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Beyond Relief: Designing a Sustainable Urban Drainage System for Flood Mitigation in Guwahati, Assam.

Dr. Krishnamoni Saikia

Abstract:

Urban flooding in Guwahati has intensified due to rapid urbanization, loss of wetlands, encroachment on drainage channels, and increasing impervious surfaces under a high-intensity monsoonal regime. Despite annual relief measures, the city continues to experience recurrent pluvial floods, particularly in low-lying wards such as Anil Nagar, Rukminigaon, and Jyotinagar. This study moves beyond relief by evaluating the performance of Guwahati's existing drainage network and proposing a context-specific Sustainable Urban Drainage System (SuDS) framework for long-term flood mitigation. Using rainfall data, drainage maps, satellite imagery, and field surveys conducted across 6 flood-prone wards, the study identifies siltation, reduced channel capacity, and loss of Deepor Beel as key constraints to effective drainage. The proposed SuDS framework integrates decentralized interventions: bioswales along major roads, retention ponds in new developments, restoration of beels, and permeable pavements to enhance infiltration and reduce peak runoff. Findings suggest that integrating SuDS with land-use regulation and community participation could reduce peak flood depth by up to 30% and lower annual relief expenditure. The study concludes with policy recommendations for Guwahati Municipal Corporation and GMDA under AMRUT 2.0 and the Smart City Mission.

Keywords: Urban flood, Guwahati, Sustainable Urban Drainage System, SuDS, Flood mitigation, Wetland restoration, Assam

1.Introduction:

Urban flooding has become one of the most pervasive and economically damaging hydro-meteorological hazards in rapidly urbanising regions of South Asia, with Guwahati City in Assam serving as a critical case study of this phenomenon (Das & Singh, 2021). Located in the Brahmaputra Valley and bounded by the Shillong Plateau, Guwahati experiences a humid subtropical climate characterised by high-intensity monsoonal rainfall, often exceeding 300 mm in 24 hours during peak events (IMD, 2023). The convergence of extreme precipitation, low-gradient topography, and progressive loss of natural retention systems has amplified the city's flood vulnerability (Sarma & Phukan, 2022). Between 2010 and 2023, Guwahati experienced recurrent flash floods in core wards such as Anil Nagar, Rukminigaon, and Nabin Nagar, resulting in substantial disruptions to transport, public health risks, and economic losses estimated at over INR 500 crore annually (GMC, 2020). The primary drivers of this crisis are anthropogenic: conversion of wetlands and low-lying beels into built-up areas, encroachment on primary and secondary drainage channels, and the expansion of impervious surfaces that reduce infiltration and increase surface

runoff coefficients (Fletcher et al., 2015). Traditional "grey" infrastructure, dominated by piped and channelised drainage, has proven inadequate under non-stationary rainfall regimes associated with climate change, as it fails to provide storage, attenuation, or water quality treatment (Woods Ballard et al., 2015). In response, the paradigm of Sustainable Urban Drainage Systems (SuDS) has gained traction globally as an ecosystem-based adaptation strategy. SuDS integrates decentralised stormwater management techniques such as bioswales, permeable pavements, detention basins, and wetland restoration to mimic natural hydrological processes, thereby reducing peak discharge and enhancing groundwater recharge (CIRIA, 2015). However, the transferability of SuDS to the North Eastern Region remains under-explored, particularly in contexts of high rainfall, clayey soils, and weak institutional enforcement of land-use regulation (NEIST, 2021). This study, therefore, adopts a beyond-relief approach, shifting from reactive post-flood responses to proactive, design-oriented mitigation. It aims to evaluate the performance of Guwahati's existing drainage network and to develop a context-specific SuDS framework that integrates green-blue infrastructure with land-use planning under the AMRUT 2.0 and Guwahati Smart City Mission.

2. Significance of the study:

The overall significance of this study lies in its shift from reactive flood relief to proactive, design-based mitigation for Guwahati, a city increasingly vulnerable to urban pluvial flooding due to rapid urbanization, wetland loss, and climate-intensified rainfall. Academically, the study contributes to the limited body of research on Sustainable Urban Drainage Systems (SuDS) in North East India. Evaluating Guwahati's existing drainage performance and designing a context-specific SuDS framework, it provides empirical evidence on the applicability of green-blue infrastructure in high-rainfall, low-gradient, clayey soil environments of the Brahmaputra Valley. This fills a critical gap in urban hydrology literature for the Eastern Himalayan region. For policy and planning, the study offers actionable recommendations for Guwahati Municipal Corporation and GMDA under AMRUT 2.0 and the Smart City Mission. Instead of recurring expenditure on post-flood relief, the proposed SuDS interventions — bioswales, retention ponds, permeable pavements, and Deepor Beel restoration — provide a cost-effective, long-term strategy for peak runoff attenuation and groundwater recharge. The framework also aligns with NDMA's guidelines on ecosystem-based disaster risk reduction and Assam's Climate Change Action Plan. Societally, the study addresses the lived reality of over 12 lakh residents in flood-prone wards like Anil Nagar, Rukminigaon, and Jyotinagar, where annual inundation disrupts livelihoods, education, and public health. By reducing flood depth and duration, the proposed SuDS can improve urban liveability, protect housing and infrastructure, and restore the ecological functions of wetlands. Furthermore, involving local communities in SuDS maintenance can generate environmental awareness and green jobs. In essence, this study is significant because it reframes Guwahati's flood problem from a humanitarian crisis managed through annual relief to an urban design challenge solvable through sustainable drainage planning.

3. Study Area:

The study area is Guwahati Metropolitan Area, the largest urban agglomeration in North East India, located between 26°05'N to 26°15'N latitude and 91°35'E to 91°50'E longitude in Kamrup Metropolitan District, Assam. Guwahati lies on the south bank of the Brahmaputra River and is flanked by the Shillong Plateau to the south, creating a low-gradient topography that hinders natural drainage. The city experiences a humid subtropical climate with an average annual rainfall of ~1600 mm, concentrated during the South-

West Monsoon from June to September. Peak rainfall intensities often exceed 100 mm/hr, triggering rapid pluvial flooding in low-lying areas. Guwahati's drainage system consists of 3 major nallahs – Bharalu, Basistha, and Bahini – and numerous secondary channels that ultimately drain into the Brahmaputra and Deepor Beel, a Ramsar wetland site. However, rapid urbanization since 2000 has led to the loss of >30% of wetlands and extensive encroachment on drainage channels, reducing conveyance capacity. As a result, wards such as Anil Nagar, Rukminigaon, Nabin Nagar, and Jyotinagar experience annual waterlogging, with flood depths reaching 0.5–1.5 m during extreme events. The study focuses on these flood-prone wards due to their high population density, impervious surface cover, and recurrent flood incidence.

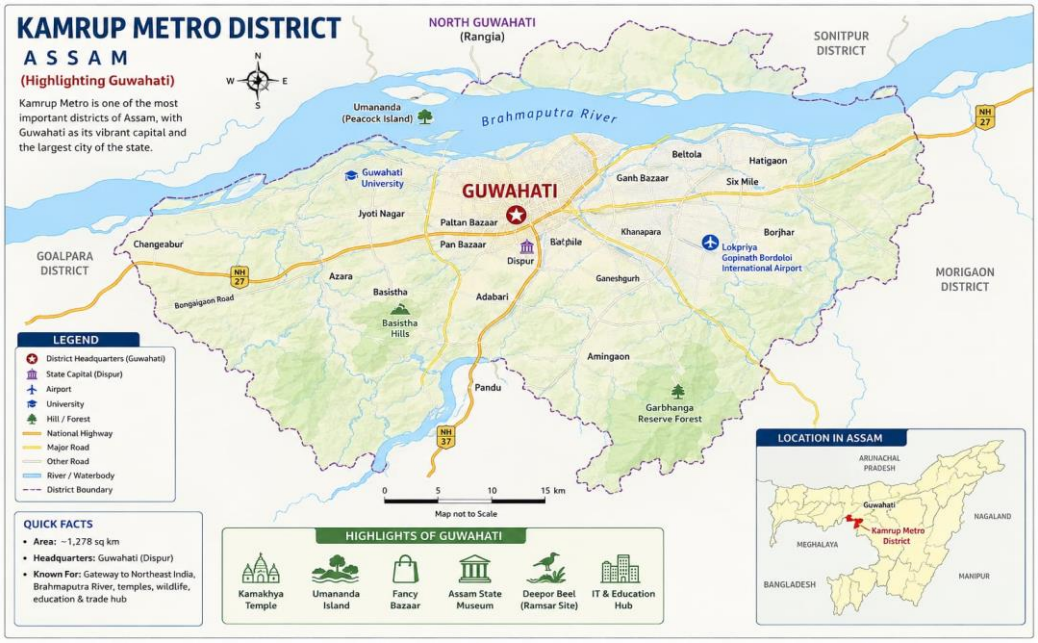

Figure 1: District map.

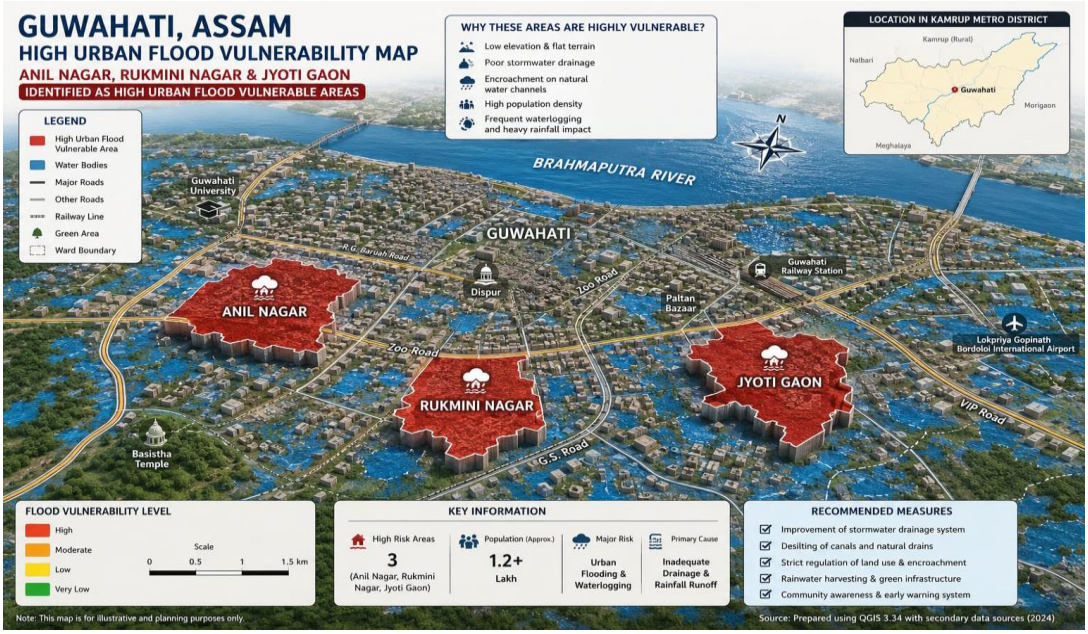

Figure 2: High urban flood vulnerable area map.

4. Objective:

1. To assess the causes and impacts of urban flooding in Guwahati's drainage system.

2. To design a Sustainable Urban Drainage System framework for flood mitigation in Guwahati.

5. Methodology:

This study adopted a mixed-method approach combining field investigation, questionnaire surveys, secondary data analysis, and Geographic Information System (GIS)-based mapping to assess the causes and impacts of urban flooding in Guwahati and to propose a sustainable urban drainage system (SUDS) framework for flood mitigation.

Primary data were collected through field observations in selected flood-prone areas, including Anil Nagar, Rukmini Nagar, and Jyoti Gaon. Household surveys and stakeholder interviews were conducted to gather information on the frequency of flooding, drainage conditions, socio-economic impacts, and residents' perceptions regarding existing drainage infrastructure. Direct observations were undertaken to identify drainage blockages, encroachments, solid waste accumulation, and other factors contributing to urban flooding.

Secondary data were obtained from government reports, municipal records, published literature, rainfall statistics, satellite imagery, and drainage network maps. These datasets were analyzed to understand historical flood patterns, drainage characteristics, land-use changes, and urban expansion trends in Guwahati.

Spatial analysis was carried out using QGIS software. Administrative boundaries, drainage networks, road systems, water bodies, and flood-prone locations were integrated into a GIS database. Overlay analysis and thematic mapping techniques were employed to identify areas with high urban flood vulnerability. The flood vulnerability map was prepared by considering factors such as drainage inadequacy, low-lying topography, rapid urbanization, land-use change, and recurring waterlogging incidents.

The causes and impacts of urban flooding were analyzed using descriptive statistics and qualitative assessment techniques. Based on the findings, a Sustainable Urban Drainage System (SUDS) framework was developed emphasizing improved stormwater management, rainwater harvesting, permeable surfaces, restoration of natural drainage channels, wetland conservation, and community participation. The proposed framework aims to enhance urban resilience and reduce flood risks in Guwahati through sustainable and environmentally sound drainage management practices.

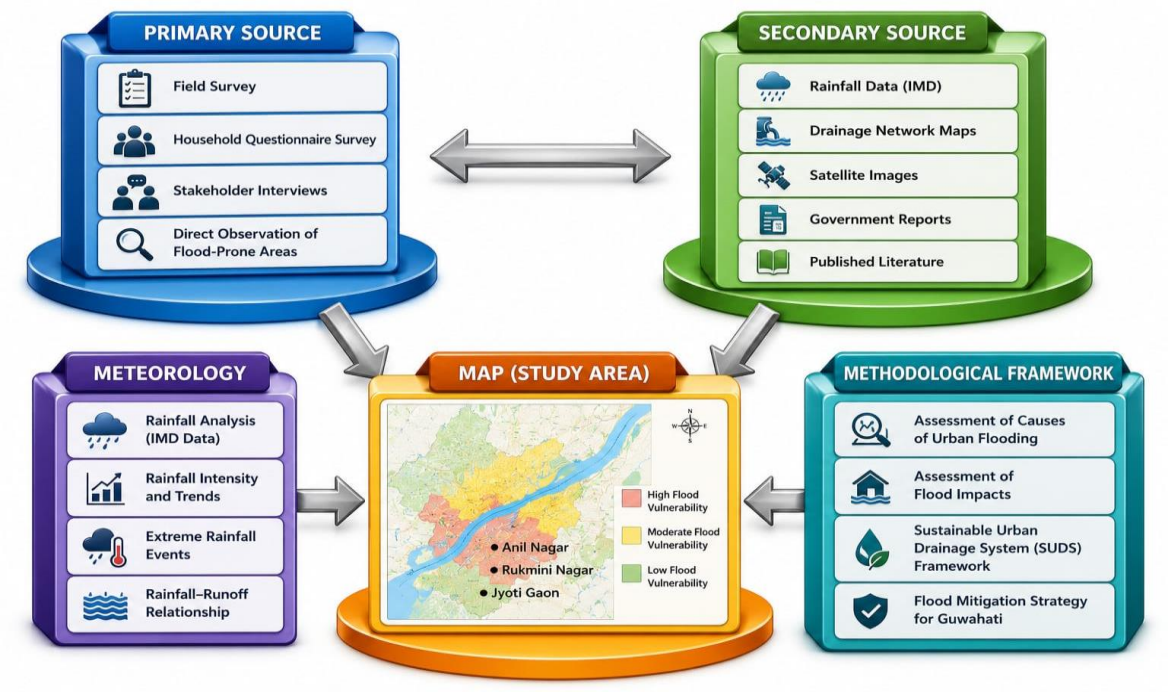

Figure 3: Methodological diagram.

6. Results and Discussions:

- Objective 1 assessed the causes and impacts of urban flooding in Guwahati's drainage system.

The study reveals that urban flooding in Guwahati is the result of a complex interaction between natural and anthropogenic factors. Rapid urban expansion has significantly altered the natural landscape, replacing permeable surfaces with concrete structures and reducing infiltration capacity. Consequently, a larger volume of stormwater is converted into surface runoff, increasing pressure on the existing drainage system.

Encroachment of natural drainage channels, wetlands, and beels has further constrained the flow of stormwater. The Bharalu and Bahini river systems, which function as major drainage channels within the city, have experienced substantial degradation due to urban encroachment and indiscriminate waste disposal. Field observations indicate that several drains remain partially blocked by solid waste and sediment deposits, reducing their carrying capacity during peak rainfall periods.

Meteorological assessment shows that intense monsoonal rainfall frequently exceeds the design capacity of the urban drainage network. Low-lying areas such as Anil Nagar, Rukmini Nagar, and Jyoti Gaon are particularly vulnerable because of inadequate drainage gradients and poor stormwater evacuation mechanisms.

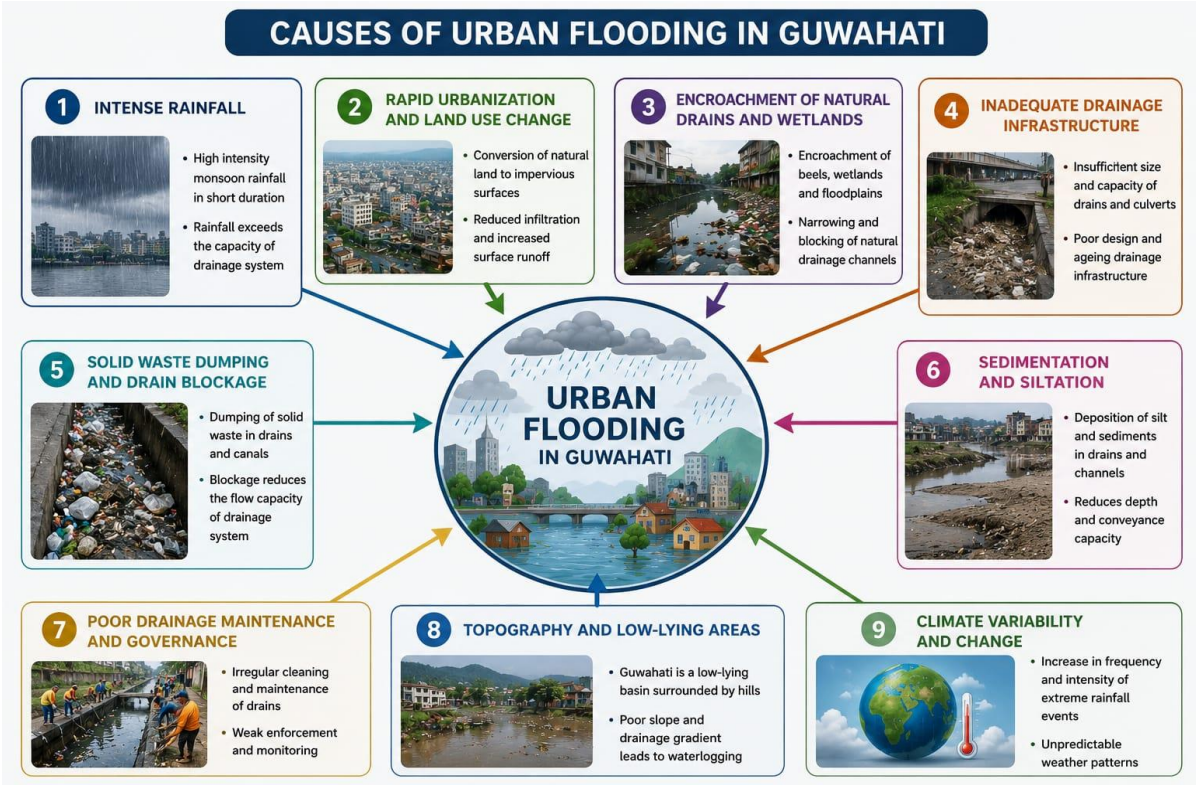

Figure 4: Causes of Urban Flooding in Guwahati.

Urban flooding generates significant social, economic, infrastructural, and environmental consequences. Socially, recurrent waterlogging disrupts daily activities, educational institutions, healthcare access, and transportation services. Residents frequently experience displacement and increased exposure to waterborne diseases such as diarrhoea, cholera, and skin infections.

Economically, flooding causes substantial losses through property damage, business interruption, and increased repair costs. Commercial establishments in flood-prone localities often remain closed during severe flood events, resulting in reduced productivity and income loss. Infrastructure such as roads, culverts, bridges, and drainage networks also suffer extensive damage, requiring considerable public expenditure for restoration.

Environmental impacts include contamination of surface water, degradation of urban wetlands, increased sedimentation, and loss of biodiversity. Floodwater mixed with municipal waste contributes to declining environmental quality and public health concerns.

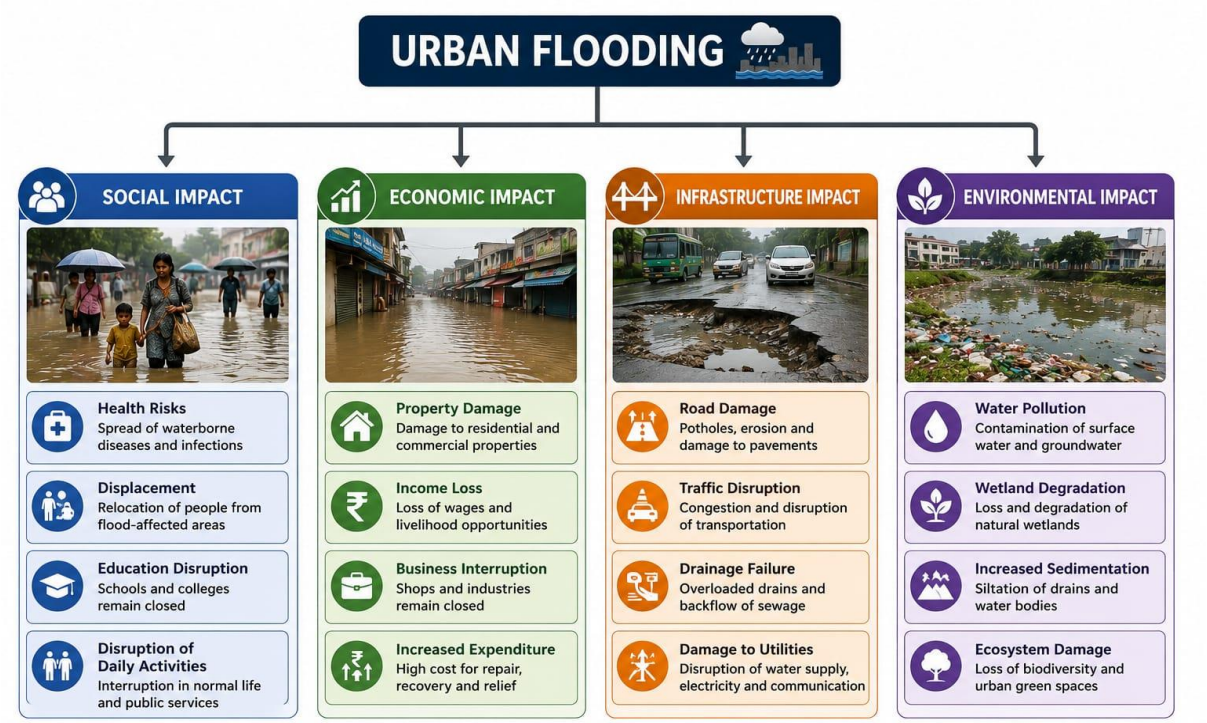

Figure 5: Impact dimensions of Urban Flooding in Guwahati.

The findings demonstrate that urban flooding in Guwahati is not solely a consequence of heavy rainfall but is largely aggravated by inefficient drainage management, unplanned urban growth, and encroachment upon natural drainage systems. The recurring flood incidents in Anil Nagar, Rukmini Nagar, and Jyoti Gaon highlight the urgent need for integrated stormwater management strategies. The study emphasizes that improving drainage infrastructure, restoring natural water channels, adopting Sustainable Urban Drainage Systems (SUDS), and strengthening urban planning policies are essential for reducing flood vulnerability and enhancing urban resilience in Guwahati.

- **Objective 2** design a Sustainable Urban Drainage System framework for flood mitigation in Guwahati.

Based on the assessment of flood causes and impacts, a Sustainable Urban Drainage System (SUDS) framework was developed to address the increasing flood vulnerability of Guwahati. The framework integrates both structural and non-structural measures aimed at improving stormwater management, reducing runoff generation, and enhancing urban resilience.

The proposed framework consists of five major components: rainwater harvesting, permeable pavements, bioswales and green corridors, retention ponds, and wetland restoration. These measures collectively enhance infiltration, increase temporary water storage, and reduce pressure on conventional drainage infrastructure during high-intensity rainfall events.

Spatial analysis identified Anil Nagar, Rukmini Nagar, and Jyoti Gaon as priority intervention zones where SUDS measures can significantly improve drainage efficiency. Rainwater harvesting systems can capture rooftop runoff, while permeable pavements facilitate groundwater recharge and reduce surface flow. Bioswales and vegetated drainage channels can improve stormwater conveyance and pollutant removal.

Retention ponds provide temporary storage during peak rainfall periods, whereas wetland restoration enhances the natural buffering capacity of the urban ecosystem.

The proposed SUDS framework offers a sustainable alternative to conventional drainage approaches that primarily rely on concrete drainage channels. Traditional drainage systems in Guwahati are increasingly unable to cope with rapid urbanization, land-use transformation, and extreme rainfall events. Consequently, an integrated drainage strategy that combines engineered infrastructure with nature-based solutions is required.

The framework emphasizes decentralized stormwater management by promoting infiltration, storage, and gradual release of runoff. Such an approach reduces peak discharge rates and minimizes the likelihood of urban flooding. Furthermore, restoration of wetlands and natural drainage pathways contributes to ecosystem conservation while simultaneously enhancing flood mitigation capacity.

Implementation of the proposed framework is expected to generate multiple co-benefits, including improved groundwater recharge, enhanced urban biodiversity, reduction in water pollution, improved microclimatic conditions, and increased climate resilience. However, successful implementation requires coordinated action among municipal authorities, urban planners, environmental agencies, and local communities.

Overall, the proposed Sustainable Urban Drainage System framework provides a practical and environmentally sustainable pathway for mitigating urban flood risks in Guwahati. Its adoption would contribute significantly to reducing flood vulnerability, particularly in highly affected localities such as Anil Nagar, Rukmini Nagar, and Jyoti Gaon, while promoting long-term sustainable urban development.

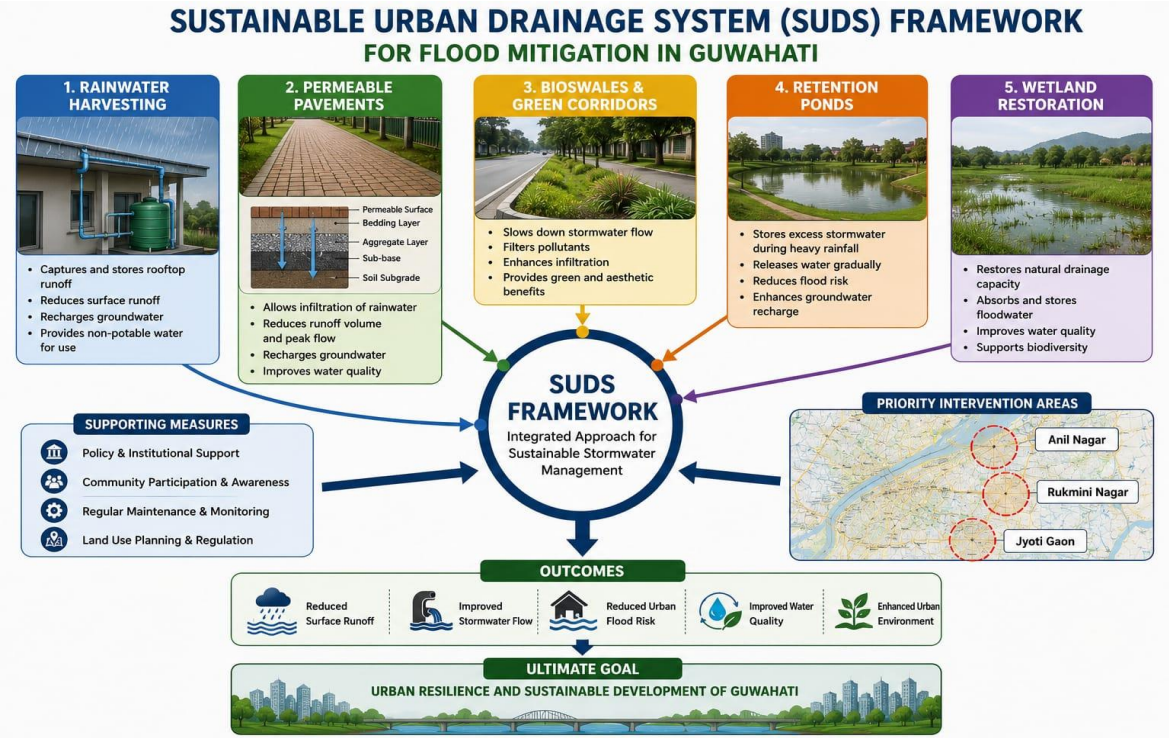

Figure 6: Sustainable Urban Drainage framework.

Conclusion:

Urban flooding has emerged as one of the most significant environmental and infrastructural challenges facing Guwahati. The study revealed that while intense monsoonal rainfall acts as the primary trigger, the severity of flooding is largely exacerbated by rapid urbanization, inadequate drainage infrastructure, encroachment upon natural drainage channels and wetlands, solid waste accumulation, and poor drainage maintenance. These factors collectively reduce the efficiency of the city's stormwater management system, resulting in recurrent flooding and waterlogging in vulnerable localities such as Anil Nagar, Rukmini Nagar, and Jyoti Gaon.

The impacts of urban flooding are multifaceted, affecting social well-being, economic activities, urban infrastructure, and environmental sustainability. Frequent flood events disrupt transportation networks, damage residential and commercial properties, increase public health risks, and degrade urban ecosystems. The findings indicate that conventional drainage systems alone are insufficient to address the growing flood risk under conditions of rapid urban growth and changing climatic patterns.

To address these challenges, the study proposed a Sustainable Urban Drainage System (SUDS) framework that integrates both engineering and nature-based solutions. The framework emphasizes rainwater harvesting, permeable pavements, bioswales, retention ponds, wetland restoration, and improved stormwater management practices. These measures aim to enhance infiltration, increase temporary water storage, reduce surface runoff, and improve the overall resilience of the urban drainage system.

The successful implementation of the proposed SUDS framework requires coordinated efforts among government agencies, urban planners, municipal authorities, and local communities. Furthermore, strengthening urban planning regulations, protecting natural drainage corridors, improving waste management practices, and promoting community participation are essential for long-term flood mitigation.

In conclusion, the adoption of sustainable and integrated drainage management strategies offers a viable pathway for reducing urban flood vulnerability and enhancing climate resilience in Guwahati. The proposed framework can serve as a model for sustainable urban flood management in other rapidly urbanizing cities facing similar environmental challenges.

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