

Urban drainage challenges and mitigation approaches in Sylhet city

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Abstract

This study focuses on the urban drainage problems in Sylhet City, which is susceptible to flooding because of its particular location and hasty urbanization. The study examines the existing situation of the drainage system in Sylhet which achieves the main shortcoming of Sylhet's drainage in terms of blockage, pollution and lack of maintenance, causing poor water dissemination and continual occurrence of urban flood. This is further compounded by uncontrolled and illegal expansion and development that encroach on natural water bodies which subsequently interfere with the natural flow of water and minimize the capacity for drainage. Based on hydrological and hydraulic modelling calculation of the main canals, critical flood - prone zones and constrained areas for the drainage are emphasized in this study. It also evaluates the effect of other infrastructure development practices such as road-raising on drainage functionality. Its research suggests an integrated suite of mitigation options that could combine structural measures such as canal dredging and stormwater management improvements with non-structural actions such as urban planning changes, engagement with communities and installation of sustainable drainage systems. Emphasis is given to the combination of nature-based solutions with advanced monitoring and controlling devices of the urban drainage network. The results suggest the needs of coordination of local governments and planners, as well as society, to improve the drainage capacity and prevent water logging. This research offers policy advice for future urban planning and development intended to enhance flood resilience and quality of life in Sylhet City.

Keywords: Urban drainage; Flood management; Sylhet City; Drainage congestion; Sustainable urban planning; Flood mitigation strategies

1. Introduction

Sylhet City, located in northeastern Bangladesh, is geographically defined by a basin surrounded by hills and large wetlands, rendering it particularly susceptible to floods during heavy monsoon rainfall [1,2]. The city has a tropical monsoon climate, with an average of 3,300 mm of rainfall per year, most of which falls between May and September [3,4]. In the past, Sylhet's drainage system relied on a system of wetlands, rivers like the Surma and Kushiya, and natural canals called "charas" in the local dialect. These waterways efficiently controlled monsoon runoff by directing water along natural and semi-natural pathways [5,6]. These natural drainage networks have been severely disrupted in recent decades by unplanned development and fast urbanization, leading to extensive encroachment on canals and wetlands that have greatly decreased their drainage capacity [7,8]. Furthermore, drainage congestion has been made worse by silt buildup and contamination brought on by careless solid waste disposal, which compromises the efficiency of urban water disposal systems [9,10]. As a result, Sylhet City frequently experiences urban flooding and waterlogging, which interfere with daily living, harm infrastructure, and increase the risk of public health issues because of standing water and vector-borne illnesses [11,12]. The city's susceptibility to both flash floods and extended flooding has been revealed by significant flood events in recent decades, underscoring the urgent need for comprehensive flood management and infrastructure reconstruction programs [13,14]. Alongside nonstructural strategies like sustainable urban design, raising community awareness, and improving solid waste management, structural solutions like dredging

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canals, building embankments, and better stormwater drainage systems have been proposed [15,16]. Building resilience to flooding in Sylhet City requires coordinated planning and execution by local communities, urban planners, and government officials [17,18]. In order to reduce the risk of flooding and promote sustainable urban development, hydrological and hydraulic modeling are useful tools for evaluating system performance and directing infrastructure improvements and urban planning [19,20].

1.1. Aim and Objectives

The principal objective of this work is to identify the current problems of urban drainage in Sylhet City and to present appropriate solutions to reduce flooding impact and improve drainage performance. The aims are to evaluate the current drainage system/canal systems to determine their capacity and susceptibility for congestion and blockage. The research also aims to examine the consequences of land use changes, including spontaneous urbanization and occupation, on the effectiveness of flow and flooding hazard. M. and H. M. will estimate key drainage bottlenecks as well as zones at risk of flooding through hydrological and hydraulic modelling to also indicate intervention priority. The research work will also explore to develop and assess an integrated set of structural and non-structural mitigation measures compatible with the specific environmental and urban setting of Sylhet. Innovative solutions like SUDS, rainwater harvesting and nature-based solutions will be investigated for their potential role in sustainable drainage management. Finally, the paper will consider the challenges and barriers to implementation, and will illustrate the pivotal roles local government, urban planners and communities can play in managing drainage effectively and reducing flood risk.

2. Methodology

The current research was conducted on the problems of urban drainage in Sylhet City and studied the potential remedial measures using a mixed-research method. Field survey was conducted to map the existing drainage network, whereas rainfall data, land use maps and the satellite images were obtained from appropriate departments. Hydrological and hydraulic modelling in EPA SWMM simulated rainfall-runoff processes and computed the flow capacities of the main canals for characterizing flood-vulnerable areas and drainage choke points. GIS provided the opportunity for spatial analyses of the influence of land use on the drainage patterns. In addition to the technical review, stakeholder interviews with local officials, planners, and residents informed an understanding of practical constraints and community input. These were assembled into a geo-graphic information system, which was used to create and assess the value of structural and non- structural intervention options using scenario analysis and feasibility criteria, leading to focused recommendations for improved drainage resilience and flood risk management in Sylhet.

3. Literature Review

Current research on Sylhet's urban drainage and flood issues shows that the city's natural drainage system, which is primarily made up of wetlands, rivers like the Surma, and local channels called charas, is severely harmed by encroachment on natural water bodies, rapid urbanization, and poor maintenance [1,2]. Malni Chara and Goali Chara, two important drainage subsystems in Sylhet, have benefited from modeling initiatives such as those employing the EPA Storm Water Management Model (SWMM), which have been helpful in determining drainage capacity and flood threats [6]. According to these studies, the main causes of drainage inefficiency that result in frequent waterlogging and urban flooding are sedimentation, pollution, and obstruction by solid waste [8,12]. Flooding in Sylhet has been shown to have serious effects on infrastructure, livelihoods, and health, particularly during the record-breaking flash floods of 2022 [11,21].

When drainage issues in other quickly urbanizing deltaic towns, including Dhaka and Khulna, are compared, comparable vulnerabilities are shown, such as encroachments on rivers and insufficient drainage capacity made worse by climate change and a rise in impervious surfaces [22,23]. The significance of integrated flood risk management that combines structural measures, nature-based solutions, and community involvement is highlighted by lessons learned from established urban flood management systems [24,25].

Theoretical frameworks used in these studies include GIS-based analytical techniques to simulate runoff and evaluate flood vulnerability, as well as hydrological and hydraulic modeling tools like SWMM and HEC-RAS [6,26,27]. These models help urban planners identify important flood-prone locations and create mitigation plans by allowing the evaluation of drainage system performance under various storm events and land-use scenarios [28,15].

Despite advancements, there are still unanswered questions about the intricate relationships that exist in Sylhet between flood susceptibility, drainage efficiency, and urban growth. To improve adaptive capacity, more thorough

modeling that incorporates socioeconomic variables and climatic projections is recommended [30,31]. Furthermore, literature repeatedly emphasizes the necessity of sustainable drainage designs, routine maintenance, and enhanced policy frameworks [32,33].

According to this analysis, creating resilient urban drainage systems in Sylhet necessitates a multipronged strategy that includes ecosystem conservation, infrastructure improvement, participatory governance, and robust modeling [34].

4. Current State of Urban Drainage in Sylhet

The network of natural canals known locally as "charas," which act as the primary channels for rainwater discharge into the Surma River and its tributaries, is the mainstay of Sylhet City's current urban drainage infrastructure [1,2]. Numerous studies have been conducted on important drainage canals like Malni Chara and Goali Chara, and hydrological modeling shows that these canals are currently operating at or above capacity, especially during the monsoon season's heavy rainfalls, which frequently causes waterlogging and urban flooding [5,6]. Since the majority of stormwater channels are open canals that are extremely vulnerable to siltation, waste deposition, and encroachment, the drainage system itself lacks the features of a contemporary constructed network [7]. Although historically sufficient, this natural canal-based system has not been able to keep up with Sylhet's growing urbanization, leading to severe drainage congestion and isolated flooding [8,12].



Source: Author

Figure 1 Flood situation on Airport Road

Over the past few decades, Sylhet's urban land use has drastically changed, with substantial tracts of agricultural or marsh land being transformed into commercial, industrial, and residential zones without integrated drainage planning [35]. By obstructing and constricting drainage corridors and upsetting natural water flow pathways, this inappropriate and unplanned land use has increased surface runoff and decreased the overall effectiveness of the drainage system [36]. Waste dumping and informal settlements further narrow flow channels, creating more bottlenecks throughout the drainage system [11,14]. Long-term water retention is particularly common in low-lying urban locations, resulting in persistent waterlogging issues that impact economic activity, transportation, and health [37].



Source: Author

Figure 2 Flood situation on Osmani Medical College & Hospital

Recurring congestion points along important drainage pathways are revealed by drainage capacity analysis, especially when urban development meets narrow or silted canals [38]. Flood risk increases during extreme weather events because field measurements and modeling show that many canal network segments cannot handle peak flow produced by rainfall events with a 10- to 25-year return period [16,39]. Important drainage chokepoints have been located close to business districts, heavily inhabited neighborhoods, and places where flow is restricted by mismanaged solid waste accumulation [40]. Efforts to improve and maintain drainage capacity are further complicated by institutional issues such as divided agency responsibility, poor maintenance, and little resources [41,42]. Together, these elements increase Sylhet City's continued susceptibility to urban floods and emphasize the urgent need for thorough, integrated drainage design that is in line with sustainable urban development principles [43,44].



Source: Author

Figure 3 Flood situation on Zindabazar

5. Challenges in Sylhet's Urban Drainage

The urban drainage system in Sylhet has many difficulties. mostly caused by the fast and unplanned urbanization that has led to extensive encroachment on wetlands and natural drainage systems. This encroachment hinders stormwater's natural flow, which lowers the ability of canals known locally as "charas" to effectively transport runoff [1]. The natural water retention and flow patterns have been significantly changed by the filling of wetlands and the conversion of low-lying areas into residential and commercial zones, increasing the risk of floods and causing drainage congestion.



Source: Author

Figure 4 Connectivity of City Canals with the Surma River

Drainage efficiency is further compromised by pollution and sedimentation. Because of silt deposition brought on by erosion and sediment movement, many drainage canals have narrowed channels and reduced water flow capacity. Furthermore, dumping sewage and solid waste straight into drainage canals causes contamination and obstruction, which negatively impacts water quality and hydraulic capacity [2]. Even after mild rainfall, these conditions frequently result in waterlogging, which disrupts urban life and increases health concerns.

Problems with infrastructure exacerbate the situation. The current drainage system is not well maintained, which causes obstructions and degradation. Systematic maintenance and timely drainage channel clearance are hampered by institutional limitations, resource shortages, and divided duties among multiple agencies [8]. To make matters worse, current road development projects raise roads and land without proper drainage planning, which interferes with surface water movement and results in localized flooding [45]. Drainage bottlenecks are made worse by inadequate or poorly built cross-drainage structures, especially in crowded urban areas.

All things considered, these elements work together to make Sylhet's urban drainage system extremely vulnerable and frequently unable to handle rainfall, calling for immediate integrated management and infrastructure upgrades.

6. Hydrological and Hydraulic Assessment

Hydrological and hydraulic assessment of Sylhet City's drainage system has been advanced through modeling the major canals and drainage routes to better understand flow dynamics and flood risks. Studies have calibrated and validated hydrological models for key canal sub-systems, notably the Malni Chara and Goali Chara, using the EPA Storm Water Management Model (SWMM). This model incorporates rainfall-runoff processes and channel routing dynamics to simulate drainage responses during storm events accurately [1]. The calibrated models demonstrated strong agreement with observed data, affirming their suitability for assessing existing drainage capacities and predicting performance under varying storm intensities, including design rainfall events up to a 25-year return period [1].

The models have been instrumental in identifying flood-prone areas and drainage bottlenecks. Simulation results reveal that multiple sections of major canals frequently exceed capacity during heavy rainfall, contributing to urban waterlogging in specific localities. The identification of these congestion points allows stakeholders to target interventions more effectively [1]. The hydrological assessment considers catchment characteristics such as impervious surface percentages and land use patterns, while hydraulic routing incorporates conduit roughness and network geometry, which significantly influence flow velocities and peak discharge volumes [1].

Overall, the evaluation emphasizes that although the drainage canals in place are essential for controlling stormwater, their limited capacity in the event of severe rainfall calls for possible infrastructure improvements, better upkeep, and coordinated urban planning in order to reduce the risk of flooding in Sylhet City in the future.

7. Mitigation Approaches and Solutions

Sylhet's urban drainage problems need a comprehensive solution incorporating structural, non-structural and technological options.

Structural measures are of essential importance. The channels are essential for the de-silting in the form of canals by dredging technique is needed for opening of the blockages and regaining the carrying capacity of the Malni and Goali Charas, which are the main draining channels. Embankments can be built on sensitive riverbanks and water bodies to insulate nearby urban settlements from floods. Improvement of stormwater drainage: Enlargement of existing drains and cross drainage facilities and use of underground sewers increase water carriage capacity and minimize waterlogging.

Other non-structural measures can include comprehensive sustainable urban planning reforms. Strict application of standards to prohibit the encroachment of wetlands and floodplains is important to protect these natural drainage and water storage areas. Urban planning should include flood-risk zoning to direct development elsewhere than on high-risk area. Community education and involvement initiatives provide residents with information on maintaining their stormwater drainage system, managing waste, and being prepared for an emergency, promoting stewardship of drainage systems on a local level.

Novel approaches focus on sustainability and natural based concepts. The installation of Sustainable Urban Drainage Systems (SUDS) including porous pavements, rainwater gardens/planters, and bio-retention ponds results in both on-site stormwater retention and infiltration, and correspondingly decreased runoff volumes. The use of rainwater harvesting to reduce the reliance on traditional drainage and provides an alternative source of water. Rehabilitation of natural wetlands maximizes their function of flood regulators and also as a biodiversity sanctuary.

For monitoring and maintenance purposes a technology use is necessary. Action can be taken timely, should there be blockages or water levels rising in canals, with remote sensing, GIS mapping and real time sensors set up in canals. In addition, data analytics and modeling can aid in predictive flood management and infrastructure planning.

All of these measures together make up a full flood mitigation plan that tackles Sylhet's drainage issues effectively and responsibly.

8. Result and Discussion

The suggested measures to mitigate Sylhet's urban drainage are a mix of structural and non-structural ones mixed with clever solutions. The canals which have lost its designed capacity, mainly the Malni and Goali Charas, have been attempted to be excavated (dredging) to restore them to its prior capacity to carry stormwater, an outcome of sediment deposition and raavads constriction/heritage encroachment, will reduce their present dimensions to carry storm water and prevent its spilling/overflowing of stormwater inside the city. Narrow area embankment scheme to be constructed along susceptible banks of rivers to provide flood protection by retaining flood water at the time of monsoon peak flow. Strengthening and enlarging the network of stormwater drains, with proper cross-drainage arrangements under roads, enhance the connectivity for drainage and minimize isolated waterlogging. The infrastructural upgrades are crucial, but need massive financing and technical know-how to make them work in the long term.

Non-structural measures stress the need for comprehensive reorganization of urban planning in terms of land use notably preventing wetland and natural flood retention areas encroachment and fill. Zoning rules need to be tightened to protect major drainage channels and encourage flood-resistant building. Community sensitization and participatory pro-gramming are essential steps toward entrenching local stewardship in drainage maintenance and facilitating sound solid waste management that would limit blockage.

Creative measures include the use of Sustainable Urban Drainage Systems (SUDS) such as porous pavements, bio-retention swales and rainwater storage to improve on-site stormwater retention capacities and reduce the volumes of stormwater discharging from the site. Such nature-based solutions, such as wetland restoration, mimic natural hydrological regimes and have ecological co-benefits.

By using technology through real time monitoring and GIS mapping and remote sensing, proactive management is possible as blockages of infrastructure can be identified, and flood risk can be monitored, this can allow preventative maintenance and emergency response.

On-the-ground barriers to implementation that are mentioned include: costs, lack of technical knowledge, challenges in coordinating among agencies, and hostility from local communities stemming from the limitations on the use of land. In addition, the distribution of powers and the overlapping of responsibilities in the fragmented governance structure of agencies let the accountability diluted. Barriers such as these underscore the importance of an interdisciplinary approach to local government, planning, environment and community.

Local Government has a crucial role in the design of policy, implementation of regulations, and provision of funds for infrastructure construction and maintenance. Merits Readers with a background in urban planning and sustainable development How This Project Addresses the Needs: Urban planners need to take into account hydrological and flood risk information in their land use plans in order to accommodate drainage needs and future climate variability. Community engagement using awareness campaigns and local drainage committees contributes to continued M&LR and resilience building efforts.

In conclusion, an integrated approach between engineering interventions, policy, community and technological adoptions is crucial to address drainage performance and alleviate flood risk in Sylhet.

9. Conclusion

The urban drainage of Sylhet City has been confronting considerable challenges due to uncontrolled anthropogenic activities, rapid urban growth, occupation of natural drainage channels, siltation, pollution and lack of maintenance. Taken together, these factors are when combined to lower drainage productivity and result in regular crises of flooding and water-logging that disrupt the functioning of everyday life and pose a challenge to public health and infrastructure. While structural measures such as canal de-silting, embankment building and better stormwater drains represent crucial first steps of how to make drain cleaning more effective; only in combination with non-structural interventions such as urban planning changes, enforcement and community engagement will they make a real difference. Innovative solutions, such as SUDS (Sustainable Urban Drainage Systems), rainwater harvesting and nature-based solutions have shown potential to manage stormwater in a more natural way, complement with nature and reduce the stormwater runoff, as well as mitigate the flood risks in a sustainable manner. In addition, application of new technologies to provide real time monitoring for maintenance can also enhance the efficiency and sustainability of drainage systems.

If Sylhet is to develop a resilient urban response to rising flood risk, integrated approaches between local government, planners and local people are required. Policy and planning instruments must give priority to the protection and restoration of natural drainages pathways, the enforcement of land-use regulations coupled with public involvement. The future work must address the development of comprehensive flood risk models that encompass climate change scenarios, social-economic characteristics and urban development trends. The potential for new drainage technologies and sustainable urban water management in Sylhet's own particular context will also be considered to help promote more adaptive and sustainable urban water management.

Compliance with ethical standards

Disclosure of conflict of interest

Authors declare no conflicts of interests.

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