

# Physiographic Landscape Elements for Water Sensitive Urban Development: Lessons from Indigenous Land-Water Interface

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**Abstract** Human development and the natural environment interact to shape distinctive landscapes, particularly in regions where water plays a central role between society and resilience. This research focuses on the Eastern Periphery of the Dhaka Metropolitan Area (DMA), where indigenous settlements have long integrated natural waterbodies into their development patterns. The problem lies in the ongoing urbanization that threatens these long sustained traditional practices, leading to the degradation of natural landscapes and water management systems. The aim of the paper is to analyze the physiographic landscape of this area and promote sustainable, water-sensitive urban development by understanding local land-water interactions. To achieve this, the study adopts a mixed-method approach, incorporating satellite image analysis, GIS mapping, field observations, and interviews with local inhabitants. Both qualitative and quantitative analyses were conducted to width, slope gradient, surface quality, and land division patterns, in response to seasonal fluctuations and water level variations. The findings reveal that the local land-water interface has evolved naturally and dynamically, driven by landscape parameters such as size, width, slope, surface quality and local land utilization patterns. The study identifies important landscape elements that could be incorporated into urban design to foster water-sensitive development in deltaic cities like Dhaka. As a whole, this

research underscores the importance of understanding indigenous landscape characteristics and local knowledge to guide sustainable urban development and address water-related urban crises.

**Keywords** Physiographic Landscape, Land-water Interface, Indigenous Settlements, Sustainable Urban Development, Water-sensitive Urban Design

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## 1. Introduction

The intricate relationship between society and the environment shapes distinct landscapes, each characterized by unique development patterns. These landscapes emerge from the co-evolution of human activities and the natural surroundings, where local climate, topography, and water resources play vital roles [1], [2]. Traditional settlements, particularly those near water, have historically evolved in harmony with their environments. Local communities skilfully utilized nearby waterbodies to form physiographic landscapes that reflected their environmental context, practices, and ways of living. These settlements typically exhibited a high level of resilience to environmental changes, largely due to their sustainable practices and adaptive designs [3]. Studying

these traditional settlements provides valuable insights into sustainable urban development for contemporary cities.

Bangladesh, located in the largest delta of the world, is defined by the confluence of the Ganges, Brahmaputra, and Meghna rivers [4]. The region's enormous and dynamic natural landscape resources have shaped its geographic and historical identity. Dhaka, the capital city, sits at the convergence of these river systems, where the natural hydrological network has long influenced its settlement patterns and infrastructure. Surrounded by rivers and marshes, Dhaka's development has been closely tied to its hydrological features, and this land-water relationship has become a defining characteristic of the region's identity [5], [6].

However, the city's rapid urbanization, coupled with increasing pressure on its natural land and water resources, has generated serious concerns regarding the sustainability of its urban settlements [7]. Rapid urban growth of Dhaka has altered its natural landscape, especially the waterbodies, leading to environmental challenges. The city's natural water system, once crucial for drainage and flood protection, has been replaced by engineered solutions like embankments and sluice gates. These developments have led to the conversion of natural lowlands into built-up areas, exacerbating waterlogging and flood risks. The city's current urban development disregards its unique geomorphological features, further exacerbating ecological and hydrological issues.

In order to respond to the contemporary urban crisis, the current understanding of urban design and planning has stressed the assimilation of local hydrological resources into the region, based on the hydrological process [8], [9]. The methods and means of incorporation of land and waterbodies for hydrological, ecological, environmental, socio-cultural uses are recommended for analyzing and incorporating from the local perspective for the purpose of sustainable development [10], [11], [12]. The contemporary water sensitive approaches involve common measures with similar nature, such as: 'green-blue network', 'storage of water', 'steering away from tech-fix-solutions for water edge management', 'bringing urban water cycle closer to natural cycle', 'retaining-storing-draining of runoff water', 'nature-based solutions' [13], [14], [15], [16], [17], etc. extracted from the local long-standing settlement for sustainable land-water integration. Modern urban design can learn from traditional practices by integrating passive techniques, sustainable water management, and community-based planning approaches, creating resilient, water-sensitive urban environments.

This paper aims to explore the traditional physiographic landscapes of Bangladesh's land-water (L-W) interface. By examining the indigenous settlements, the study seeks to extract sustainable landscape features that can guide the future development of water-sensitive urban areas, particularly in rapidly urbanizing regions such as Dhaka.

## 2. Urban Land Conversion and Hydrological Challenges in DMA

The urbanization process in many developing countries is an unplanned and demand-based phenomenon which alters the fundamental natural landscape without concern for probable adverse effects or minimum requirements for sustainable environment [7], [18], [19]. The prevailing urbanization trend, characterized by fast and unregulated growth, poses greater danger to natural land and water landscape of Dhaka. There were several lowlands, khals, and waterways existed within and surrounding Dhaka city just a several decades ago, effectively ensuring the city's environmental equilibrium [20]. Nonetheless, the circumstances have altered significantly in recent years due to the city's unchecked development over vital land and water areas. Dhaka city development process accelerated after the independence of Bangladesh in 1971. In a similar context, Hassan & Southworth [21] revealed that the built-up expansion increased drastically over the last four decades, reaching from 55.5 km<sup>2</sup> in 1972 to 250.0 km<sup>2</sup> in 2015. This massive urbanization primarily happened in Dhaka's northern, north-western, and south-western zones where previously natural essential landscapes were transformed into built-up areas through landfills. On the periphery of the city, land-water interface is generally characterized by seasonal wetlands which are locally utilized for agricultural production. The study of Hassan & Southworth [21] analyzed that nearly 77% of agricultural land, 43% of the vegetated area, and 41% of waterbodies in DMA had diminished due to urban growth during the previous 40 years. Furthermore, another study observed that, total decrease in the vegetation of the DMA was 56% from 1989 to 2020 [22]. In this regard, the seasonally flooded agricultural area, which is the vital for the hydrological and ecological protection of the city, has seen the greatest conversion rate.

The unplanned land use change in the Dhaka city is found to have negative impact on the hydrological and ecological conditions of the city, particularly water-born calamities. Many parts of Dhaka are at risk of flooding and other climate-related disasters because of the city's low elevation and the rivers and canals that surround it [23], [24]. Due to the change of natural landscapes into urban built-up areas, Dhaka experiences waterlogging and rainfall-induced urban floods, which generate enormous problems for urban populations and are getting worse. Altering natural waterbodies and land resources has reduced water storage, caused drainage network obstruction, and increased peak precipitation output. Disconnected, obstructed, and interrupted water drainage networks are unable to carry the rainfall from cities to rivers and lowlands. Lowlands filling and morphological changes affect their water holding capacities and water infiltration due to rainfall and river flood. Removing surface waterbodies and eliminating vegetation,

agricultural areas, and impermeable urban land disrupts water flow into the water network and increases surface water runoff. Each of these factors eventually contributes to the increased frequency and severity of floods and waterlogging, which have been recognized as one of the most critical challenges in Dhaka City.

In addition to hydrological problem the urban surface land impacts other ecological and environmental deterioration events like reduction of the recharging section of ground water, enhanced urban heat island, interference with bio-diversity and natural habitats, conversion of agricultural land and fresh food production area, increase of the extent of impermeable surfaces, change of the beautiful and balanced living environment. Local landscapes characteristic of villages and consisting of natural land and water resources are gradually being converted into urban land and there is no place for waterbodies and other types of landscape activities in them. The local process of land development is at risk due to the destruction of spontaneous settlements caused by unplanned construction. These eventually threaten the integration of natural resources and the loss of locational identity.

### 3. Water Sensitive Landscape in the Periphery of DMA

Ancient civilizations developed ingenious water management and subsistence methods, rooted in a deep understanding of hydrology, topography, and seasonal weather. These methods significantly shaped human settlements, influencing their development, vitality, and eventual decline [25]. Cities built around water, like Can Tho, Hou An, Singapore, Bangkok, Dhaka, and others developed strong relationships with water, incorporating it into their everyday practices and landscape formations [26]. The spatial footprint of these cities was largely determined by rational water management, with informal but effective integration of land-water dynamics, all based on the specific hydrological conditions of their local environments [27]. Settlements were designed around available water resources, seasonal variations, and precipitation patterns, ensuring resilience and sustainability. Several practices across different regions and urban areas like Colombo, Sri Lanka; Sydney Olympic Park, Australia; Suncheon Bay, South Korea; Panama City, Panama; etc. demonstrated innovative strategies and methods for integrated natural land and water resources into and beyond urban areas for water management, production, infrastructure planning, ecosystem generation and so on [28].

Bangladesh, as a deltaic, riverine country, has a landscape dominated by rivers, canals, wetlands, and flood plains, which converge to form the largest and most fertile river deltas in the world [4]. Dhaka, the capital city and a

rapidly expanding megacity, is situated in a low lying area at the southern edge of an ancient alluvial terrace. Its topography features highland areas surrounded by marshes and old riverbeds, with elevations ranging from 1m to 14m above sea level [29], [30]. The tropical monsoon climate results in heavy rainfall, with wetlands and natural water bodies acting as retention areas, draining water by gravity through streams and rivers [31]. The hydrological system has thus historically shaped the city's built environment, settlement patterns, and landscape formations (Figure 1).



**Figure 1.** The spontaneous urban peripheral development is integrating natural landscape into their settlement

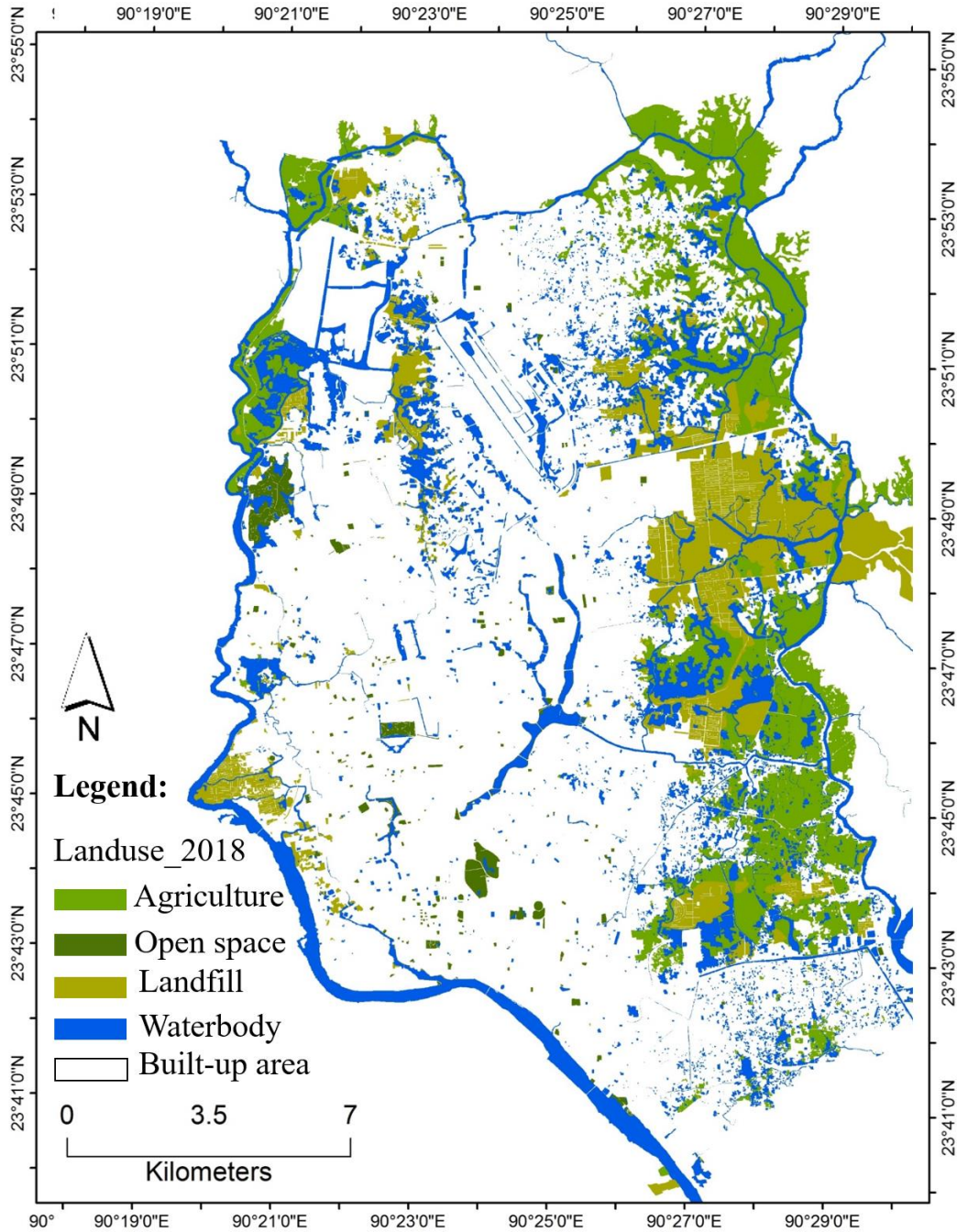
Geographically, the peripheral areas of Dhaka are rich in natural canals, waterbodies, and landscapes that serve as natural drainage systems during the monsoon (Figure 2). These areas are topographically low-lying (2m-5m above Public Works Datum-PWD), sloping gradually towards the surrounding rivers ([32] particularly in the eastern part of the DMA (Figure 3). Historically, most of the peripheral regions submerged during the monsoon transforming the region into a vast water retention zone, while during the dry season, they were used for agriculture enhancing local productivity. Local inhabitants in these regions still integrate waterbodies into their settlements, utilizing the land-water interface for various agricultural and landscape practices. The seasonal expansion and contraction of waterbodies, particularly during the rainy season, play a crucial role in local livelihoods, providing for aquaculture, storage of surface runoff, and productive agricultural landscapes during the dry season. This dynamic, seasonally adaptive system ensures efficient drainage, while the natural landscape, including agricultural land and diverse vegetation, remains an integral part of the settlements.

From a geomorphological perspective, the peripheral areas of Dhaka exemplify the Pleistocene Madhupur Clay, characterized by alluvial low plains and wetlands formed by river overflows [33]. The traditional village-like homesteads in these areas have been historically integrated into this landscape, with houses built on higher ground while marshlands, valleys, and flood plains are used for production and water management [34]. The area's natural water resources, including rivers, canals, and valleys, have long supported a resilient way of life, rooted in ecological and hydrological sustainability.

Despite the rapid urbanization and development pressures faced by Dhaka, these traditional settlements in

the periphery maintain a harmonious relationship with the natural landscape. Their integration with the local environment supports a unique cultural identity and provides valuable insights for modern urban planning. Investigating these traditional water-sensitive settings can

uncover lessons for contemporary urban development, particularly in managing water resources, enhancing ecological balance, and fostering sustainable living environments.



**Figure 2.** Seasonally flooded lowland converted to agricultural land near major water networks of peripheral areas of DMA

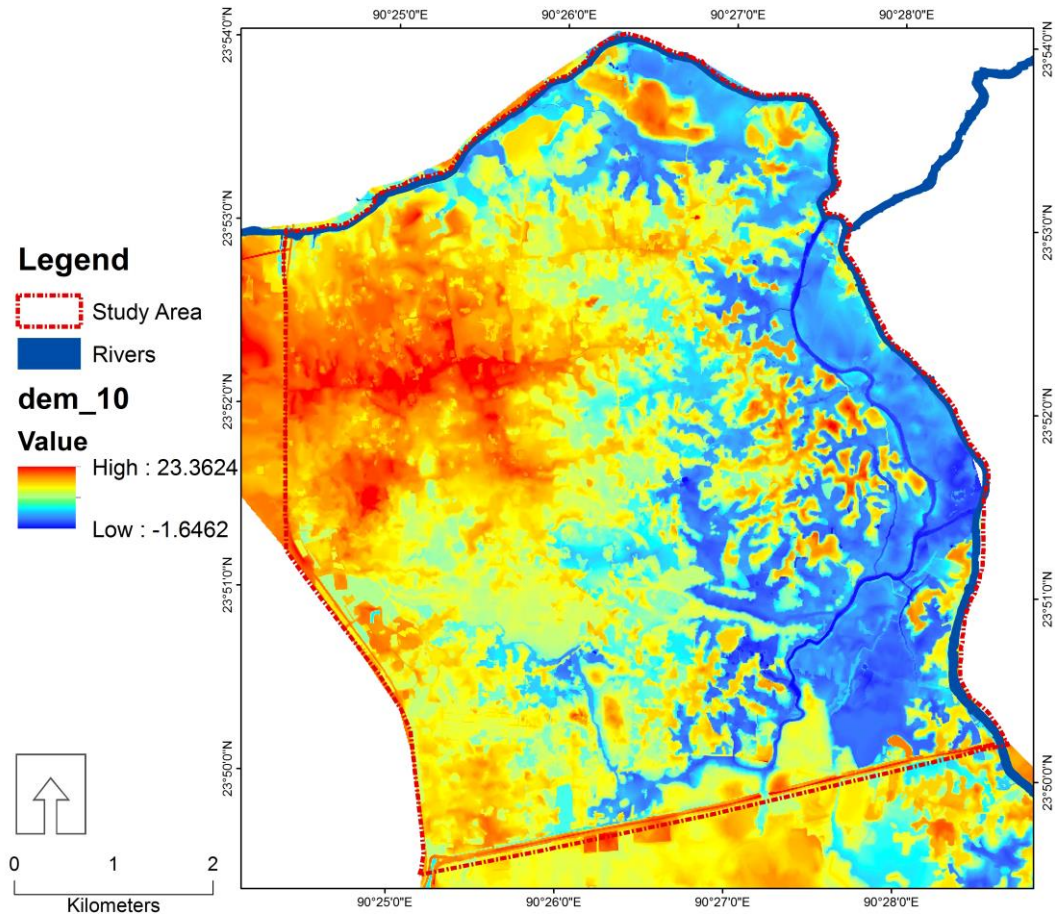


Figure 3. DEM (Digital Elevation Model) of the upper extern peripheral area of DMA

#### 4. Physiographic Landscape Elements for Land-Water Interface Analysis

Physiographic landscapes encompass the physical features of the earth's surface, which significantly influence hydrology, soil properties, vegetation patterns, and climate. On the other side, the land-water interface, sometimes referred to as a riparian region, is a linear system that extends along the length of water bodies [35], [36]. This narrow strip of land controls hydrological and biological processes in streams through its vegetation, soils, and terrain [35], [37]. The physiographic characteristics in the land-water interface play a pivotal role in water flow, storage, and distribution, particularly where terrestrial and aquatic ecosystems converge. The land-water interface has a crucial role in regulating water flow, particularly during floods, which is the recurring disastrous event of the built environment due to climate change, and uncontrolled urbanization. This is achieved by retaining excess water, managing stormwater runoff, and facilitating groundwater recharge through processes like infiltration, evapotranspiration, and water control mechanisms.

The general patterns and evolution of land-water landscapes is a continuous process shaped by factors such as regional geology, hydrology, soil type, land use,

agricultural practices, biodiversity, and climate [38], [39]. Water, as a key morphogenetic agent, plays a significant role in shaping these landscapes [40]. Numerous topographic and geomorphic elements contribute to the hydrological dynamics of the land-water interface. These include the width, length, and slope of water edges; landforms and surface quality; the channel network; meanders; soil quality and permeability; vegetation diversity; and watercourses like lakes, pools, and wetland ponds [41], [42], [43]. Each landscape element performs distinct functions within a given area. Natural water edge acts as a home for many plants and animals, and also retains water in the soil as moisture, as well as in the underground aquifer [44]. Vegetation, in particular, plays a vital role by creating a "sponge effect," reducing surface runoff velocity, promoting groundwater infiltration, minimizing erosion, and stabilizing the water's edge. Permeable network of natural vegetation of land-water interface reduces frequency and intensity of peak flows by increasing surface roughness and by contributing to the storage of water and resistance to flow through vegetation, which also enhances the infiltration and recharge of the groundwater [45]. The large, expanded area in the land-water interface ensures sufficient inundated area during seasonal variation to store water for stormwater management, flood detention as well as for reproduction or

feeding of aquatic lives [46], [47]. Together, these elements help regulate surface runoff and moderate flood risks. Furthermore, it is also important to note that edge of the water such as the soil and vegetation plays a role in water purification where nutrients and pollutants intercept surface water before it flows into the waterbody [18], [44]. The slope of the water edge has potential impact on surface runoff velocity and infiltration [48], while plains facilitate infiltration and groundwater recharge. Marshy land-water interfaces support diverse ecosystems, functioning as natural water filters and providing essential habitats. Therefore, the area, width, edge condition, slope gradient, etc. altogether form the distinct physiographic physical characteristics of the land-water interface of any regional settings which has been listed below.

**Table 1.** Elements of the Landscape for the Assessment of Physiographic Features at the Land-Water (L-W) Interface

Area of (L-W) Interface	Width of the L-W Interface	Slope gradient and Length	Surface condition and quality	Land division patterns
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The unique characteristics of any given landscape are the result of a complex interplay between man-made features and natural waterbodies, as well as the establishment of landscape infrastructure to support economic, ecological, and hydrological activities [49]. Consequently, any landscape analysis must depend on precise assessment of the layers constituting of that geographical context [50]. Similarly, Tjallingii's Ecological Conditions Strategy [51] emphasized the investigation of hydrology, landform, soil, subsoil, and the water cycle to identify the landscape characters for managing water flow in local landscapes.

Drawing lessons from these approaches and other modern methodologies, this study aims to analyse the land-water interface's physical geography, with a particular emphasis on the landscape elements that define it. These elements capture the key physiographic characteristics that shape the interface and are critical for sustainable land and water management. Table 1 summarizes these important physiographic landscape elements, which form the basis of the investigation. Through a detailed study of these features, it becomes possible to design more resilient and adaptive strategies for land and water use in any regional setting facing urbanization and climate pressures.

## 5. Methodology

The study was conducted in the eastern periphery of the

Dhaka Metropolitan Area (DMA), chosen for its rich natural and traditional landscapes, where indigenous settlements coexist with natural land-water resources. This region is interspersed with numerous natural canals, water bodies, and traditional homesteads. The development pattern reveals that local residents continue to integrate natural water bodies into their settlements, employing landscape practices rooted in local resources to manage the land-water interface. For the purpose of the study, five sample locations, each measuring 1.25 km by 1.25 km, were selected (Figure 4). The selection criteria were based on the presence and distribution of land and water resources and how these elements are integrated into the local settlement patterns. In addition to traditional landscapes, the sample locations included areas impacted by urbanization to assess how development has influenced the natural land-water relationship.

The methodological approach was centred on analysing the land-water interface in each of the selected sample locations. This analysis involved multiple steps, including satellite image analysis, map analysis and interpretation, ArcGIS map and 3D analysis, field observations, photographic survey, discussions with local communities, expert interviews, and secondary data review. In every sample location, the composition and dynamics of the landscape components were carefully examined. The objective was to understand how traditional practices relate to the physiographic features of the land-water interface, taking into account seasonal fluctuations and other influencing factors. To achieve this, the study analysed key attributes of the land-water interface, such as area, width, slope gradient, slope length, surface quality, and meanders. These features were examined with respect to two distinct seasonal periods: the rainy season (monsoon) from April to October, and the dry season (summer) from November to January. Several data like, land use, google earth imagery, digital elevation model (DEM), metropolitan survey (MS) mouza maps, and revisional survey (RS) mouza map were generated and collected to conduct the detailed analysis.

Through this comprehensive methodology, the study aimed to generate an in-depth understanding of the interaction between traditional landscape practices and the physical geography of the land-water interface. By employing a combination of geospatial analysis tools such as ArcGIS, along with field-based observations and community input, the research sought to capture the intricate relationships that define the seasonal dynamics and land-water interactions in this deltaic region.

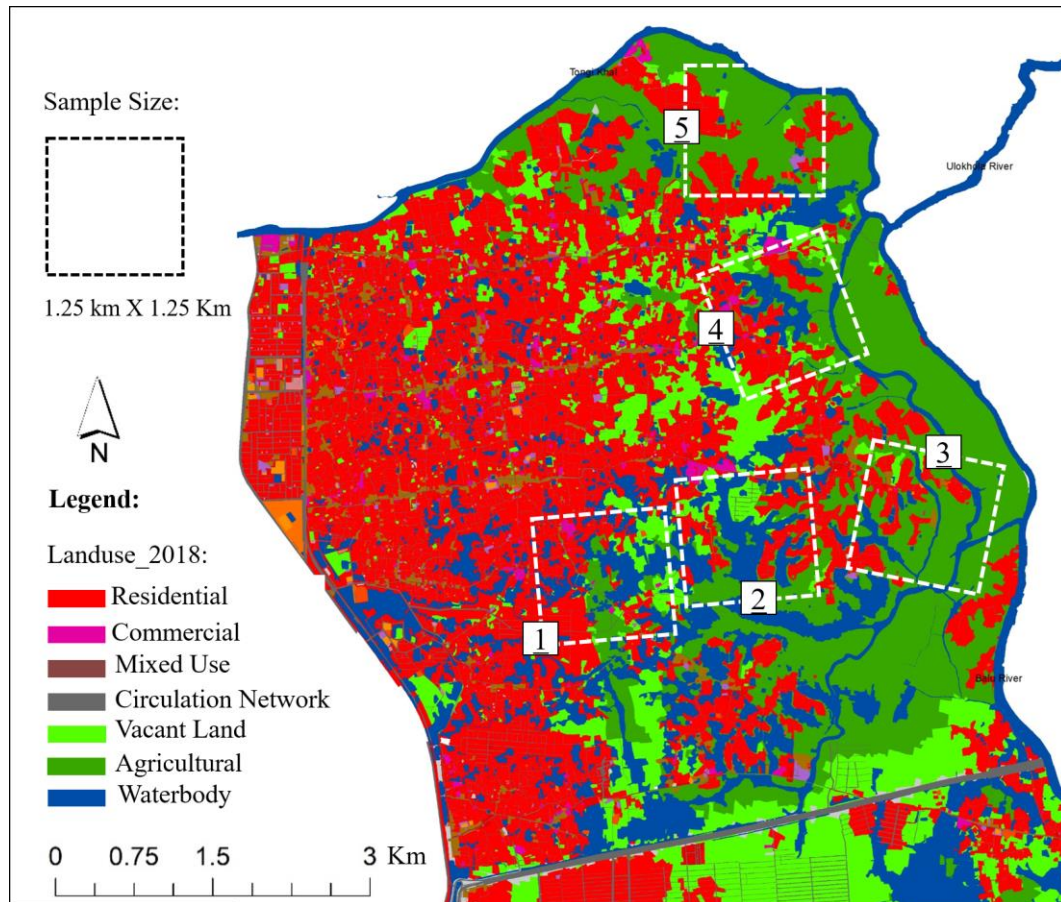


Figure 4. Selected samples from the study area

## 6. Land-water Interface of Eastern Periphery of Dhaka

The primary objective of this research paper is to explain the logic and interplay of the processes and patterns that local physiographic landscape elements use to perform hydro-ecological functions. The characteristics of physiographic landscape elements in each sample location of the research areas are examined, taking into account seasonal variations. Additionally, all the pattern, process, and landscape elements are evaluated together with locational particulars. This technique aids in understanding the fundamental elements that led to the establishment of local practices for landscape element formation, which impacts the integration of settlements and natural land-water resources. The following section provides a more detailed explanation.

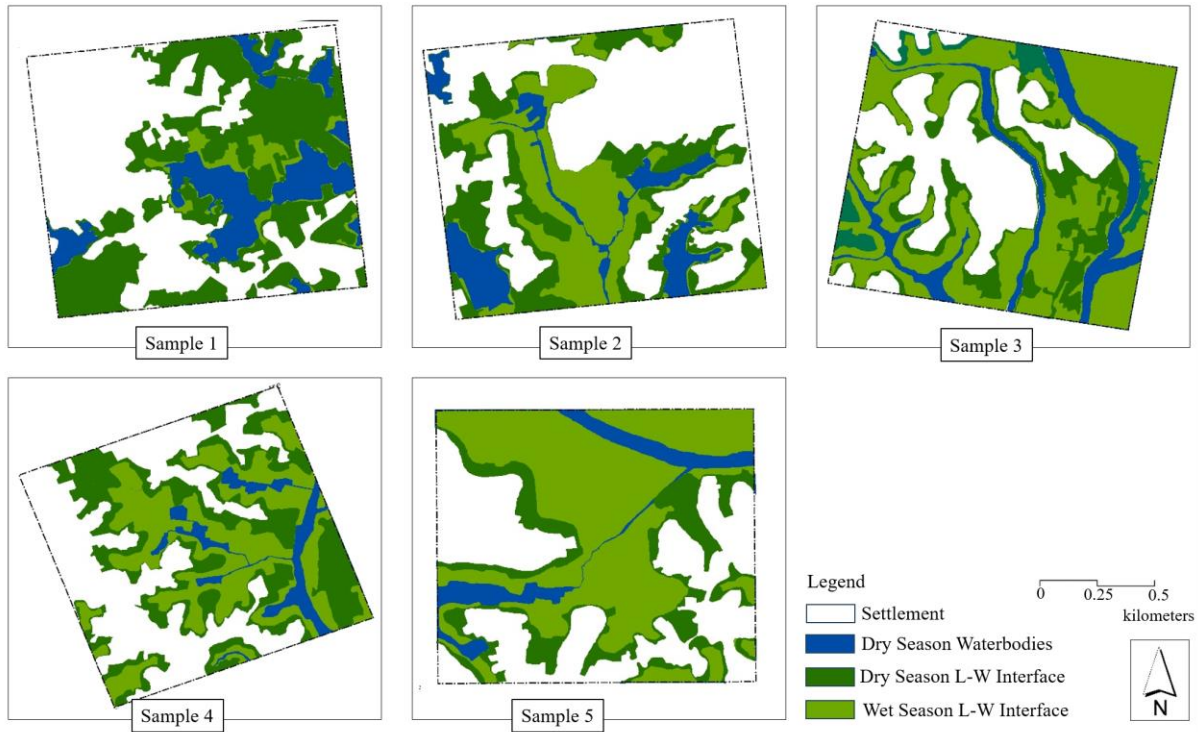
### 6.1. Area of Land-Water Interface

The seasonal fluctuation of water levels significantly impacts the land-water interface, requiring careful monitoring of the highest and lowest water levels to understand the full extent of this variation. In tropical regions like this, two primary seasons—summer and monsoon—play a major role in altering water volume, which directly influences the land-water relationship.

These seasonal changes create dynamic conditions that shape the landscape and its usage.

Through map analysis (Figure 5), it becomes evident that the land-water interface area experiences significant shifts between seasons for most samples, with only one exception. During the dry season, the interface area tends to expand considerably. According to the data presented in Table 2 and Figure 5, two sample pairs display similar trends in area fluctuation across seasons. In some instances, the interface area nearly doubles in the dry season, particularly in lowlands and marshlands where narrow canals persist, shrinking the waterbodies during this period. However, during the monsoon season, these lowlands and marshes transform into vast water expanses, drastically reducing the land-water interface to a minimal area of higher, flood-free land.

For certain samples, the land-water interface increases by over 250% in the dry season (Table 2), especially in areas where waterbodies such as rivers and nearby lowlands are more prominent. Traditional settlements in these regions show a greater sensitivity to the natural water flow, leaving a larger buffer zone between the land and waterbodies. This indicates a deep awareness of the hydro-ecological functions of the natural water edge, as these communities have historically adapted to the natural rhythms of the water cycle.



**Figure 5.** The land-water interface area in the sample locations for both the dry and monsoon seasons

**Table 2.** Area (in acre) of the land-water interface during the dry and monsoon seasons, together with the percentage increase due to seasonal change

Seasons/Samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Wet Season Area (acre)	135.97	76.49	65.65	104.61	61.39
Dry Season Area (acre)	148.92	159.19	218.22	209.02	224.54
Area Increase by % (dry season)	9.5%	92.5%	232.4%	99.8%	265.8%

The natural fluctuation of water levels in the study area is reflected in the changing land-water interface, which also allows for more diverse land use during the dry season, including agricultural activities (Figure 6). This seasonal variation in the interface provides fertile ground for different types of crops and landscape features. However, in one sample where urbanization has replaced traditional rural settlements, the seasonal variation in the interface area is negligible, highlighting how development can disrupt the natural relationship between land and water.



**Figure 6.** Expandable area of the land-water interface within the study area are used for diversified land use with seasonal variation

### 6.2. Width of Land-Water Interface

The width or breadth of the land-water interface,

measured laterally from the settlement perimeter to the water's edge, plays a crucial role in maintaining the health and quality of nearby waterbodies. It is a key factor in controlling pollutants and ensuring the watercourse remains ecologically viable [52]. The width of this buffer zone varies depending on the type of waterbody, and seasonal changes further influence these dimensions. The samples analyzed in this study represent different types of waterbodies, and the land-water interface widths vary accordingly.

The analysis reveals that the interface width experiences significant seasonal fluctuations. Throughout the wet months, the width of the land-water interface across the samples ranges from a minimum of 15 meters to a maximum of 200 meters, while in the dry months, it expands significantly, varying from 20 meters to approximately 530 meters (Figure 7). This variation is particularly pronounced in areas adjacent to flowing waterbodies such as rivers. The graph in Figure 7 highlights that these wider and more variable interface widths are found in samples close to rivers, where the natural flow of water contributes to the dynamic interface

changes. In contrast, the samples that feature wetlands or marshlands exhibit high interface widths as well, but the seasonal variations are less pronounced compared to river-adjacent areas.

The long, variable widths of the land-water interface serve multiple purposes, particularly in supporting agricultural activities during the dry season. The seasonal shifts in interface width not only reflect the topographical dynamics within the land-water interface but also facilitate diverse land uses that are shaped by local practices (Figure 8). These wide buffer zones, enriched by hydrological features, moisture content, and soil quality, allow for a dynamic use of the landscape throughout the year. This diversity is most visible in areas where traditional land management practices have remained intact.

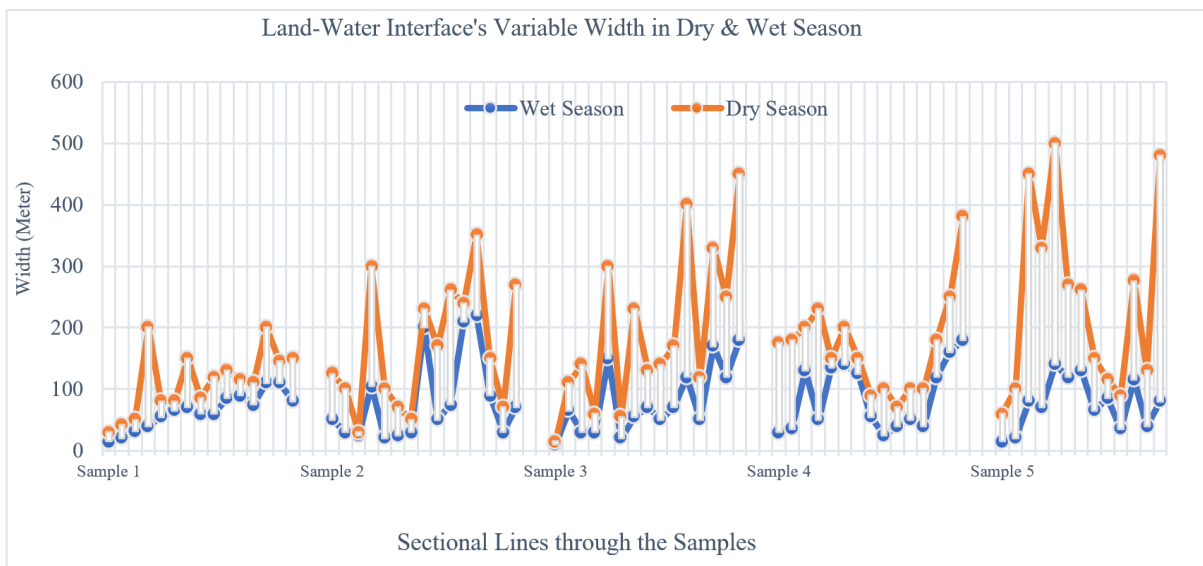
Among the five samples analyzed, sample 1 stands out for its narrower interface width, with less significant differences between the wet and dry seasons. This reduced variation is attributed to increased built-up areas and landfilling, that have transformed the natural topography. Therefore, the long, varied land-water interfaces that are typically associated with landscape diversity are less evident in this area, indicating the impact of urbanization on natural land-water dynamics.

### 6.3. Slope Gradient and Length

The slope gradient of the land-water interface impacts the rate of water flow, which is also contributing to the retention of nutrients and sedimentation [53]. A steeper slope increases the velocity of water, reducing the time available for nutrients, pollutants, and sediments to be trapped within the buffer zone. Additionally, factors such

as floodwater retention, agricultural activities dependent on water levels, and the capture of pollutants are closely tied to the slope's length and gradient, from the upland areas down to the water's edge [54]. As the slope becomes steeper, the effectiveness of the land-water interface as a buffer diminishes, since overland flow moves more rapidly. Research indicates that steep slopes, typically defined as gradients greater than 1:10 (10%) to 1:2.5 (40%), provide limited value for buffering and contaminant filtration [55], [56].

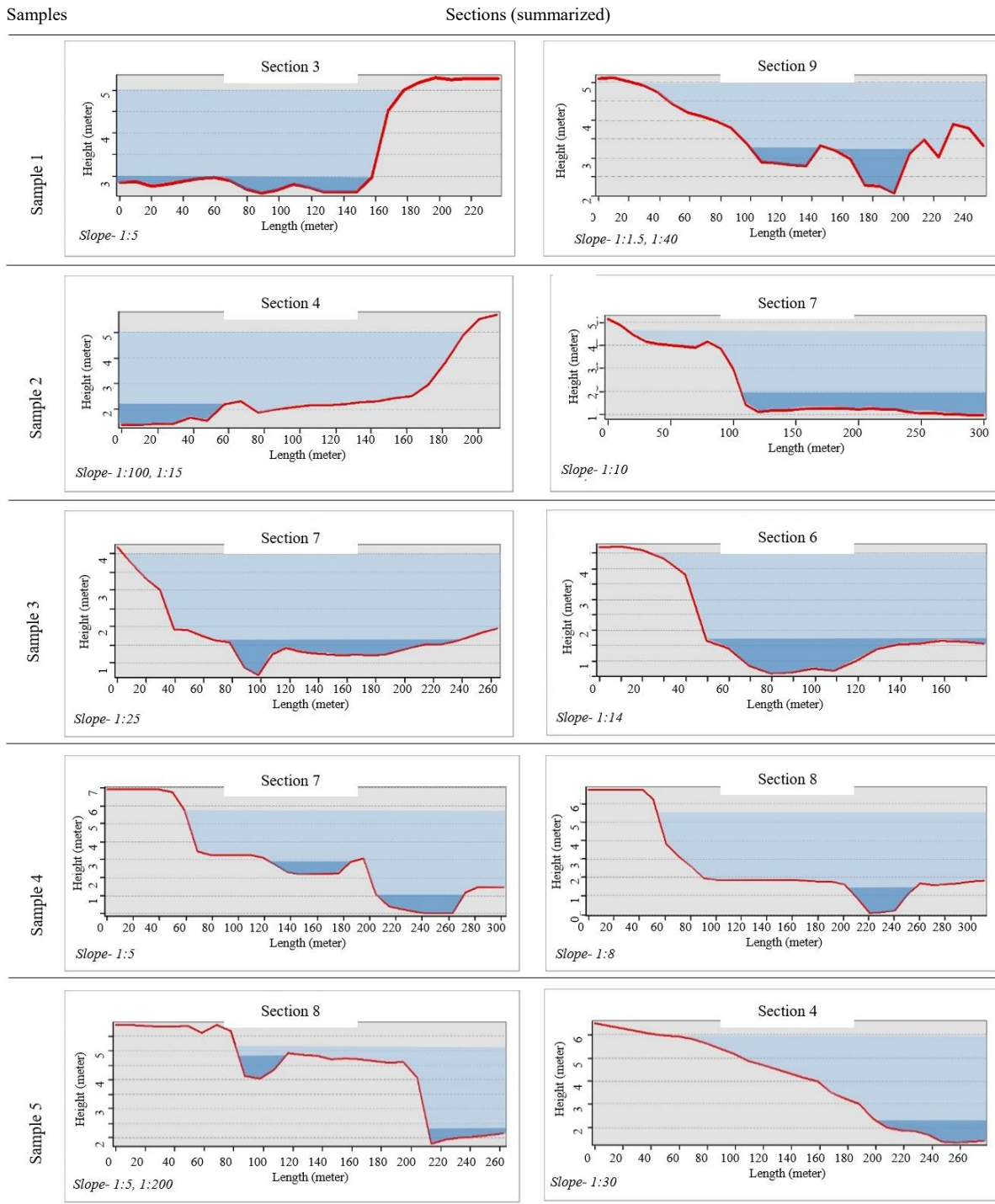
To assess the slope inclination and length for this study, 10 sectional lines were drawn through each sample, crossing the settlement, land-water interface, and waterbodies. These sectional lines were generated using a Digital Elevation Model (DEM) with a 10-meter resolution in ArcGIS 10.3. The summarized results are illustrated in Figure 9. Based on the sectional graphs (Figure 9), it was found that more than 30 of the 50 sections analyzed have slope gradients between 1:15 and 1:20 (5% to 7% and below). A few sections exhibit steep slopes, while others display very mild slopes. Steep slopes, with gradients of 1:10 or more (10% and above), are mainly observed in sample 1, where traditional landscapes have been altered due to built-up areas and landfills. Steeper slopes are also observed in areas where abrupt depressions, such as pools or ponds, exist within the land-water interface. In contrast, samples with extensive riparian buffers in proximity to significant rivers and natural waterbodies had relatively moderate slopes, such 1:100 (1% or less). These findings suggest that traditional processes (Figure 10) did not disturb the natural slope patterns, instead utilizing them for agricultural purposes.



**Figure 7.** Land-water interface's width and their seasonal differences among the samples



**Figure 8.** The width of the traditional land-water interface changes with the seasonal variations and accommodate various activities along its edge



**Figure 9.** Slope gradient and topographical condition of water edge through sectional lines of Samples



**Figure 10.** Slope of the water edge exists variably

In addition to slope ratio, the length of the slope also affects water quality in nearby waterbodies. Sediment trapping, nutrient retention, and moisture conservation are all influenced by the length of the slope in relation to its gradient. Approximately 50% of the study area's slopes range in length from 20 to 30 meters. Aside from a small proportion with shorter slopes (10 to 12 meters), most of the samples feature extensive slopes, varying from 150 to 600 meters in length. These longer slopes, especially in areas with natural water resources, support diverse landscape practices and contribute to the ecological functions of the land-water interface.

#### 6.4. Surface Roughness

Surface characteristics such as coarse woody debris, rocks, boulders, vegetation, and other micro-roughness elements play a crucial role in shaping overland flow patterns [57]. These elements influence the water content, moisture penetration and the ability to prevent polluting particles from draining to the neighboring water sources. The roughness of the surface can also influence the effectiveness of the buffer zone between land and water. During field surveys, it was observed that most of the samples exhibited substantial surface roughness within the land-water interface. The water edge buffer zones are characterized by soft, permeable surfaces with natural vegetation, undulating topography, and areas of depression.

Local residents utilize diverse agricultural strategies along the land-water interface, depending upon soil quality and seasonal variations. The land supports a wide range of crops and vegetation, including tree cultivation, highland crops, fruit trees, vegetation crops, paddy crops, herbaceous crops, and perennial wetland features like beels and haors. These activities contribute to varying levels of surface roughness, which in turn create diverse landscape patterns. The field survey, conducted across different seasons, provided evidence of surface roughness due to these agricultural and landscape variations (Figure 11).

The terrain within the interface does not exhibit a uniform slope toward the waterbodies, which helps slow down surface runoff, enhances moisture retention in the soil, and facilitates pollutant trapping.



**Figure 11.** Surface roughness of the water edge with diversifies greeneries

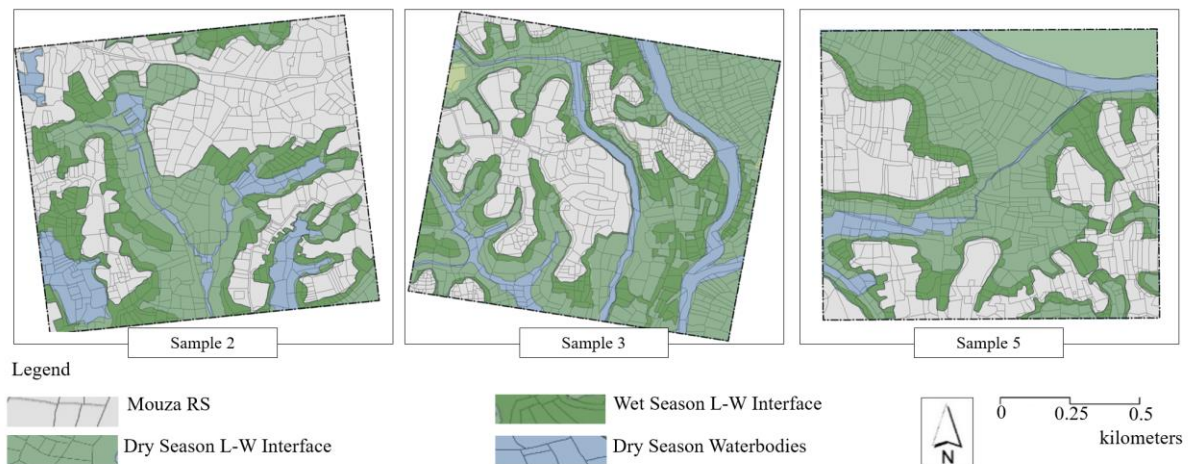
These irregular landforms and vegetation patterns also play a critical role in supporting diverse agricultural activities, each requiring specific moisture levels. By interrupting the flow of water, the surface roughness helps maintain soil moisture, making the land-water interface more resilient and productive. In essence, the interaction between surface roughness and agricultural practices ensures that the interface remains a dynamic and multifunctional landscape capable of adapting to environmental changes and sustaining local livelihoods.

#### 6.5. Land Partition Configuration

The survey and mapping indicate that indigenous people have traditionally constructed their homesteads in a strategic and systematic manner, selecting high-elevated, flat land that is naturally flood-free. The sloped areas of the land-water interface are left undeveloped and are used primarily for natural landscapes, often dedicated to agricultural purposes. These communities manage the interface areas by utilizing the varying topographical layers for different types of production. The exposure of the land-water interface fluctuates with the topographical elevation, and locals adapt their land use practices accordingly. Ownership and usage of the land in these areas are reflected in the mouza maps, which document landownership patterns over time (Figure 12).



**Figure 12.** Local land division following on water edge topography



**Figure 13.** Land division pattern of L-W interface in RS Mouza map following the topographic direction

The study examined both RS Mouza and MS Mouza maps to explore how local land division practices have evolved. It became clear through map observations that the division of flat land differs markedly from that of the slopping land-water interface. The demarcations for land partition follow to both the lateral and transverse gradients of the land-water interface, taking into account the natural contours of the landscape. These division lines are not random but rather follow the natural slope angles and directions, showcasing the local wisdom in organizing land ownership and use. Figure 13 provides a visual representation of how the RS Mouza and MS Mouza maps reflect this rational approach to land division, illustrating the harmony between traditional land management and the natural topographical features of the land-water interface.

## 7. Key Physiographic Landscape Elements from the Indigenous Setting

The detailed investigation conducted in this study highlights the rich landscape diversity found within indigenous settlements, particularly in relation to the physiographic characteristics of their land-water interfaces. Key elements such as area, width, slope gradient and length, and the surface condition of the land-water interface exhibit a strong contextual identity, offering valuable insights for sustainable and resilient development practices in deltaic regions. The existence of diverse waterbodies within these settlements ensures hydrological balance in response to climatic fluctuations. Despite the rapid disappearance of these waterbodies in urbanized areas, indigenous communities continue to integrate them into their local practices, relying on traditional knowledge to maintain equilibrium.

The variations in waterbody types contribute to different configurations of the land-water interface, which in turn

affect its area and width. These changes allow for a variety of landscape practices that adapt to moisture levels and land availability across different seasons. For instance, during the monsoon, the expanded interface areas not only enhance rainwater collection but also support a range of agricultural and aquaculture activities. This variability in area and width provides essential hydro-ecological performances to the surrounding built up areas.

The slope gradient of the land-water interface plays a crucial role in regulating stormwater flow, allowing for a gradual rise and fall in water levels prior to and following the rainy season. Gentle slopes help slow the water's movement, retaining moisture in the soil for extended periods and recharging the aquifer. These conditions support diverse agricultural practices that depend on adequate moisture content. Local inhabitants make use of the sloped water edges through indigenous methods such as creating stepped terraces and earthen dikes for crop cultivation.

Additionally, the surface roughness in these areas is largely absorptive, promoting water infiltration into the subsoil, reducing surface runoff, and maintaining moisture levels in the soil. These factors contribute to essential ecosystem services, supporting a water-sensitive built environment. The combination of these physiographic attributes—area, width, slope, and surface roughness—demonstrates the hydro-ecological potential of indigenous land-water interfaces, offering a model for sustainable urban development.

Based on these findings, the study identifies several landscape elements that needed be incorporated into a comprehensive landscape framework for future planning and development of the urban water edge. These elements leverage the natural features and traditional practices observed in indigenous settlements to promote sustainable, water-sensitive environments.

- **Physiographic Landscape Element 1:** A natural, wide, and variable land-water interface is crucial for

ecological balance and hydrological stability (Table 3). To preserve this local hydro-ecological process, it is important to incorporate the local landform characteristics into designing of the water edge's shape.

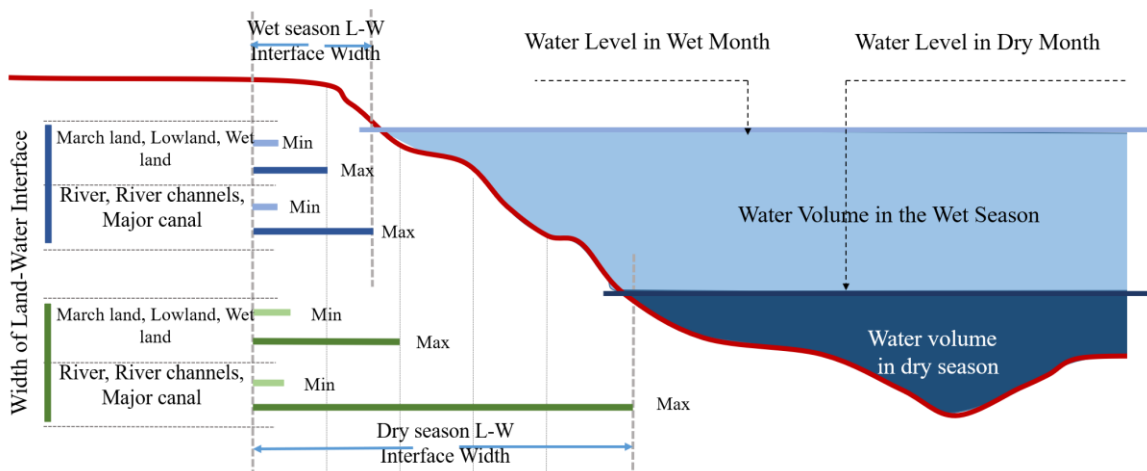
- **Physiographic Landscape Element 2:** The area of the land-water interface should exhibit variability, with the capacity to expand between 100% and 200% in response to seasonal changes and the typologies of waterbodies present (Table 3, Figure 14). Due to higher volume of water in the wet months and the productive landscape in the dry months, there are the need for adequate space in the water edge after

assessing the hydrological characteristic of that region. The water management authority of the city should refer to such landscape criteria for solving the problems of flooding.

- **Physiographic Landscape Element 3:** The width of the land-water interface needs to have the ability to variably proportionally to between 20m and 500m depending on the type of water bodies involved as shown in Table 3 & Figure 14 below. The width of the land-water interface needs to have the ability to variably proportionally to between 20m and 500m depending on the type of water bodies involved as shown in Table & Figure below.

**Table 3.** Space for water in the land-water interface through variable area and width

Types of Waterbodies and Seasons	Lowland, Marsh land, Wet land		River, Branches of river, Major canal	
	Wet Season	Dry Season	Wet Season	Dry Season
Width of L-W Interface	Min- 20 m	Min- 30 m	Min- 15m	Min- 15m
	Max- 100 m	Max- 200 m	Max-150m	Max- 500m
Area of L-W Interface increased in dry season	Increased by 100%		Increased by 200%	



**Figure 14.** Adjustable land-water interface width for seasonal fluctuation

- **Physiographic Landscape Element 4:** The slope gradient of the land-water interface should be adaptable, ranging from 1:20 to 1:100 to accommodate different ecological contexts (Figure 15). To mitigate surface runoff, enhance soil moisture content, and improve water infiltration, the city's water management authority should incorporate these landscape features for controlling water-related problems of the locality.
- **Physiographic Landscape Element 5:** The slope length typically should measure around 30 meters, with potential extensions reaching up to 500 meters in certain segments, allowing for diverse hydrological functions (Figure 15).
- **Physiographic Landscape Element 6:** The surface characteristics of the land-water interface should predominantly soft, uneven, non-structural, and porous, facilitating effective moisture retention and infiltration in most scenarios.
- **Physiographic Landscape Element 7:** The land partition configuration within the land-water interface should adhere to traditional Indigenous practices, ensuring a culturally sensitive approach to land use and management (Figure 16).

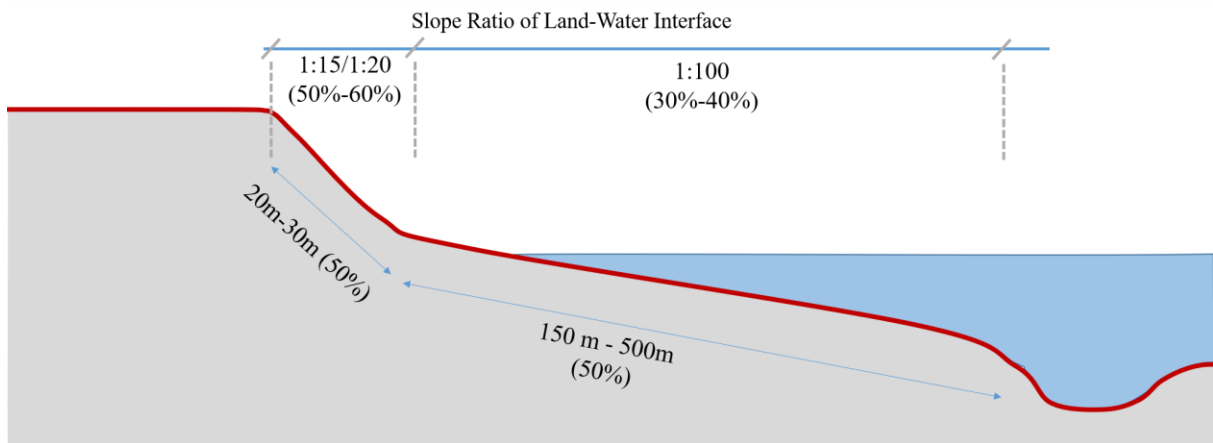


Figure 15. Slope gradient through the land-water interface

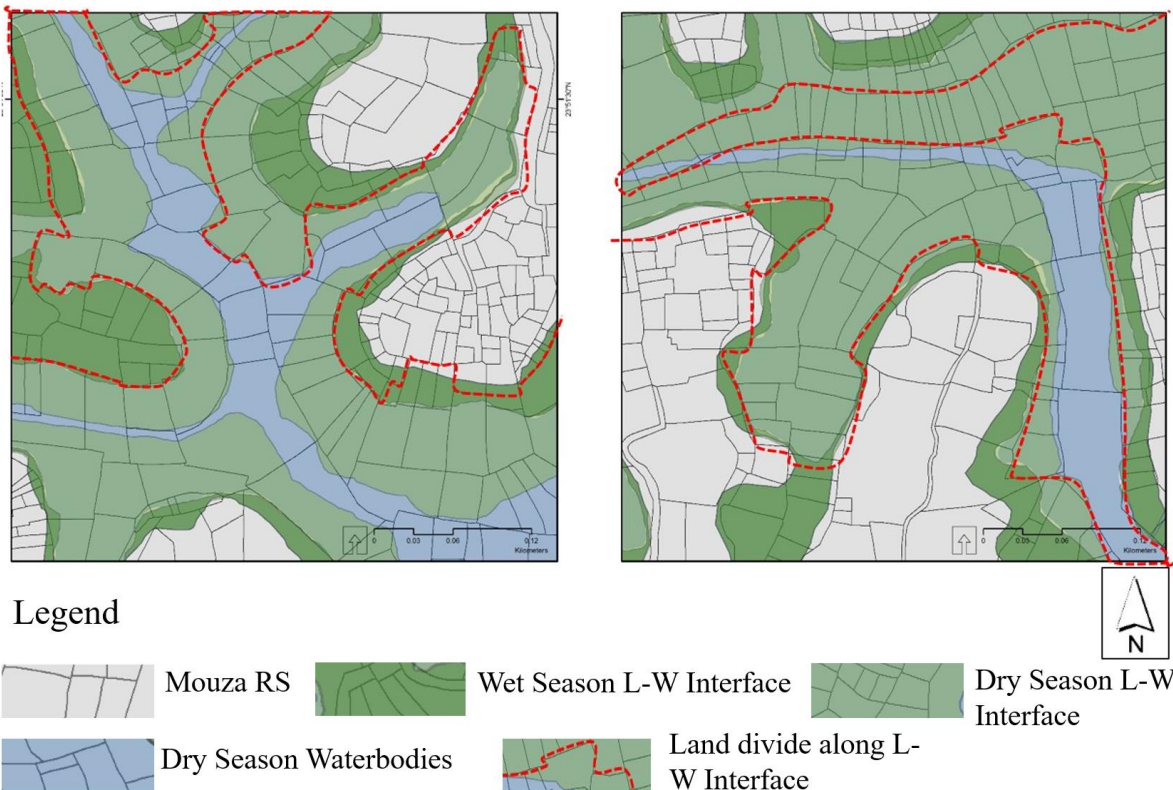


Figure 16. Land partition configuration following the slope direction

## 8. Conclusions

The study underscores the critical role of indigenous land-water interfaces in shaping sustainable urban development, particularly in water-sensitive regions like Dhaka. By examining the traditional settlements in the Eastern Periphery of the Dhaka Metropolitan Area, the research highlights how these communities have historically integrated natural waterbodies into their physiographical landscapes for various functional, ecological, and cultural purposes. The findings reveal that these practices contribute to effective water management, flood resilience, and biodiversity conservation. In contrast, modern urban expansion often disrupts these natural systems, leading to increased environmental degradation and vulnerability to water-related issues. Incorporating traditional knowledge and practices into contemporary urban design offers a pathway to create resilient and sustainable cities. The study advocates for the preservation and integration of natural physiographical landscapes of land-water interfaces into urban planning to enhance ecological balance, improve water management, and maintain cultural identity. By understanding and applying the principles of traditional settlements, modern urban development can better address current challenges and foster environments that are both sustainable and adaptable to changing climatic conditions. This research provides valuable insights for policymakers, urban planners, and designers aiming to achieve sustainable urban growth while preserving the natural and cultural heritage of water-sensitive regions.

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