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Analyzing the Interconnection of Water Scarcity and Urban Flooding in Bengaluru: A Comprehensive Study of Combined Challenges

Evangleen.J[1], Jyothi Gupta[2]
School of Architecture, Christ (Deemed to be University), Bangalore, Karnataka.

Abstract: ***Water scarcity and urban flooding are major challenges in Bangalore, worsened by rapid urban growth, climate change, and the depletion of natural water resources. The destruction of lakes and green spaces has reduced the city's ability to retain water, making it more prone to flooding. This has created a cycle of water shortages and flood risks. This study explores how urbanization and the loss of natural water sources have worsened the city's water crisis, using geospatial tools to map areas affected by water shortages and flooding, as well as the decline of green spaces. It also examines how urbanization has led to groundwater depletion and increased flood risks. In order to improve water management and lessen floods, the results emphasize the necessity of restoring lakes and green areas. The study concludes with the need for groundwater recharge to effectively address the city's water challenges, while also identifying gaps in the literature regarding the role of green infrastructure and sustainable urban planning.***

Keywords: Water scarcity, GIS, Urban floods ,Climate change, Sustainability

Introduction

Known for its thriving tech industry and vibrant culture, Bangalore, the capital of Karnataka, is quickly becoming a major urban hub in southern India. Once acknowledged for its abundance of lakes and lush greenery, the city is now dealing with a complex water crisis, with frequent flooding and water shortages despite heavy rainfall during the monsoon season. These seemingly incompatible problems are brought on by rapid urbanization, ineffective water management, and the effects of climate change. On the one hand, the city's expanding infrastructure and population have caused excessive groundwater extraction, heavy reliance on outside water sources, and pollution of local water bodies, all of which have contributed to the city's water scarcity. On the other hand, the poor management of drainage systems, loss of natural water bodies, and widespread development of impermeable surfaces have made the city more vulnerable to flooding, particularly during heavy rains. This paper delves into the complex relationship between water scarcity and flooding in Bangalore, exploring how both issues are symptoms of broader urban planning challenges. The focus is on understanding the root causes of these problems.

Aims and Objective

aim:

The goal of this research is to better understand the complex relationship between water scarcity and urban flooding in Bangalore, with a focus on how urbanization, groundwater depletion, and the degradation of natural water systems, particularly lakes and green/blue spaces, contribute to these problems. This study aims to analyze the environmental, urban, and policy elements of Bangalore's water using geospatial technologies.

1. How has Bangalore's urban growth influenced water scarcity and urban flooding?
2. What is the impact of the sustainability of green and blue spaces on the city's water management and flood mitigation?

objective:

1. To assess the current situation of Bangalore's groundwater levels, the number of existing lakes..
2. To examine ten relevant literature reviews, develop a taxonomy of key findings, and identify research gaps in the field of water scarcity and urban flooding.
3. To create GIS maps of Bangalore that illustrate the geographical distribution of water scarcity, and flood-prone areas.

The goal of this research is to better understand the complex relationship between water scarcity and urban flooding in Bangalore, with a focus on how urbanization, groundwater depletion, and the degradation of natural water systems, particularly lakes and green/blue spaces, contribute to these problems. This study aims to analyze the environmental, urban, and policy elements of Bangalore's water using geospatial technologies.

3. How has Bangalore's urban growth influenced water scarcity and urban flooding?
4. What is the impact of the sustainability of green and blue spaces on the city's water management and flood mitigation?

scope:

The intent of this study paper is to look into the relationship between water shortage and urban flooding in Bangalore, with a special emphasis on the effect of urbanization, the degradation of natural water systems, and the impact on water management measures. This research aims to better understand the underlying reasons, analyze the current situation of water resources, and investigate prospective options to alleviate both water scarcity and flooding threats in the city.

literature analysis:

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Title of the paper	Water scarcity: A global hindrance to sustainable development and agricultural production – A critical review of the impacts and adaptation strategies	Vulnerability assessment of flood-affected locations of Bangalore by using multi-criteria evaluation	Water, Modern and Multiple: Enriching the Idea of Water Through Enumeration Amidst Water Scarcity in Bengaluru
Journal Name and Publisher	Biswas, A., Sarkar, S., Das, S., Dutta, S., Choudhury, M. R., Giri, A., ... & Paul, D. (2025). Water scarcity: A global hindrance to sustainable development and agricultural production–A critical review of the impacts and adaptation strategies. Cambridge Prisms: Water, 3, e4.	Prasad, NN Rama, and Priya Narayanan. "Vulnerability assessment of flood-affected locations of Bangalore by using multi-criteria evaluation." Annals of GIS 22.2 (2016): 151-162.	Vogt, Lindsay. "Water, modern and multiple: Enriching the idea of water through enumeration amidst water scarcity in Bengaluru." Water Alternatives 14.1 (2021): 97-116.
Month and Year of Publication	Jan-25	Apr-16	Feb-21
Objectives of the Study / Research	This study evaluates the impact of water scarcity on global agriculture, food security, and socio-economic development, focusing on sustainable development goals. It reviews adaptation strategies, proposes policy interventions, and explores future water management in light of climate change, population growth, and increasing water demand.	The report examines Bengaluru's water stress, linking it to industrial demands and urbanization. It advocates for fair solutions and highlights socioeconomic gaps in water access. However, a deeper understanding of economic factors influencing water use and realistic implementation tactics would improve the study. Despite focusing on regional and long-term remedies, the report offers insightful analysis of Bengaluru's water situation.	Investigates how water is perceived and utilized in various cultural, social, and economic situations in order to better understand the intricacies of Bengaluru's water shortage. The study gathers information on water availability, access, and usage in the city by enumeration. It seeks to provide a more complex understanding of the problem by highlighting both contemporary and traditional viewpoints on water. The study's ultimate goal is to provide guidance for sustainable water management plans that take into account the various demands of the metropolis.
Methodology adopted in the Study / Research		The study uses a historical case study methodology to examine colonial Bangalore's water governance, focusing on socio-political dynamics and the impact of colonial government systems on water availability. It uses qualitative techniques like content analysis and integrates political ecology and urban history to understand the intricate connections between resource allocation and industrialization.	Enumeration via surveys and data collecting on water scarcity, access, and usage in Bengaluru are probably part of the process. Case studies and qualitative interviews shed light on the cultural and social aspects of water. Analyzing secondary data places the results in the perspective of larger patterns. By analyzing social, economic, and environmental aspects, the framework combines contemporary and traditional viewpoints on water. In order to guide policy suggestions, it also assesses fairness, sustainability, and water governance.
Results of the Study / Research	The paper "Water Scarcity: A Global Hindrance to Sustainable Development and Agricultural Production – A Critical Review of the Impacts and Adaptation Strategies" highlights the negative impacts of water scarcity on agriculture, economic, social, and environmental degradation. Adaptation strategies include water conservation techniques, technological innovations, policy interventions, and global cooperation.	The report highlights the fragmentation of Bangalore's colonial water governance, with various sectors being governed independently. It highlights the depletion of public water tanks due to unequal access to water by textile mills. The study highlights inefficiencies and disparities in water management, emphasizing the need for a reevaluation of current governance to address contemporary water issues in Bangalore.	The study reveals significant water access disparities among socioeconomic classes in Bengaluru, with underprivileged populations experiencing severe shortages. Traditional water management techniques, like community wells and rainwater harvesting, are still essential. The study emphasizes the need for inclusive water governance, incorporating traditional practices and modern technology.
Limitations of the Study / Research	Indigenous water management techniques are underexplored,Lack of Primary Data	The study's relevance to contemporary water governance challenges may be limited due to its focus on colonial Bangalore, reliance on historical records, and insufficient consideration of long-term environmental effects. Comparing Bangalore's water governance to other colonial cities could be beneficial, and the study may not have explored the direct link between colonial practices and post-independence governance.	The limitations of the study include its focus on Bengaluru, which may limit generalizability to other regions, and potential issues with data reliability, particularly in informal areas. The study may also overlook seasonal or long-term variations in water availability and could oversimplify complex social dynamics. Additionally, without a longitudinal approach, it may not capture changes in water management practices over time.
Gaps Identified in the Study / Research		The study highlights a knowledge gap regarding the long-term effects of colonial water management methods on the environment, particularly regional water ecosystems. It calls for more comparative research on water governance in other colonial capitals, focusing on socioeconomic effects, particularly in underserved areas. The report also calls for further investigation into how colonial governance influences post-independence water management.	The study highlights gaps in integrating traditional water practices with modern solutions, lacks in-depth analysis on local governance, social inequalities, climate change impacts, and community-driven water management initiatives in Bengaluru, highlighting the need for a cohesive approach.
Remarks		The paper explores the historical context of Bangalore's urban water governance, highlighting its long-term impact on water problems. It links colonial practices and industrialization to current water management issues. While it provides valuable insights, further research is needed to understand the connection between colonial times and post-independence water management developments.	The paper explores water scarcity in Bengaluru, highlighting disparities and urbanization challenges. It uses enumeration and qualitative methods, but could benefit from integrating traditional and modern practices for actionable solutions. It contributes to sustainable water management discussions.

	4	5	6
Title of the paper	Karnataka's Climate Crisis: Urban Challenges and Sustainable Solutions for Bangalore	Water Stress in Bengaluru, Silicon City	Urban Flooding: Case Study of Bangalore
Journal Name and Publisher	Mohan, Chippy, et al. "Karnataka's Climate Crisis: Urban Challenges and Sustainable Solutions for Bangalore." (2024).	Das, Subhajyoti. "Water Stress in Bengaluru, Silicon City." Journal of the Geological Society of India 100.6 (2024): 767-772.	Mukhopadhyay, Pallavi, and Bijay Kumar Das. "Urban Flooding: Case Study of Bangalore." 9th International Multidisciplinary Conference on Current Research Trends (IMCCRT). Vol. 34. No. 2. 2023.
Month and Year of Publication	January-24	Jun-24	2023
Objectives of the Study / Research	With an emphasis on environmental effects like resource shortages and extreme weather, the study intends to investigate the urban issues Bengaluru experiences as a result of Karnataka's climate crisis. It aims to comprehend how these issues are made worse by urbanization and the city's susceptibility to climate change. The study looks into long-term ways to lessen these effects in an urban environment. It also assesses programs and policies meant to solve climate-related concerns. The ultimate objective is to suggest workable methods for enhancing Bengaluru's sustainability and resilience to climate change.	In Bengaluru, sometimes known as the "Silicon City" of India, the study intends to look into the causes and effects of water stress. It looks at how fast urbanization, industry, and depleting water supplies interact. The efficiency of current water management measures in meeting the city's increasing water demand is also assessed in this report. It investigates the socioeconomic effects of water stress on various Bengaluru communities. In order to provide fair access throughout the city, sustainable water management measures are to be suggested.	The study investigates urban flooding in Bangalore, focusing on factors like climate change, inadequate infrastructure, and rapid urbanization. It examines the relationship between drainage systems, land use patterns, and stormwater management, as well as the socioeconomic impacts of flooding on Bangalore communities. The goal is to reduce flooding risks and improve urban flood control techniques.
Methodology adopted in the Study / Research	The study uses a mixed-methods approach, incorporating qualitative interviews and quantitative data on Bengaluru's resource usage, climate trends, and environmental deterioration. It focuses on community-based climate resilience strategies, governance, and policy analysis.	The study uses a mixed-methods approach, combining qualitative interviews with quantitative data on water supply and usage. Surveys measure public opinion on water conservation, and the framework examines sustainability principles, water policy, urbanization patterns, and effective water management techniques in metropolitan settings. It emphasizes environmental justice and social equity.	The paper uses a case study methodology to analyze recent flood episodes in Bangalore, utilizing qualitative and quantitative techniques like interviews and GIS mapping. It explores causes and effects, hydrological analysis, climate adaptation tactics, urban planning theories, governance frameworks, and flood control policies to improve resilience.
Results of the Study / Research	According to the report, climate change and growing urbanization are to blame for Bengaluru's rising heatwaves, water shortage, and flooding. It concludes that, particularly in underserved areas, the urban infrastructure currently in place is unable to handle these catastrophic weather occurrences. Successful local projects like rainwater collection and green spaces are highlighted in the study as possible models for other locations. It also emphasizes how important it is for local, state, and federal governments to better coordinate their policies. Lastly, in order to guarantee long-term sustainability, the study promotes greater community involvement in climate adaption initiatives.	The rapid industrial and urbanization growth in Bengaluru has led to increased water stress, particularly in vulnerable areas. The crisis is primarily caused by surface water contamination and excessive groundwater extraction. The report highlights weaknesses in water management regulations, particularly for informal settlements. To mitigate the situation, it recommends improved infrastructure, stronger governance, and extensive water conservation measures.	Bangalore's urban floods are primarily caused by rapid development, wetland encroachment, and insufficient drainage infrastructure. Inadequate urban planning and the disappearance of natural water sources increase vulnerability. Low-income communities are disproportionately affected due to inadequate infrastructure. Current flood management regulations need better coordination among urban authorities. Incorporating green infrastructure, such as urban wetlands and rainwater collection, is crucial.
Limitations of the Study / Research	The study's conclusions may not be applicable to other Karnataka or Indian cities, as it focuses solely on Bengaluru. It may also overlook larger political and economic limitations, limited data availability, and overlook the long-term effects of climate adaptation efforts due to short-term focus.	The study's focus on Bengaluru may limit its applicability to other cities with similar water stress issues. The study's accuracy in water data and lack of thorough examination of long-term climate change effects on water supply are also limitations. Further research on economic variables influencing water demand and regional or interstate water disputes could enhance the study's findings.	The study's applicability to other cities may be limited due to Bangalore's concentration, lack of precise flood data, and insufficient consideration of climate change's long-term effects on flooding patterns. A comprehensive comparison of Bangalore's flood management policies with other cities would be beneficial. Additionally, the report may not cover land tenure and governance in flood-prone areas, making policy execution more challenging.
Gaps Identified in the Study / Research	The report highlights a gap in long-term data on climate impacts in Bengaluru, hindering accurate predictions about future trends. It also highlights the lack of coordination between climate policy and urban planning, leading to dispersed adaptation initiatives. The study also highlights political and economic obstacles preventing sustainable solutions adoption, and the potential of rural-urban connections for improving climate resilience.	The study highlights a gap in incorporating climate change estimates into water management strategies, undervaluing alternative water sources like desalination and wastewater recycling, and a lack of a comprehensive long-term plan for water conservation. It also emphasizes the need for a thorough examination of socioeconomic issues affecting water availability, particularly in the informal sector.	The report highlights a flaw in Bangalore's flood control and urban development plans, highlighting the lack of climate change estimates and comprehensive information on flood risks in underdeveloped areas. It calls for more local-level adaptation techniques and community-based solutions to manage urban flooding, and calls for further investigation into urban green spaces and water bodies.
Remarks	The study provides a comprehensive overview of Bengaluru's climate issues and offers practical solutions. It includes adaptation techniques for various urban settings. However, a more comprehensive analysis of political and economic barriers to adoption and a more extensive policy analysis would be beneficial. Despite this, the study contributes significantly to the conversation on urban climate resilience.	The report explores Bengaluru's water stress, highlighting socioeconomic disparities and advocating for equitable solutions. It suggests a need for a deeper understanding of economic factors influencing water use, particularly in the industrial sector. While the report provides valuable insights, it could benefit from a more comprehensive analysis of regional and longer-term solutions.	The study highlights infrastructure and urban planning issues, as well as the causes of urban flooding in Bangalore. It emphasizes the socioeconomic impact of flooding, particularly on underprivileged populations. The report provides some practical solutions but needs more regional comparison. While it offers some solutions, it lacks research on long-term climate adaptation measures. Overall, it contributes significantly to urban flood management.

	7	8	9	10
Title of the paper	Development of an urban flood model for Bengaluru city, Karnataka, India	Understanding Urban Floods as Extreme Events and Disaster	Integrating socio-economic variables in urban flood damage assessments: a case study of Bengaluru, India	(Re) envisioning inclusive futures: Applying narrative foresight to deconstruct the problem of urban flooding in the slums of Bengaluru, India
Journal Name and Publisher	Mujumdar, P. P., et al. "Development of an urban flood model for Bengaluru city, Karnataka, India." Current Science 120.9 (2021): 1441-1448.	Bindal, Sonal, Sandipan Samanta, and Anil Kumar Gupta. "Understanding Urban Floods as Extreme Events and Disaster Management: A Case Study of Bengaluru." Climate Change and Environmental Impacts: Past, Present and Future Perspective. Cham: Springer International Publishing, 2023. 415-427.	Pathak, Abhishek A., Apoorva R. Mathad, and Alexandre S. Gagnon. "Integrating socio-economic variables in urban flood damage assessments: a case study of Bengaluru, India." Natural Hazards (2024): 1-26.	Nadimpalli, SriPallavi, Sahil Mathew, and Tashina Madappa Cheranda. "(Re) envisioning inclusive futures: Applying narrative foresight to deconstruct the problem of urban flooding in the slums of Bengaluru, India." Development Policy Review 42 (2024): e12786.
Month and Year of Publication	2021	Jan-23	Nov-24	Jun-24
Objectives of the Study / Research	The project aims to create an urban flood model for Bengaluru to understand flood patterns and assess flood risk. It will analyze drainage infrastructure, land use, and rainfall, assess current control tactics, and identify areas needing development. The model will guide urban development decisions and provide policymakers with a tool to manage flood threats.	The study explores Bengaluru's urban floods and their impact on disaster management. It examines the city's urban layout and infrastructure, governance, legislative frameworks, and response systems' effectiveness in reducing flood damage. The study also evaluates the effectiveness of current flood management techniques and aims to recommend improvements in urban resilience and disaster preparedness.	The study aims to understand the impact of flooding on neighborhoods in Bengaluru by incorporating socioeconomic factors into urban flood damage assessments. It investigates the relationship between flood risk, damage, income, education, and house quality, offering a nuanced view of flood hazards and examining how socioeconomic factors affect community adaptation and recovery from floods.	The study explores urban flooding in Bengaluru's slums using narrative foresight. It aims to include stakeholders in flood risk management and investigate other futures. The study highlights socioeconomic vulnerabilities in slums and how they worsen flooding effects. It aims to provide community-driven, inclusive strategies for flood resilience, highlighting the voices of slum inhabitants often overlooked in urban planning and crisis management.
Methodology adopted in the Study / Research	The study uses hydrological and hydraulic modeling to map flood-prone areas and simulate flood scenarios using remote sensing technology and GIS. It uses probabilistic and deterministic approaches to predict flood risk. The model is calibrated and validated using local weather data and field observations, incorporating historical rainfall data.	The study investigates recent urban flooding incidents in Bengaluru using a case study approach. Qualitative techniques like focus groups and interviews with local government representatives and disaster management specialists are used. The study evaluates flood-prone locations and infrastructure efficiency using historical flood data and GIS mapping. It also assesses flood response system stakeholders' functions.	The study uses a mixed-methods approach to analyze flood damage data, combining qualitative and quantitative data. It surveys and interviews residents in flood-affected areas, overlaying socioeconomic data with GIS mapping to identify vulnerable communities. Vulnerability theory is integrated, and statistical analysis is used to measure the correlation between socioeconomic factors and flood damage.	The study employs a narrative foresight methodology, involving urban planners, policymakers, and slum populations in co-creating narratives about resilience and urban floods. Through workshops and conversations, participants imagine various futures based on current issues. Systems thinking is used to understand interrelated elements causing urban flooding in slums. Key themes and potential flood resilience avenues are identified.
Results of the Study / Research	The study creates a flood model in Bengaluru using past rainfall data and land-use trends, identifying areas most susceptible to floods, particularly those with poor drainage systems. The model highlights impermeable surfaces, water body encroachment, and inadequate stormwater management as increasing flood risks. The report recommends targeted urban infrastructure upgrades, including improved drainage, green spaces, and flood retention zones.	The report highlights the significant factors contributing to urban flooding in Bengaluru, including fast urbanization, poor land use planning, and inadequate drainage infrastructure. It also highlights the disjointed flood control plans and disproportionate suffering in low-income areas and informal settlements. The report recommends strengthening governance, enhancing community-based disaster planning, and upgrading stormwater management systems for a more effective flood response.	The study highlights the significant impact of socioeconomic factors on flooding damage, particularly for marginalized and lower-income populations. Inadequate shelter and lack of preparation increase the likelihood of severe flood impacts. These areas lack government assistance and resources for post-flood recovery. The study emphasizes the importance of incorporating socioeconomic factors into flood damage models for accurate risk assessments and recommends policies to increase flood resilience.	The study reveals that Bengaluru's slum dwellers are disproportionately affected by urban flooding due to inadequate infrastructure, resource scarcity, and social marginalization. It suggests community-driven flood management tactics can outperform top-down techniques. The narrative foresight approach suggests addressing social injustices and physical infrastructure for inclusive flood management. Policies should prioritize slum populations' opinions for disaster readiness and response.
Limitations of the Study / Research	The study's model relies on current, potentially inaccurate data, especially in informal or rapidly changing regions. It doesn't fully consider future climate change impacts on flood patterns. The data resolution may affect forecast accuracy in high-risk areas. Validation is limited as it doesn't thoroughly examine model performance in actual flood situations and doesn't consider socioeconomic factors affecting flood susceptibility.	The focus on previous floods and the underrepresentation of underprivileged people may be limitations of the study on flood hazards in Bengaluru. The long-term impacts of climate change on future flood hazards are not fully taken into account, and bias may be introduced by qualitative interviews. The study would have benefited from additional data on the efficacy of flood response during actual disasters, as the report primarily focuses on urban infrastructure and governance.	The study's limitations include its focus on a single city, potential bias due to over-reliance on self-reported socioeconomic data, insufficient consideration of long-term socioeconomic shifts and their impact on flood resistance, limited data availability and accuracy, and insufficient examination of local government policies' impact on socioeconomic vulnerability during floods.	The paper's qualitative narratives may not provide a comprehensive quantitative study of flood risks or impacts, and its context-specific approach may not be applicable to other cities or areas. Additionally, the study may not adequately address the impact of external variables like climate change on slum flooding scenarios, making it less actionable and potentially unreliable.
Gaps Identified in the Study / Research	The study highlights a gap in integrating climate change projections into flood modeling, particularly in unplanned regions and informal settlements. It also highlights the lack of comprehensive data on socioeconomic and demographic indicators for flood mitigation. The research emphasizes the need for cooperation from various stakeholders, including governmental organizations, and emphasizes the importance of increased community involvement and public knowledge in flood risk mitigation.	The study highlights a gap in integrating long-term climate change estimates into disaster management and flood risk assessments, highlighting ineffective cooperation between stakeholders and lack of reliable data collection methods. It calls for increased consideration of social vulnerability in flood management, particularly in informal settlements, and calls for comprehensive disaster preparedness plans that include community awareness and infrastructure.	The study highlights a lack of comprehensive information on the long-term impacts of floods on socioeconomic well-being, particularly in at-risk communities. It also highlights the absence of integrated flood damage models considering physical and socioeconomic characteristics. The research emphasizes the need for local governance and policy frameworks to address socioeconomic gaps in flood control, and calls for improved community involvement in risk assessments and recovery planning.	The study highlights a gap in urban catastrophe management, particularly in underserved regions, in using foresight tools. It highlights the lack of a comprehensive framework for flood resilience, incorporating slum residents' perspectives into urban governance, and the inability to coordinate flood risk management with long-term socioeconomic development objectives. The paper calls for interdisciplinary research linking social justice, climate science, and urban planning in flood resilience initiatives.
Remarks	The study provides a comprehensive flood model for Bengaluru, combining urban data with hydrological technologies to predict flood risks. It suggests future climate scenarios and socioeconomic factors could enhance its applicability. However, more practical verification and stakeholder cooperation are needed for its effective use. Overall, the study provides valuable insights into Bengaluru's flood issues.	The study highlights Bengaluru's urban flooding issues and the shortcomings in disaster management plans. It highlights the disjointed nature of flood governance and lack of stakeholder collaboration. Further research on socioeconomic effects and climate change's role in future floods could improve the study. The research provides a solid foundation for improving Bengaluru's flood control.	The research contributes to urban flood risk management by incorporating socioeconomic factors in flood damage estimates. It advocates for inclusive flood management techniques and highlights differences in flood impact among different socioeconomic groups. However, a global comparison of towns or regions with different socioeconomic profiles could improve the study's applicability. The findings can guide fair flood risk management and resilience-building strategies.	

Title of the paper	Water scarcity	Urban floods	GIS	Climate change	Sustainability
Water scarcity: A global hindrance to sustainable development and agricultural production – A critical review of the impacts and adaptation strategies	✓			✓	✓
Vulnerability assessment of flood-affected locations of Bangalore by using multi-criteria evaluation		✓		✓	
Water, Modern and Multiple: Enriching the Idea of Water Through Enumeration Amidst Water Scarcity in Bengaluru	✓				
Karnataka's Climate Crisis: Urban Challenges and Sustainable Solutions for Bangalore					✓
Water Stress in Bengaluru, Silicon City			✓		
Urban Flooding: Case Study of Bangalore	✓			✓	
Development of an urban flood model for Bengaluru city, Karnataka, India		✓	✓		
Understanding Urban Floods as Extreme Events and Disaster		✓			
Integrating socio-economic variables in urban flood damage assessments: a case study of Bengaluru, India		✓			✓
(Re) envisioning inclusive futures: Applying narrative foresight to deconstruct the problem of urban flooding in the slums of Bengaluru, India		✓			

RESEARCH QUESTIONS:

1. **How has the loss of natural water bodies (lakes, wetlands) and green spaces impacted the city's ability to manage water resources effectively?**

Bangalore, which started as a small walled town in the 1500s under the rule of Kempe Gowda, has undergone remarkable changes over the centuries. In the 16th and 17th centuries, the city was centered around the Bangalore Fort, with agriculture and natural water bodies like lakes playing a key role in managing local water resources. During British rule in the 1800s, the city expanded as the British developed the cantonment area, adding infrastructure like roads, parks, and military bases. After India gained independence, Bangalore's growth accelerated, particularly in the 1970s and 1980s, when industrialization and the booming IT sector attracted both migrants and businesses, shaping the city into the urban center it is today (Shown in Fig-1).As a result, the city's boundaries began to spread into surrounding places like Whitefield and Hebbal. Starting in the 1990s, the IT boom stimulated the creation of new commercial and residential neighborhoods, stretching the city's limits even further into what was once rural terrain (Shown in Fig-2). Bangalore's natural water bodies have been destroyed by unplanned urban growth; lakes, marshes, and rivers that once had a vital role in supplying water, regulating floods,

and replenishing groundwater have been encroached upon, filled in, or repurposed for development; the loss of these green and blue spaces has only made the city's water scarcity and flooding problems worse. As Bangalore grew, areas rich in water-retaining features were replaced by impervious surfaces like concrete roads and buildings, which decreased the city's capacity to manage water naturally, making it more vulnerable to flooding during the monsoon and increasing its reliance on outside water sources.

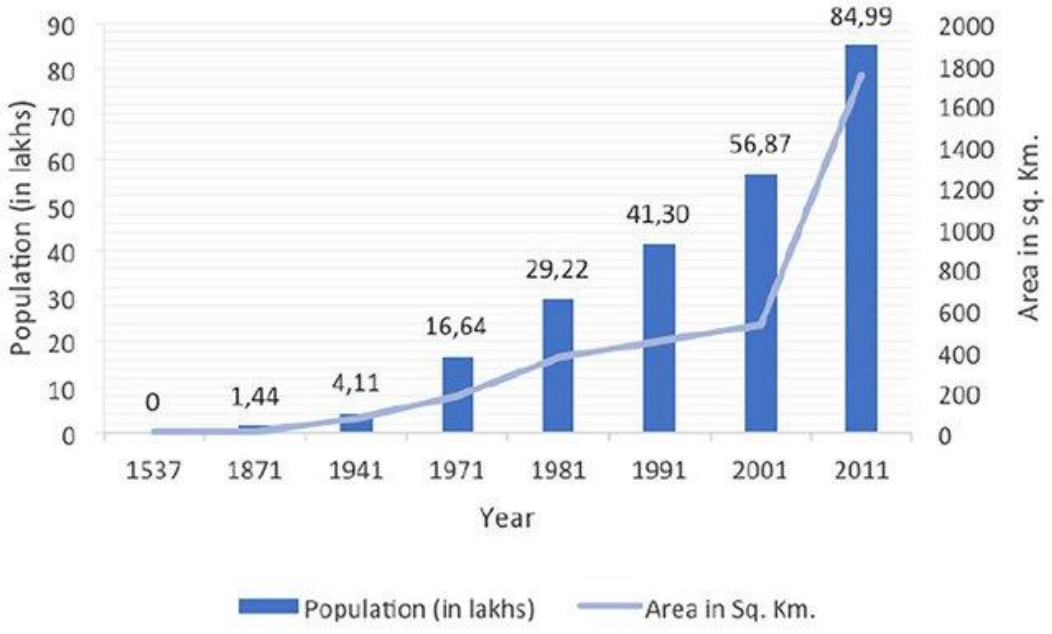


Fig-1 (Population growth of Bangalore from 1537 to 2011. Source. Census of India..)

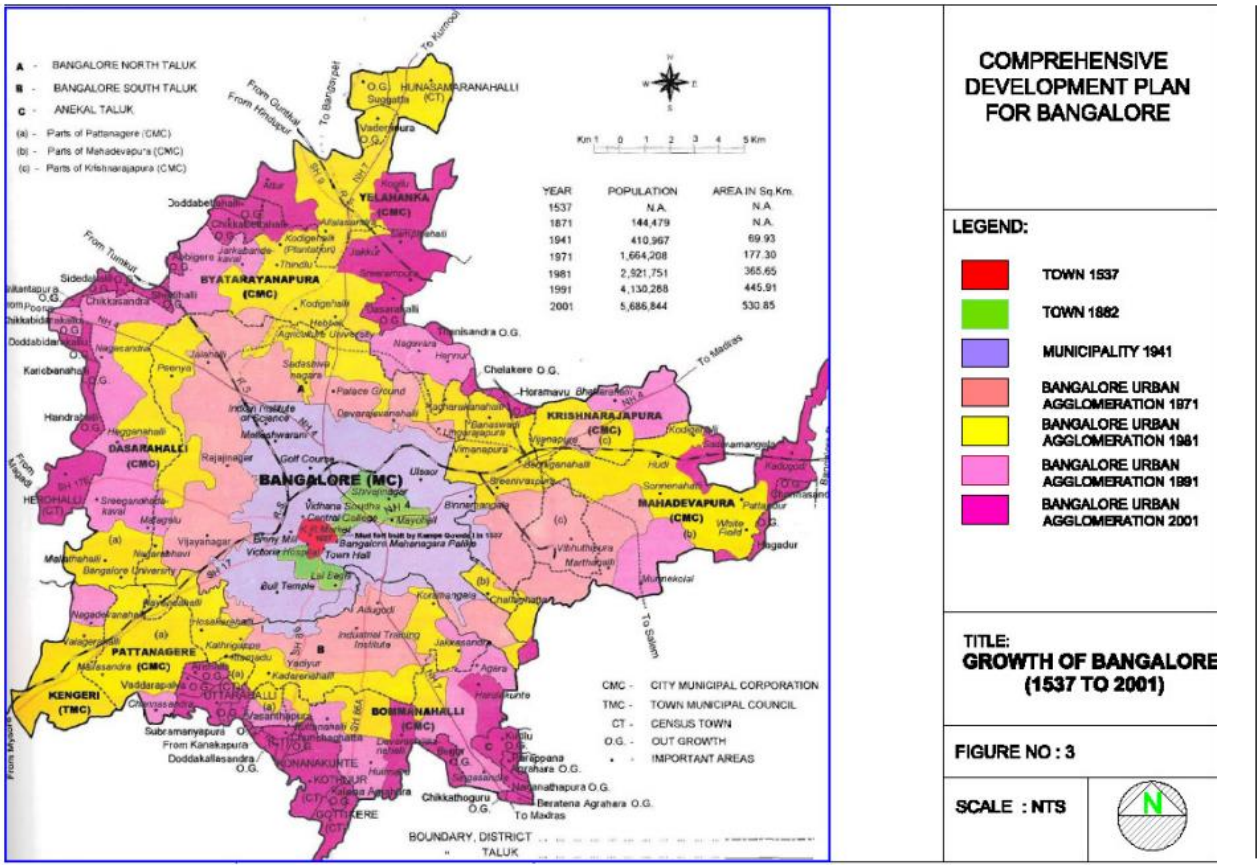
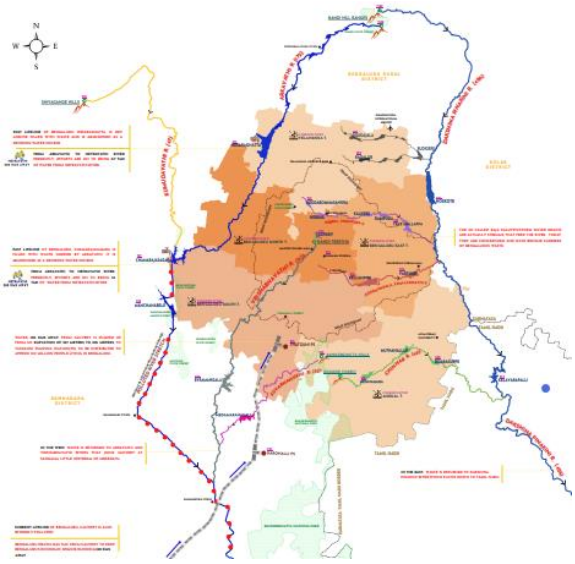


Fig-2(The growth of Bengaluru) Source: CDP 2009

2. **How has the degradation of Bangalore's green and blue spaces affected the natural water retention capacity of the city, exacerbating both water scarcity and urban flooding?**

Bangalore's fast urbanization has seriously impacted its natural water management systems, owing to the encroachment of the city's three major valleys—Koramangala, Challaghatta, and Vrishabhavathi.(fig-3) Historically, these valleys were part of the city's natural stormwater drainage system, channelling precipitation into nearby lakes and wetlands. However, as urbanization grew fast in the late 20th and early 21st centuries, these valleys became more encroached upon and built over. Roads, buildings, and other infrastructure have blocked the natural flow of water, which was once channelled to natural catchment areas such as the lakes in these valleys.

The city's water management system has been disrupted by the encroachment on Bangalore's valleys, which were once floodplains that helped manage excess monsoon water. However, rapid development has led to more surface runoff and waterlogging, and the shrinking of these valley spaces has also affected the flow of water to key lakes like Bellandur, Vengayyana, Hebbal, Agara, Ulsoor, Sankey, and others, which have historically played vital roles.As shown in the map of Bangalore's lakes (fig-4), many of these lakes have been gradually filled in or encroached upon, reducing their ability to store water and manage excess rainfall. With these lakes no longer functioning as natural buffers, excess rainwater now floods the city, overwhelming drainage systems and worsening flooding in low-lying areas. The loss of these natural water retention areas has only made Bangalore's water scarcity and flooding problems worse.



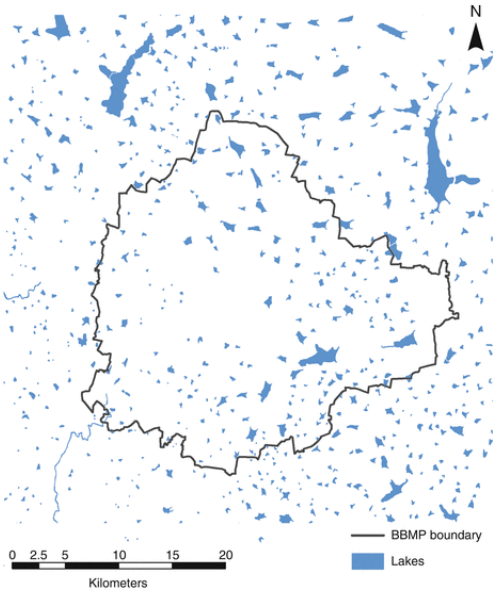


Fig-3(Major valleys of Bengaluru) Paani.Earth
Fig4(LakeBengaluru)https://commons.wikimedia.org/

The rapid development of infrastructure in Bangalore has disrupted the natural flow of water, with impermeable surfaces like roads and buildings preventing rainwater from replenishing the groundwater table. The replacement of green spaces with concrete has increased surface runoff, which in turn has overloaded the city's drainage systems. As a result, stormwater isn't being absorbed or diverted properly, leading to persistent water shortages and frequent flooding during heavy rains.

Bangalore's lakes and wetlands were once natural catchment areas, capturing excess monsoon water and gradually releasing it to recharge groundwater. However, due to widespread encroachment, pollution, and the loss of surrounding open spaces, many of these lakes—especially Hebbal and Agara—have either shrunk or become non-functional. This disruption has impaired their ability to manage water flow, contributing to poor water quality and a nearly 30% drop in groundwater levels over the past decade (KSPCB, 2019). With these lakes no longer serving as natural storage, rainwater is either diverted or lost to evaporation, while the increased surface runoff overwhelms the city's stormwater systems, as seen in the Vengayyana Lake catchment area where encroachment and inadequate drainage further exacerbate the issue (BDA, 2015).

Bangalore's rapid growth has drastically changed the landscape, particularly by expanding built-up areas and reducing green and blue spaces (Fig-5). Natural features like lakes, marshes, and valleys once played a crucial role in managing stormwater, storing excess water, and maintaining hydrological balance. But as more housing,

roads, and infrastructure are developed, much of these natural spaces have been encroached upon or replaced by impermeable surfaces. This has significantly diminished the city's ability to retain water, as rainwater can no longer seep into the ground or accumulate in lakes and wetlands.

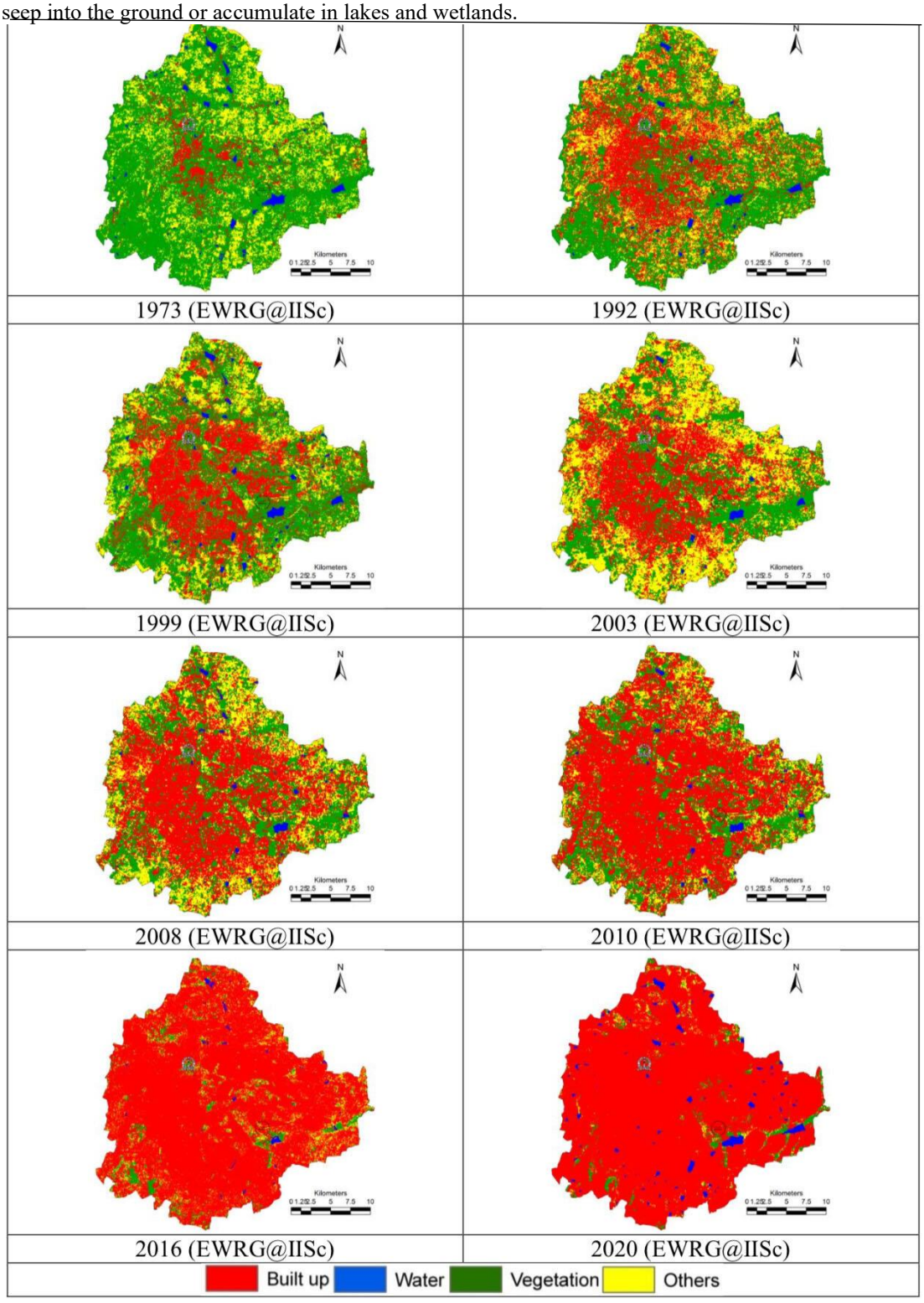


Fig-5(Green and blue cover reduction due to urbanization).Source: EWRG, CES, IISc

The parts of Bangalore identified as having substantial water scarcity are strongly related to locations where lakes have been closed or drastically reduced in capacity. These lakes have historically played an important role in groundwater recharging and stormwater management. However, as urbanization has increased, many of these lakes have been encroached upon, filled up, or rendered non-functional, resulting in a significant decline in natural water retention capacity(Fig-6). Water-scarce zones on the map include Whitefield, Electronic City, and

Koramangala, which were once sustained by functional lakes such as Vengayyana, Bellandur, and Agara. As these lakes have dwindled or disappeared, the groundwater recharge that they formerly provided has been lost, directly contributing to water scarcity in these areas (KSPCB 2019). The closure of these lakes has left these areas heavily reliant on external water sources, intensifying the city's overall water crisis. (Fig-7).

The flood-prone areas of Bangalore on the map approximate closely to regions where lakes have been blocked or encroached upon. (Fig-8). Lakes like Bellandur, Hebbal, and Vengayyana have historically played an important role in stormwater management, absorbing surplus rainwater during the monsoon season and averting flooding. However, encroachment and deterioration have greatly diminished these lakes' ability to store and manage precipitation. As a result, water that would have been absorbed or gradually released into the ground is instead freely flowing as surface runoff, overloading the city's drainage infrastructure. The degradation of these lakes, combined with increased development, has made these areas more vulnerable to floods, emphasizing the need for immediate restoration of these water bodies to decrease flood hazards.

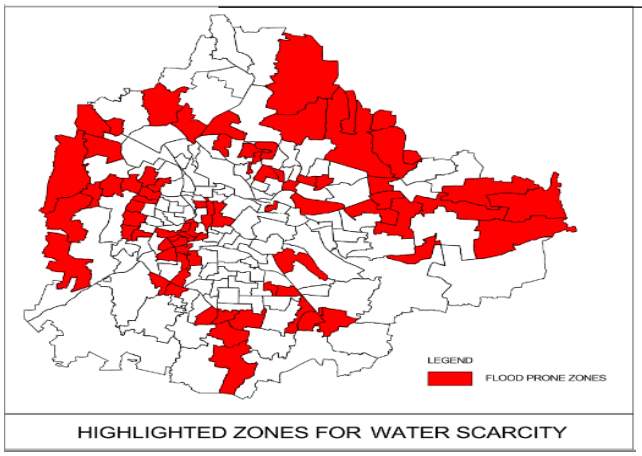


Fig-6(water scarce zones.)

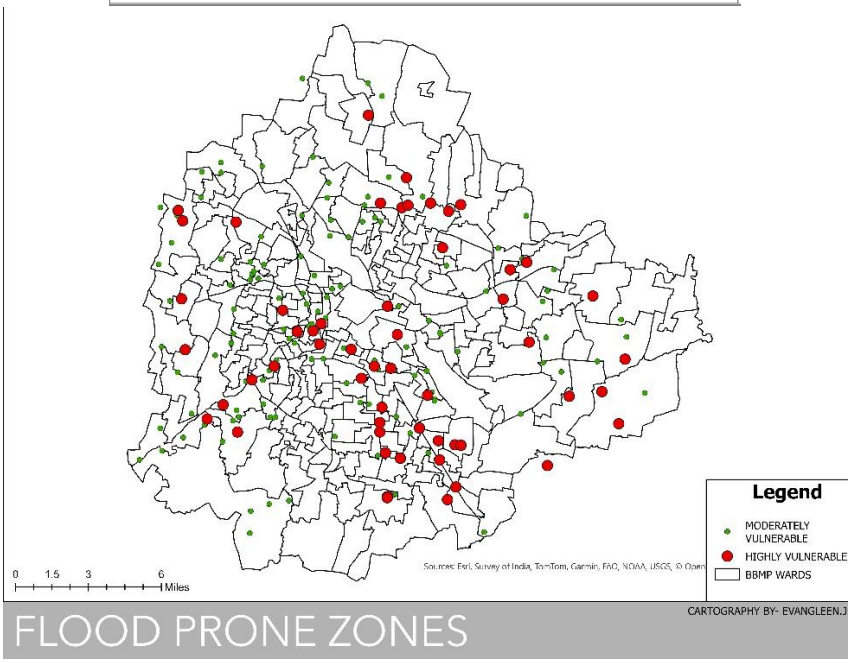


Fig-7 (Flood prone areas.)

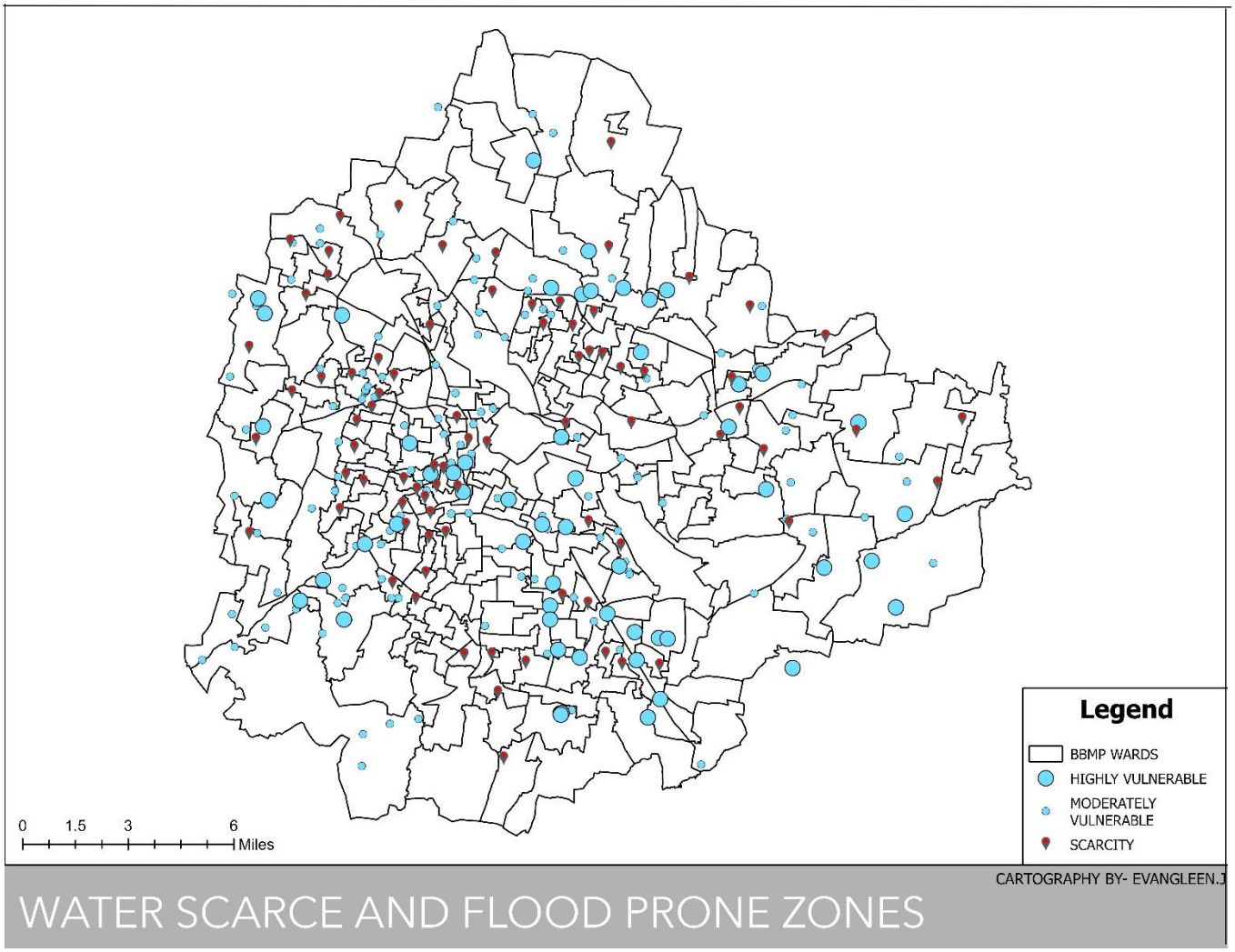


Fig-8(Understanding flood-prone areas and water scarcity zones

METHODOLOGY:

The methodology used for this study employs a multifaceted strategy that combines qualitative and quantitative data, GIS technologies, and field-based analysis to evaluate the relationship between water scarcity and urban floods in Bangalore. The study emphasizes the influence of urbanization, the destruction of natural water bodies (lakes, marshes, and valleys), and the need of green and blue spaces in sustainable water resource management.

- Involves analyzing current academic literature, government data, and case studies to develop a theoretical framework and identify major concerns in the interaction between Bangalore's urbanization, water scarcity, and flooding.

- Geospatial technologies will be utilized to map the geographical distribution of water scarcity, flood-prone areas, and the locations of Bangalore's major lakes and natural water bodies. This enables analysis of the relationship between urban development and water-related challenges.

- **Process**:

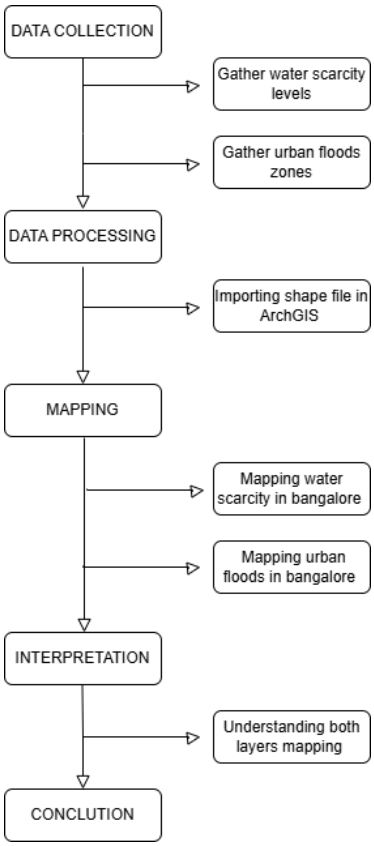
1. Mapping historical land use and urban growth.

2. Identifying areas with high urbanization and low natural water retention (lakes, wetlands).

3. Mapping flood-prone and water-scarce regions based on current data.

4. Comparing past and present maps to identify changes and trends.

- To determine the quantitative impact of urbanization and the loss of green and blue spaces on water management. Data will be collected on groundwater levels, rainfall patterns, flood frequency, and stormwater discharge volume.



LIMITATIONS:

The study's limitations include the availability and accuracy of historical data on Bangalore's water bodies, which may be insufficient or inconsistent as a result of growing urbanization and encroachment. Furthermore, the complexity of urban water management systems makes it difficult to pinpoint the precise effects of lake degradation on flooding and water scarcity. The study's limitations include a lack of real-time data on groundwater levels and rainfall, which could have allowed for a more dynamic analysis. Finally, policy proposals may be limited by the political and economic viability of large-scale lake restoration and urban development changes.

GAP:

A significant gap in this research is the analysis of parks and green areas in Bangalore as part of green mapping for water management. While lakes and wetlands have been investigated, urban parks' contributions to stormwater management and groundwater recharge have received less attention. Future study should focus on incorporating parks into urban development in order to improve flood mitigation and water conservation. Sustainable design strategies, such as permeable surfaces and rainwater harvesting, may be critical in alleviating Bangalore's water issues.

CONCLUSION:

To summarize, the destruction of Bangalore's natural water bodies has contributed considerably to both water scarcity and urban flooding. The loss of lakes and wetlands, combined with rising development, has reduced the city's ability to store water and recharge groundwater. Effective restoration of these water bodies, together with

improved urban planning, is critical to managing both flooding and water scarcity problems. To ensure Bangalore's water resilience, sustainable water management strategies must prioritize the integration of green spaces.

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