IMPLEMENTATION OF WATER SENSITIVE URBAN DESIGN TECHNOLOGIES: OPPORTUNITIES AND CHALLENGES IN A DEVELOPING COUNTRY

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ABSTRACT

Urban environmental stresses and issues such as water logging, urban flooding, water pollution, groundwater depletion, urban heat island, ecosystem distortion, etc. are exacerbated nowadays due to the ever increasing and fast urbanization around the world especially in a developing economy like Bangladesh. Water Sensitive Urban Design (WSUD) technologies including infiltration trenches, permeable pavements, bioretention systems, vegetated swales, green roofs/walls, rain gardens, rainwater harvesting systems, etc. in practice could be the solution to these issues, with benefits such as water recycling, climate change mitigation/adaptation, biodiversity enhancement, improving city aesthetics and livability, improved health and wellbeing, and so on. However, there are many challenges in implementing these WSUD technologies in a specific city. Some of the technologies may not be feasible in built-up areas and require open spaces for implementation. Again, the implementation of some technologies requires adequate funding arrangements, and some require behavioral changes among city dwellers. Thus, possibilities of application of the technologies in different cities may vary with the land use patterns, economic situations, administrative arrangements, socio-cultural scenarios, and so on. In this study, different WSUD technologies are critically reviewed and possibilities of their implementation in the city corporations of Bangladesh are analyzed. For this purpose, GIS analysis is performed to calculate the percentage of different land cover classes in each city corporation of Bangladesh using the global land cover data of the European Space Agency (ESA) during 2020. Analyzing land cover patterns and other scenarios of each city, different site specific WSUD technologies are proposed. Probable challenges that may arise during implementation are also critically reviewed in this study. According to the outcome of the analysis, the built-up area percentage covered by the city corporation in ascending order as follows: Rangpur (5.07) < Mymensingh (11.27) < Barishal (14.35) < Gazipur (16.75) < Cumilla (17.95) < Chattogram (30.62) < Rajshahi (34.15) < Sylhet (39.54) < Khulna (41.4) < Narayanganj (46.16) < Dhaka North (48.11) < Dhaka South (58.89). In the cities with less built-up area, it will be easy to implement all kinds of WSUD technologies. However, in the existing built-up areas, some of the technologies will not be easy to implement. Rainwater harvesting, and constructing green roofs/walls in the existing buildings can be implemented in such a scenario. The outcomes of this study would assist policymakers and relevant authorities in transforming the cities into Water Sensitive Cities (WSC) and making them more livable, sustainable, and resilient. However, the technical design and economic feasibility of the proposed technologies while implementing in a specific city can be studied further.

Keywords: *Water Sensitive City, Water Sensitive Urban Design, Land Cover, Opportunities, Challenges*

1. INTRODUCTION

The identity of our cities is inextricably linked to water. Numerous factors, including population expansion, urbanization, climate change, ageing infrastructure, and others, are causing cities all over the world to face a variety of challenges with their urban water systems. As a solution to these problems and a vision for making future cities more habitable, resilient, and sustainable, the Water Sensitive Urban Design (WSUD) concept has arisen. The urban water cycle is designed in an integrated way through WSUD, which takes into account environmental protection, stormwater and groundwater management, wastewater treatment, urban planning, and environmental protection (BMT WBM, 2009). Water Sensitive Cities (WSC) and the term WSUD are frequently used interchangeably in Australia while a similar concept, Low impact development (LID) is used in North America (Department of Environmental Resources, 1999; Fletcher et al., 2015). Water resources, ecosystem services, and social and institutional capital are the three pillars of a water-sensitive city, which are founded on three themes: a) the city as a catchment for water supplies, b) the city as a provider of ecosystem services, and c) the city as a collection of water-sensitive communities (Wong & Brown, 2009). Infiltration systems, bioretention basins, vegetated and bio-filtration swales, sand filters, permeable and porous pavements, built wetlands, ponds, vegetated filter strips, and rainwater tanks are examples of common WSUD technologies (Beecham, 2003).

Many nations, including the USA, UK, Australia, New Zealand, Canada, France, Brazil, Sweden, Denmark, and Germany, observe the practices of WSUD, LID, SUDS, best management practices, sources control measures, alternatives technologies, green infrastructures, or similar devices (Fletcher et al., 2015). The knowledge and research attempts are also enriched for those countries regarding WSUD implementation strategies, opportunities, and challenges. Other countries are also trying to enrich their knowledge regarding this technology. For example, Carden et al., (2018) studied the opportunities and challenges for the implementation of WSUD technologies in South Africa. However, according to Wong & Brown (2009), developing cities fall behind in fulfilling WSUD goals due to intrinsic restrictions such as institutional, financial, technical, and social capacities. Application of WSUD technologies in the cities of a developing country like Bangladesh is also challenging due to many reasons including high population density, rapid urbanization, economic constraints, lack of institutional coordination, lack of awareness among mass people, climate change impact, land use change, and so on. The knowledge is not also enriched regarding this topic. Some studies analyzed implementation opportunities of WSUD and other similar technologies for Dhaka city only. For example, Wahab et al., (2016) investigated the applicability of several WSUD techniques in Dhaka city and evaluated their cost and efficiency in promoting groundwater recharge. Ahmed et al., (2019) investigated whether and how an urban blue-green infrastructure (BGI) network, which develops from the idea of water-sensitive urban design, can be suggested - both at macro and micro scales - as part of a future urban development strategy for Bangladesh's capital city of Dhaka. Siddiqua (2020) investigated the water system of the city of Dhaka, concentrating on waterlogging, flooding, and the influence of the eastern low wetlands on flood management. In addition to offering some architectural solutions to address environmental issues and flood management, the study examined changes in land usage over two decades. However, there are 12 city corporations in Bangladesh including Barishal City Corporation (BCC), Chattogram City Corporation (CCC), Cumilla City Corporation (CuCC), Dhaka North City Corporation (DNCC), Dhaka South City Corporation (DSCC), Gazipur City Corporation (GCC), Khulna City Corporation (KCC), Mymensingh City Corporation (MCC) Narayanganj City Corporation (NCC), Rajshahi City Corporation (RCC), Rangpur City Corporation (RaCC), and Sylhet City Corporation (SCC). Though some city corporations already have a high portion of developed areas there are some city corporations that have open spaces and can be developed with proper planning. Therefore, this study tried to analyze the drivers and opportunities of transforming city corporations of Bangladesh into water sensitive cities. Further, the barriers in achieving the recommended best practices of WSUD is also depicted. The outcomes of this study thus will be helpful for the improvement of knowledge in this field and also helpful for policymakers and authorities to take proper initiatives in the way of transforming cities into Water Sensitive Cities (WSC).

2. METHODOLOGY

The flowchart of the methodological approach of this study is shown in Figure 1.

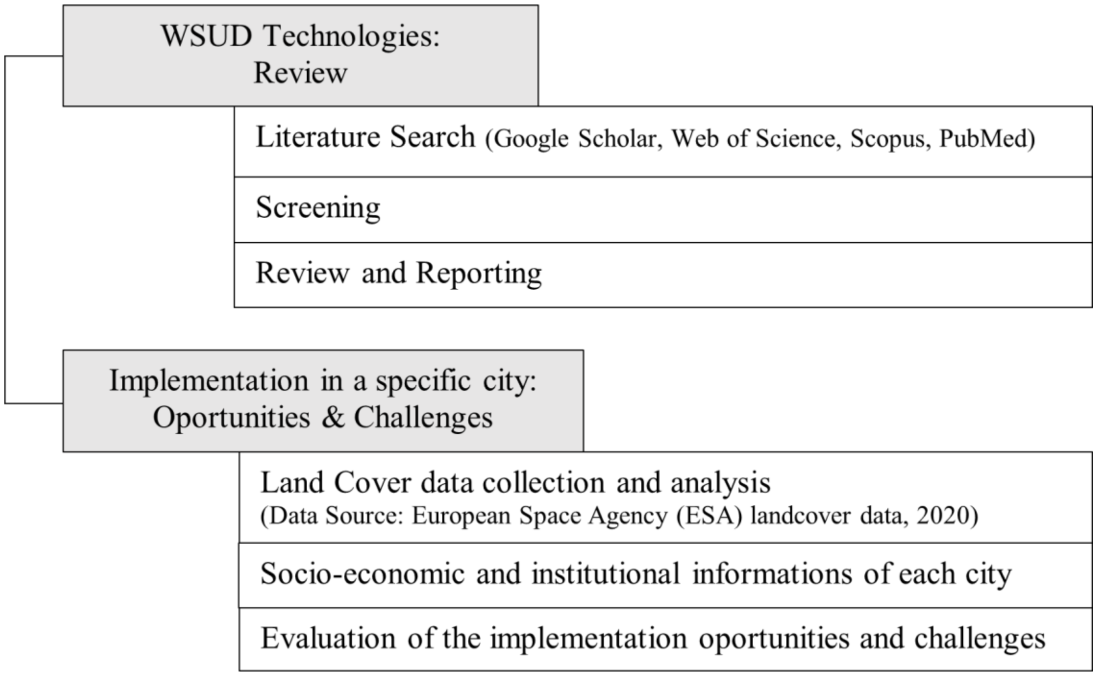

Figure 1: Methodological approach of the study

2.1 Review of the WSUD Technologies

Available WSUD technologies and their applications are thoroughly reviewed in this study to find the suitable technologies for the cities of Bangladesh. For this purpose, relevant literature was searched in Google Scholar, Scopus, Web of Science, PubMed and other databases using the keywords like WSUD technology, water sensitive city, Low Impact Development (LID), green roofs/walls, rain gardens, rainwater harvesting systems, permeable pavements, infiltration trenches, bioretention systems, vegetated swales, etc. From the retrieved articles relevant articles are finally screened and used for detailed review.

2.2 Land Cover Data Collection and Analysis

For land cover classification, the global land cover data of the European Space Agency (ESA) is used. Based on Sentinel-1 and Sentinel-2 data, the European Space Agency (ESA) released a publicly available global land cover product at 10 m resolution for 2020 in October 2021. It had 11 land cover classes and was independently evaluated with a global overall accuracy of 74.4%. The land cover data were then analyzed to find the percentage of each land cover class in the cities of Bangladesh. The boundaries of city corporations during 2020 are used for the analysis. Open-source GIS software QGIS is used for analysis purposes.

3. RESULT AND DISCUSSIONS

3.1 WSUD Technologies

Different WSUD technologies including green roofs/walls, rain gardens, rainwater harvesting systems, permeable pavements, infiltration trenches, bioretention systems, and wetland construction are reviewed in this study. Benefits and their applicability are summarized in Table 1.

Table 1: Benefits and applicability of different WSUD Technologies

WSUD Technologies	Benefits/Function	Applicability	Reference
Green roof/wall	• Enhance water quality • Reduce impermeable surfaces • Reduce heat island effect • Increase living space • Improve air quality • Improve biodiversity • Improve insulation • Increase carbon dioxide/oxygen exchange	• Appropriate for commercial, industrial, and residential constructions with large roof areas • Can be adapted to existing structures or placed during new development	Beecham et al., 2018; Department of Planning and LocalGovernment, 2009; Liu et al., 2021; Rahman et al., 2022
Rain Garden	• Reduce the pressure on the local drainage system by retaining runoff for infiltration into the soil • Enhance water quality • Improve aesthetics of the area • Easy Construction	• Can be used on a small scale as well as in large complexes • Can be used in commercial industrial, and residential settings • Can be incorporated into new construction or added to existing gardens • Relatively high space required	Bak & Barjenbruch, 2022; Department of Planning and Local Government, 2009
Rainwater Harvesting	• Reduce the importation of water from far-off catchments • Potential reduction in peak runoff rates and volumes • Reduce negative environmental consequences (including flooding, stormwater pollution, and stream erosion) • Reduce drinking water use (when safety requirements are satisfied)	• Typically implemented at the allotment level on development sites for homes, businesses, and industries • Can be used in bigger development projects at the street level	Ahammed, 2017; Department of Planning and Local Government, 2009; Liu et al., 2021
Permeable Pavement	• Reduce runoff volume • Lower peak flows by runoff retention • Reduce the amount of contaminants and sediments exported from the site	• Can be utilized in place of hardstand surfaces and traditional paving. • Appropriate in residential or commercial settings with little traffic and little loads of silt.	Department of Planning and Local Government, 2009)(Ahammed, 2017; Department of Planning and Local Government, 2009; Liu et al., 2021
Infiltration Measures	• Flood control achieved by spreading out peak flows and lowering runoff volume • Relatively simple to construct	• Sandy soils with deep groundwater are ideal case for implementation • Pre-treating runoff prior to infiltration is often necessary to prevent blockage and to safeguard the groundwater quality. • Can be constructed in open spaces, parking lots, and commercial buildings • Can be positioned beneath the pavement and pedestrian street to save space and cost	Ahammed, 2017; Chahar et al., 2012; Department of Planning and Local Government, 2009; Elizabeth et al., 2021; Liu et al., 2021
Bioretention Systems	• Infiltration of runoff • Water conveyance, • Enhance water quality • Decrease peak flow, • On-site detention and retention capacity.	• Generally constructed in parking lots, parkland areas, and the mid strip of divided roadways. • Can be implemented in both "retrofit" and new construction scenarios	Ahammed, 2017; Department of Planning and Local Government, 2009; Liu et al., 2021
Wetland Construction	• Provide habitat for fauna, • Recreational purpose • Reduce urban heat island • Wastewater treatment	• Wetlands can be built on a variety of dimensions, from small residential estates to huge regional or watershed systems • Implementation necessitates open spaces.	Department of Planning and Local Government, 2009; Parde et al., 2021

3.1.1 Green Roof/Wall

Green roof, a stormwater management solution, manages the quantity and quality of the storm water and maximizes space use. This technology has contribution to 12 out of 17 Sustainable Development Goals (Rahman et al., 2022). After its introduction in an article in 1960, this technology gained momentum post-2009 (100+ papers published) and widespread attention by 2017 (400+ papers published) (Rahman et al., 2022). Both extensive and intensive green roofs effectively control stormwater quantity, with intensive profiles showing greater water retention in dry climates, reducing supplementary irrigation needs. Green roofs and walls mitigate the Urban Heat Island (UHI) effect, reducing city electricity consumption. Enhancing water quality is one of WSUD's objectives, however living walls and green roofs can occasionally be sources of pollution, especially in the early stages of plant development (Beecham et al., 2018). Green roof/wall technology can be implemented both in existing built-up areas and open spaces for new development.

3.1.2 Rain Garden

Rain gardens are similar to regular gardens, with one significant exception: drainage from paved surfaces, downspouts, or rainwater tanks is diverted into the garden. Rain gardens serve many purposes, and in addition to managing rainfall, protecting water, and promoting ecosystem health, they also offer other advantages. Unlike green roofs (especially those added or planned for existing structures), rain gardens don't require as much documentation, specialized knowledge, or complicated projects. It's not always necessary to employ large machinery (Bak & Barjenbruch, 2022).

3.1.3 Rainwater Harvesting

A traditional method of managing stormwater, Rainwater Harvesting (RWH) systems involve gathering, storing, and using stormwater as a major or supplemental source of water (Fewkes, 2012; Gomes et al., 2012). Around the world, a lot of cities have used rainwater harvesting techniques. For example, prior to the implementation of conventional water supply schemes, rainwater harvesting was the only method of obtaining water in the Caribbean (CEHI, 2009). It is an affordable method of providing water for residential, industrial, and agricultural use (CEHI, 2009). Rainwater harvesting provides several benefits including peak flow reduction, urban flooding mitigation, drinking water use reduction, and so on. To mitigate water scarcity and minimizing flood, the capital development authority of Bangladesh, RAJUK mandated rainwater collection for newly constructed homes in Dhaka city in 2011. These technologies can be incorporated both in the construction and retrofitting phases.

3.1.4 Permeable Pavement

Pavements that sustain loads and allow water to pass through them are referred to as pervious pavements, or porous and permeable pavements (Department of Planning and Local Government, 2009). In order to increase road safety in rainy weather, permeable pavements were most likely initially created in North America in the 1970s (Brown et al., 2009; Ranieri et al., 2010). Several advantages of permeable pavement include runoff reduction, pollutant reduction, and cost-effectiveness. Despite their cost effectiveness, permeable pavements' mechanical performance under traffic loads is still under examination (Lian et al., 2011). Permeable pavements can be used as a replacement for hard pavement and are mainly suitable in residential or commercial settings with little traffic and little loads of silt (Ahammed, 2017; Department of Planning and Local Government, 2009; Liu et al., 2021).

3.1.5 Infiltration Measures

The primary objectives of infiltration measures are to control floods by spreading out peak flows and lowering runoff volume (Dechesne et al., 2005). The most common form of infiltration measure is a shallow excavated trench, or "tank," intended to hold a specific amount of runoff before it seeps into the nearby soils (Gold Coast City Council, 2008). Leaky wells and soakaways are some other types of infiltration measures. Large-diameter Perforated pipes with large diameter or wells that enable stormwater to seep into the nearby soils are known as leaky wells, and they are typically utilized on small-scale residential sites (Department of Planning and Local Government, 2009). Soakaways are subterranean infiltration structures that are filled with materials like gravel or extremely porous plastic media and they allow rainfall to infiltrate into the nearby soils and serve as temporary storage for runoff from roofs (Roldin et al., 2012). Leaky wells and soakaways were suggested as a means to limit the amount of stormwater in developing countries like Bangladesh by Ahammed et al. (2013). For infiltration systems to prevent structural damage from soil shrinkage or expansion, there must be enough setback distance between structures (Department of Planning and Local Government, 2009). Infiltration trenches are relatively simple to construct and are frequently used to manage stormwater runoff in open spaces, parking lots, and commercial buildings (Chahar et al., 2012; Elizabeth et al., 2021). To conserve space, they can be positioned beneath the pavement and pedestrian streets, which may help to reduce construction costs (Liu et al., 2021).

3.1.6 Bioretention Systems

Bioretention systems are infiltration tools that incorporate vegetation and trees along with media (such as sand, gravel, loam, etc.) (Ahammed, 2017). The processes of flotation, adsorption, ion exchange, volatilization, and microbial decomposition are used in tandem to treat stormwater (Younos, 2011). Bioretention trenches (Swales) or basins both act as bioretention systems. The treatment procedures used in bioretention basins and swales are identical, with the exception that basins lack a conveyance purpose. Bioretention swales and basins can create visually appealing landscape elements for urban developments, improve biodiversity, and so on (Department of Planning and Local Government, 2009). They are frequently found in parking lots, green areas, and the median strip of divided roadways. Opportunities for bioretention swales exist in both "retrofit" and new construction scenarios (Department of Planning and Local Government, 2009).

3.1.7 Constructed Wetland

Constructed wetlands are artificial reproductions of natural wetlands that use vegetation, improved sedimentation, fine filtration, and biological pollution uptake to improve water quality. Wetlands can also provide substantial biodiversity and community advantages. They provide wildlife habitat, a focal point for enjoyment, enhance the appearance of development, and can be a focal point in a landscape (Department of Planning and Local Government, 2009). To treat various wastewater types with greater removal of BOD, COD, NH_4-N, NO_3-N, TN, TP, etc., a constructed wetland can be used (Parde et al., 2021). Construction of new wetlands requires larger open spaces and cannot be implemented in a highly built-up area.

3.2 Implementation Opportunities

Opportunities for implementation of a specific WSUD technology in a specific city depend on many factors including land use patterns, economic situations, administrative arrangements, socio-cultural scenarios, available resources, and so on. In this study implementation opportunities are analyzed mainly based on land use patterns. Some other socio-economic and administrative conditions are also partially demonstrated in this study.

3.2.1 Land Cover of the Cities

The European Space Agency (ESA) land cover data is analyzed to calculate the percentage area covered by each land cover class in the city corporation of Bangladesh. The land cover of the 12 city corporations of Bangladesh is shown in Figure 1 and the summary of analysis outcomes is given in Table 1. It can be noted from the map (Figure 1) and outcome summary (Table 1) that among 11 land cover classes of ESA, Bangladesh's city corporations have 9 land cover classes. There is no land cover for two classes including "snow and ice" (map code-70) and "moss and lichen" (map code-100). Mangroves are only seen in the land cover of Chattogram city corporation (only 0.51 %).

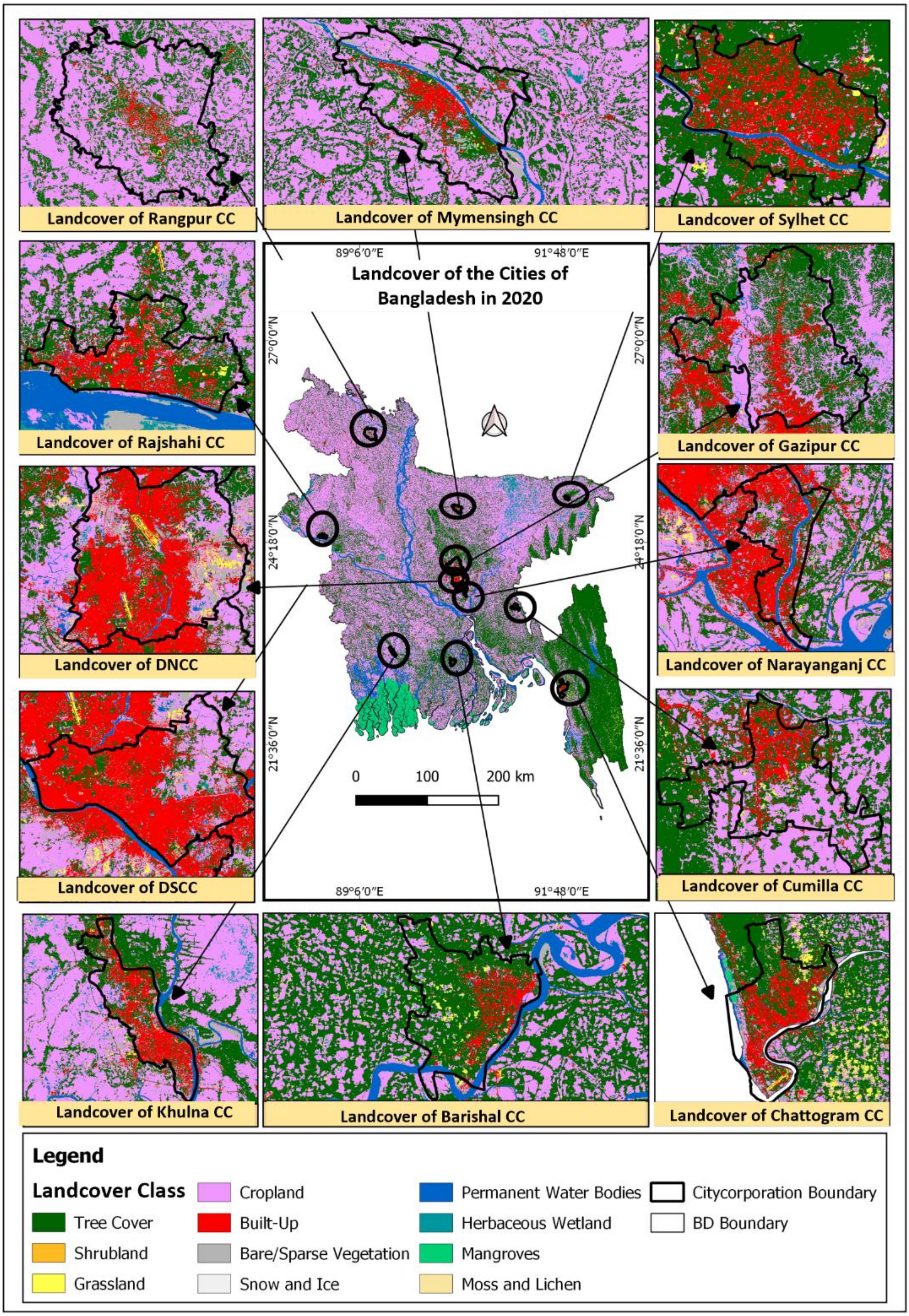

Figure 2: Land cover classes of the city corporations of Bangladesh during 2020

Table 1: Percentage of area covered by each land cover class in the major cities of Bangladesh (2020)

City Corporation	Land Cover Classes and Map Codes								
	Tree Cover (10)	Shrub land (20)	Grass land (30)	Crop land (40)	Built-up (50)	Bare/sparse vegetation (60)	Permanent water bodies (80)	Herbaceous wetland (90)	Man-groves (95)
Barishal	61.79	0.15	3.4	11.6	14.35	2.95	5.14	0.62	0
Chattogram	36.03	0.05	3.14	7.23	30.62	5.03	17.32	0.07	0.51
Cumilla	41.64	0.13	1.28	35.08	17.95	2.45	1.38	0.1	0
Dhaka North	15.49	0.03	4.01	18.9	48.11	10.36	2.74	0.37	0
Dhaka South	14.05	0.01	0.86	16.51	58.89	7.13	2.23	0.32	0
Gazipur	42.68	0.02	0.37	34.85	16.75	3.81	1.02	0.49	0
Khulna	29.26	0.02	1.58	11.35	41.4	8.51	7.78	0.1	0
Mymensingh	31.65	0.01	0.85	46.09	11.27	6.28	3.58	0.27	0
Narayanganj	21.47	0.39	0.67	15.42	46.16	6.19	9.45	0.24	0
Rajshahi	40.09	0.01	1.97	14.28	34.15	6.56	2.93	0.02	0
Rangpur	29.34	0.01	0.35	57.19	5.07	7.85	0.19	0	0
Sylhet	46.77	0.03	0.55	3.88	39.54	4.99	4.23	0.01	0

The percentage of built-up area is highest in Dhaka South City Corporation and lowest in Rangpur City Corporation. The built-up area percentage covered by the city corporation in ascending order as follows: Rangpur (5.07) < Mymensingh (11.27) < Barishal (14.35) < Gazipur (16.75) < Cumilla (17.95) < Chattogram (30.62) < Rajshahi (34.15) < Sylhet (39.54) < Khulna (41.4) < Narayanganj (46.16) < Dhaka North (48.11) < Dhaka South (58.89). In the case of some of the city corporations, the area is quite large compared to the others. For example, Rangpur City Corporation is one of the largest city corporations in terms of area. But the current built-up area is around 5% only and the majority of the area is cropland. The built-up areas are seen only in the central part of the city. Over the course of time, croplands would turn into residential areas to meet-up the growing demand. Therefore, authorities of Rangpur city should consider WSUD technologies during their development plan. Mymensingh city corporation also has larger open spaces and built-up areas are only seen in the core of the city beside the Brahmaputra Riverbank. There are also high possibilities to implement WSUD technologies during any new development initiatives. Barishal, Cumilla, and Gazipur city have a high amount of tree cover in their boundary. Therefore, careful consideration is required during any development work to conserve the trees. WSUD technologies will be beneficial for such purposes. A moderate amount of Built-up area seen for Chattogram, Rajshahi, and Sylhet city. The city boundary of 2020 is used to analyze and prepare the map. But, recently, the boundary of Sylhet City Corporation has expanded. Till 2020, the built-up area percentage was quite high (39.54%). But, after the expansion of the boundary, the percentage of built-up area has been reduced to a great extent as most of the expanded area has open spaces (cropland, grassland, and others). This area will be developed soon and therefore proper planning is required considering WSUD technologies. Khulna, Narayanganj, Dhaka North, and Dhaka South city have a high built-up area (above 40%). Some open spaces are seen in the eastern side of Dhaka North city and the north-eastern side of Dhaka South city. This area is also developing fast. Therefore, proper initiatives are required to implement WSUD technologies in any new development work and existing built-up areas.

Implementation possibilities of different WSUD Technologies in the cities of Bangladesh for different scenarios are summarized in Table 2. Green roof/wall can be constructed in both existing and newly developed household and commercial buildings. Rain garden may not be implemented in the retrofit phase in newly developed household where there is sufficient land this type of technology will be applicable but in the household with limited land it will be not constructed as it requires larger space to develop. Rainwater Harvesting can be implemented both in existing and new buildings. Permeable pavement implementation in the existing streets requires site specific investigations and can be implemented in the new development phase. Infiltration measures can be developed in all kinds of new developments. While in already developed commercial and streets infiltration measures and bioretention systems can be possibly suitable depending on site specific characteristics. Wetland construction can only be done in the designated open space in the new development phase.

Table 2: Implementation opportunities of WSUD Technologies in cities of Bangladesh for different scenarios (reconstructed after Department of Planning and Local Government, 2009; Rohilla et al., 2017)

WSUD Technologies	**Already Built-Up (Retrofit)**			**New Development**			
	HH	**Commercial**	**Street***	**HH**	**Commercial**	**Street***	**Open**
Green roof/ Wall	√	√	X	√	√	X	X
Rain Garden	X	X	X	?	√	√	√
Rainwater Harvesting	√	√	X	√	√	X	X
Permeable Pavement	X	X	?	X	X	√	X
Infiltration Measures	X	?	?	√	√	√	√
Bioretention Systems	X	?	?	X	√	√	√
Constructed Wetland	X	X	X	X	X	X	√

√ - appropriate; ? - requires investigations; X - not appropriate; HH – Household; *On slopes less than 4 %

3.2.2 Socio-economic conditions of the cities

Some socio-economic data and some other general information are summarized in Table 3. From the table, it can be seen that the population density of Dhaka South CC is the highest whereas Rangpur CC has the lowest density that follows similar trends as the built-up area percentage. The proposed budget (FY-2023-24) for Dhaka South city is also the highest. The economic strength and social and administrative arrangements may impact on choice of any WSUD technologies. Cost-effective technologies can be implemented easily by all the city corporation authorities. These aspects can be thoroughly analyzed in selecting an appropriate site-specific technology.

Table 3: General Information of the City Corporations of Bangladesh

City Corporation	**Population[a]**	**Population Density[a]**	**Area[b] (km^2)**	**Total HH[a]**	**HH Size[a]**	**Literacy Rate[a]**	**Proposed Budget FY 2023-24 (in Crore BDT)[c]**
Barishal	419484	7232	58.00	105200	3.89	88.90	442.7
Chattogram	3230507	20788	155.40	822882	3.92	84.49	1,887.28
Cumilla	440233	8300	53.04	101245	4.14	87.28	748.37
Dhaka North	5990723	30531	196.22	1636924	3.64	86.71	5269.45
Dhaka South	4305063	39406	109.25	1104703	3.85	85.56	6751.56
Gazipur	2677715	8126	329.52	836875	3.16	83.57	-
Khulna	719557	15762	45.65	188579	3.75	88.07	1,082.99
Mymensingh	577000	6318	91.33	135495	4.03	84.41	572.11
Narayanganj	967951	13364	72.43	255468	3.74	83.66	695
Rajshahi	553288	5693	97.19	133887	3.75	88.88	1,015.34
Rangpur	708570	3445	205.68	170733	3.91	80.94	-
Sylhet	532839	6702	79.50	116711	4.53	84.57	925.4

a: Population and Housing Census 2022: National Report (Volume 1) (BBS, 2023)
b: Calculated as population/population density
c: Annual reports of the city corporations

3.2.3 Institutional Arrangement

The prime responsibility for adopting the WSUD technologies falls on the city corporations. In many major cities, such as Dhaka, Chattogram, Rajshahi, and Khulna, there are development authorities who hold the responsibility of preparing strategic/ master plans in the city regions. They also prepare many residential towns for the residents. These development authorities could play vital roles in implementing the WSUD technologies. Moreover, the Water Resources Planning Organization (WARPO) has a mandate to secure water resources under the Bangladesh Water Act (2013). On the other hand, the Department of Environment (DoE) has a mandate of overall environmental protection all over Bangladesh through monitoring, approval, enforcement, awareness building, etc. The above organizations work under different ministries and their mandate and working principles vary. Thus, coordination and collaboration among these organizations are crucial for the smooth execution of the plans.

3.3 Implementation Challenges

The goal of Water Sensitive Urban Design (WSUD) is to incorporate water management into the urban environment through an innovative and sustainable approach to urban planning and development. Although WSUD has shown to be effective in several industrialized nations, putting it into practice in a developing nation like Bangladesh presents a different set of difficulties.

Rapid urbanization: Bangladesh is rapidly becoming more urbanized, which has resulted in a decrease in natural landscapes and an increase in impermeable surfaces. Urban growth proceeds at a rate that frequently surpasses the ability to plan and execute water-sensitive strategies. Rapid problem-solving may make it more difficult to incorporate WSUD ideas into urban planning.

Infrastructure limitations: Bangladesh has a lot of obstacles when it comes to its current infrastructure, particularly in urban areas. Many cities lack adequate solid waste management, sewage treatment facilities, and stormwater drainage systems. For a nation with a developing economy, implementing WSUD would need a significant investment in modernizing, and constructing new infrastructure.

Lack of awareness and education: For WSUD to be implemented successfully, policymakers, urban planners, and the general public must be aware of and comprehend its advantages. The widespread adoption of WSUD may be hampered in a developing nation like Bangladesh by a lack of knowledge and instruction regarding the significance of sustainable water management techniques.

Climate change impacts: Bangladesh is particularly sensitive to the effects of climate change, which include cyclones, floods, and other extreme weather events occurring more frequently and with greater intensity. Water-sensitive urban areas must be carefully planned and designed to be able to withstand and react to these changes, which adds another level of complexity to the implementation of WSUD.

Land use challenges: It can be difficult to locate appropriate locations for WSUD measures, including water-sensitive landscaping or green infrastructure, in heavily populated urban areas. The viability of using these elements in urban plans may be constrained by the competition for land usage between housing, industry, and infrastructure.

Regulatory and institutional frameworks: Successful adoption of WSUD practices requires the formulation and enforcement of regulations. Water-sensitive design integration into urban projects may be difficult to require or incentivize in some developing nations due to poor or inadequate regulatory frameworks.

Community engagement and participation: Community engagement is crucial for the success of WSUD initiatives. In Bangladesh, where community involvement in decision-making processes may be limited, ensuring the active participation of residents in the planning and implementation of water sensitive projects can be a significant challenge.

Capacity building: Involving the community is essential to the success of WSUD programs. Encouraging the active engagement of locals in the design and execution of water-sensitive projects can be particularly difficult in Bangladesh, where there may be little community involvement in decision-making processes.

Addressing these implementation challenges requires a coordinated effort involving government agencies, non-governmental organizations, communities, and international partners. It also demands a long-term commitment to sustainable urban development that prioritizes water-sensitive practices in the face of competing demands and constraints.

It will take a concerted effort from government agencies, non-governmental organizations, communities, and international partners to address these implementation issues. In the face of conflicting needs and limitations, it also necessitates a sustained commitment to sustainable urban development that gives water-sensitive practices due priority.

4. CONCLUSIONS

Escalating urban environmental challenges in Bangladesh demand innovative solutions, with Water Sensitive Urban Design (WSUD) technologies offering promise. This study assesses WSUD feasibility in various city corporations, considering land use patterns. Results show varying built-up areas, impacting the ease of WSUD implementation. While low-built-up areas favor comprehensive WSUD adoption, densely built cities face challenges. The study recommends site-specific WSUD solutions and identifies challenges, providing a valuable resource for policymakers. However, further investigation into the technical and economic feasibility of the proposed technologies is warranted. Ultimately, prioritizing WSUD strategies based on built-up percentages can guide city transformations, fostering more livable, sustainable, and resilient urban environments.

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