and ensuring more effective ecological integration.

Government Institutions interacted with for data collection:

- Bruhat Bengaluru Mahanagara Palike (BBMP)- the Municipal Corporation of Bengaluru
- Bangalore Development Authority (BDA) – the planning and development authority of Bengaluru
- Bengaluru Water Supply and Sewerage Board, (BWSSB)
- Bengaluru South Taluk Office for the village maps- the local Revenue Department

Notes

1. **JNNURM:** The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was a major urban modernization program initiated by the Government of India (GoI) through the Ministry of Urban Development. The mission aimed to enhance urban infrastructure and living standards. With an investment plan exceeding $20 billion over seven years, it sought to integrate infrastructure development, asset creation and management reforms, and improve access to basic services for the urban poor. The mission comprised two sub-missions: one dedicated to upgrading urban infrastructure and governance (including water supply, sanitation, and waste management), and the other focused on providing basic services to the urban poor.
2. **74th CAA:** The 74th Constitutional Amendment Act (CAA) of the GoI, enacted in 1992, is a significant piece of legislation aimed at decentralizing governance and enhancing the role of urban local bodies in the country.

REFERENCES

[1] Mathur, A., & Da Cunha. D. (2006). *Deccan traverses: the making of Bangalore's terrain*. New Delhi: Rupa.

[2] Srinivas, S. (2001). *Landscapes of Urban Memory: The Sacred and the Civic in India's High-Tech City* (NED-New edition, Vol. 9). University of Minnesota Press. http://www.jstor.org/stable/10.5749/j.ctttsnq6

[3] Prathima, N. (2021). From structuring system to backyards: Transformation of Bengaluru's water network. *International Journal of Scientific & Engineering Research*, 12(7), July 2021.

[4] Agarwal, U., & Narain, S. (1999). *Dying wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems*. New Delhi: Centre for Science and Environment (CSE).

[5] TV Ramachandra et., al. (2018). Need to Preserve the Buffer Zone Integrity of Water Bodies, ETR 152, Energy & Wetlands Research Group, *Centre for Ecological Science*, IISc.

[6] Bostancı, S. (2021). Researching for Methods in Visual Analyses of Urban Skylines. A+Arch Design International Journal of Architecture and Design, 7(2), 161-173.

[7] Times Now, (2020, October 24). Karnataka CM alerts Bengaluru civic body officials on heavy rains forecast, *Times Now News*, Bengaluru, Retrieved from https://www.timesnownews.com/bengaluru/karnataka-cm-alerts-bengaluru-civic-body-officials-on-heavy-rains-forecast/655965

[8] TV Ramachandra TV, Vinay S., Bharath H. Aithal, (2017). Koramangala Floods: Causes, ENVIS Technical Report: 131, Environmental *Information System*, CES, CES, Indian Institute of Science, Bangalore 560012.

[9] Barton, H., Grant, M., & Guise, R. (2003). *Shaping neighborhoods: A guide for health, sustainability and vitality*. Routledge

[10] Beatley, T., & Newman, P. (2006). *The sustainable urban development reader* (2nd ed.). Routledge.

[11] Shema, A. I., & Abdulmalık, H. (2022). Urban Vertical Farming as a Path to Healthy and Sustainable Urban Built Environment. A+Arch Design International Journal of Architecture and Design, 8(1), 67-88.

[12] Terlemez, A. K., & Hacihasanoglu, O. (2022). An assessment model for participatory architecture: Kuzguncuk gardens example. *A+ Arch Design International Journal of Architecture and Design*, *8*(1), 1-24.

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