Humanities, Society and Community, Vol. 2 No. 1 (2024) https://doi.org/10.31098/hsc.v2i1.2685

Research Paper

Site Suitability Analysis for Provision of Ecosystem Services for Sustainable Waterfront Development

Mazed Parvez[1*], Md Sazzadul Karim[2], A H Md Mahabub Nawaz[3], Syed Tanim Ahmed[4], Faisal M Ahamed[5], Md Fazle Rabby[5], Laila Begum[2]

[1]Pabna University of Science and Technology, Bangladesh
[2]University of Dhaka, Bangladesh
[3]North South University, Bangladesh
[4]Shahjalal University of Science & Technology, Bangladesh
[5]Jahangirnagar University, Bangladesh

Received: September 24, 2024	Revised: October 31, 2024	Accepted: December 3, 2024	Online: December 26, 2024

Abstract

The "area of a town near an area of water, such as a river or the sea" and "the interface between land and water" were two ways to define the urban waterfront. This study aimed to shed light on the pressing issue of management service deficits within canal environments, emphasizing the detrimental consequences of canal encroachment, such as heightened flood vulnerability, dwindling groundwater recharge, and the loss of ecosystems and biodiversity. Based on these issues, the study identified suitable sites for sustainable waterfront development by conducting an in-depth analysis and employing geospatial mapping techniques. The criteria included proximity to water bodies, flora and fauna, urban green space, urban built-up areas, urban fellow land, and road access, and utilized GIS, KII, and community people consultations. The study addressed the practical challenges that the capital cities of Bangladesh and similar cities worldwide face in reconciling the demands of urban development with ecological conservation. The study's aims, new findings, and contributions to the current literature are integral to advancing the discourse on sustainable urban development. Among the 4,316 evaluated locations, 50% were deemed entirely suitable, 37% predominantly suitable, and the remaining locations had lower suitability levels, including 10% slightly acceptable and none moderately suitable. This research provides actionable insights to inform urban planners, policymakers, and researchers on the creation of resilient and competitive urban regions by addressing the urgent need for holistic solutions that balance environmental preservation, social equity, and economic viability.

Keywords: *AHP, GIS, Site Suitability, Ecology and Development, Waterfront*

INTRODUCTION

Sustainability increases business practice by balancing present and future stakeholder requirements in three dimensions: economic, social, and environmental (Sahani, 2023). Waterfronts are the most compelling water features for human development. The waterfront is where the needs of the city and its inhabitants intersect, where urban expansion and the water meet. Waterfront development has encountered various social, economic, and environmental problems due to significant changes in the built environment (Keyvanfar et al., 2018). According to Baumgart et al. (2022), urban waterfronts are shaped by physical, functional, social, economic, cultural, and political factors. Urban waterfronts are crucial to a city's vibrant civic life, economic development, and physical transformation. Physically reified between land and water, regions of temporary gathering and continual dispersion occur. These are the dynamic edges at which people,

Corresponding author's email: parvezpust30@gmail.com

goods, services, and the economy interact (Yocom et al., 2016). The urban waterfront can be considered an essential resource for the community and the environment (Siddika, 2020). The waterfront represents the water's edge in cities and towns. Therefore, it is a place that naturally attracts people because it merges land and water (Ali et al., 2020). An urban waterfront is a town area close to a body of water, such as a river or ocean (Hussein, 2014). According to the notion of sustainable development (Mnini & Ramoroka, 2020; Gu & Liu, 2013), which states that an activity must be socially acceptable, environmentally suitable, and commercially viable, ecotourism has developed into a significant and growing sector (Sahani, 2019a; Mondino & Berry, 2019). Ecosystem activities that benefit people together constitute ecosystem services. The outcomes of auxiliary activities are various spatial and temporal dimensions (Farber et al., 2006). Urban areas benefit significantly from the ecosystem services that marine and freshwater ecosystems offer, such as recreational opportunities, protection from severe storms and coastal hazards, and biodiversity support (Dyson & Yocom, 2014). An integrated and coordinated strategy for waterfront development that prioritizes resiliency, cultural preservation, and social equality (Zaki & Hegazy, 2023).

The riverside must be repaired and rehabilitated using sensible methods to enhance its quality to safeguard the waterfront development process. It would not have been possible to finish the repair and rehabilitation without following these guidelines: Use I general, II planning, III design, and IV execution to identify and achieve the optimal solution for anything. Aim to re-establish connections with the riverfront community while letting nature do its thing (Humaira et al., 2019).

For waterfront development to be sustainable, environmental factors must be considered. Unfortunately, this problem is consistently disregarded in developing countries like Bangladesh. In addition, among the four elements—socioeconomic, urban, environmental, and intelligent—the ecological approach receives the most significant disregard. Nonetheless, the study's primary focus will be on ecological conservation-related issues, leading to environmentally sustainable waterfront development (Saraf & Dobariya, 2020; Siddika, 2020). This research attempts to study the construction of the Sutibhola Canal to resolve its primary issues. There is a substantial amount of habitation all around this waterway. In addition, it is bordered by ecologically significant areas, such as water bodies, flora and fauna, urban fellow land, and green space. There are few lakes in a megacity like Dhaka. Lakes are being destroyed as urbanization progresses. Given these facts, the Sutibhola Canal was chosen as the research region for this study. This study will end the city's ongoing flooding problem, improve communication among waterways, and restore the ecology of the canal.

This paper addressed the management service deficit within canal environments, specifically focusing on the severe consequences of canal encroachment. These consequences encompass heightened flood vulnerability, declining groundwater recharge areas, lowering groundwater levels, failure of natural drainage systems, and loss of local ecology and biodiversity. This research aims to bridge the current gap in sustainable waterfront development by proposing practical solutions by introducing ecosystem services. The existing problem revolves around the neglect of environmental factors, particularly in developing countries like Bangladesh. Waterfront development often overlooks ecological conservation, with the environmental approach receiving the least attention among the four key elements: socioeconomic, urban, environmental, and innovative. By identifying suitable development sites while considering essential criteria such as proximity to water bodies, flora and fauna, green spaces, urban infrastructure, fellow land, and road access, the findings offer valuable insights for policymakers and urban planners. These insights will facilitate the establishment of water-based urban ecotourism, address pollution concerns, and inspire future sustainable developments in Bangladesh and beyond. Urban waterfronts, which were formerly highly prized for development, are now facing issues such as increased flood hazards, reduced groundwater recharge, and biodiversity loss due to unmanaged urbanization. Previous development initiatives prioritized economic and social expansion over environmental sustainability, resulting in infrastructural damage and ecological deterioration. A balanced conservation-focused strategy is needed to guarantee that waterfront development improves urban resilience while protecting natural resources. To bridge the existing gap in sustainable development approaches, this study investigates the following research question: How can sustainable waterfront development practices be designed to prioritize ecological conservation and biodiversity enhancement in Dhaka's Sutibhola Canal region? The research objective of this study is to minimize this gap by focusing on ecological conservation-related issues, ultimately promoting environmentally sustainable waterfront development.

LITERATURE REVIEW

The classic literature review approach was chosen to fulfill the objectives because it allowed for the exploration of concepts, thoughts, and insights from a wide range of relevant literature in numerous disciplines (Gunardi & Meilasari-Sugiana, 2024; Ayu & Agustini, 2024; Thoo et al., 2024). Waterfronts initially received little public interest, but successful revitalizations have refocused attention to these regions (Syahrir, 2021).

By incorporating a Geographic Information System (GIS)-based Multiple-criteria decision analysis (MCDA) approach into a web-based platform, allocating a certain number of urban development zones within a selected perimeter was feasible based on ecosystem services and locational attributes (Grêt-Regamey et al., 2017; Ragheb & EL-Ashmawy, 2020). There are 12 theme layers (Sahani, 2019a), including slope, topographic roughness, vegetation, accessibility to surface and groundwater, elevation, visibility of snow peaks, proximity to settlements, hiking route, climatic compatibility, ecosystem appropriateness, and lake proximity. The weights of several themes were determined using the analytical hierarchy process (AHP) among various MCDA methodologies to identify separate eco-tourism potential zones. Analytic Hierarchical Process (AHP) method geographical evaluation of land is suitable for ecotourism activities on Masirah Island (Mansour et al., 2019). Thirteen criteria were devised to evaluate a site's suitability for ecotourism operations based on literature searches, on-the-ground observations, and fieldwork. This study establishes the requirements to help identify the ecological parameters necessary to build a waterfront using AHP approaches.

Ecotourism management via appropriate zoning should be prioritized in land-use planning. Ecology-based ecotourism includes sustainable waterfront practices. Water is necessary for life and every human activity, so urban areas have constantly developed near water. Towns have sometimes been isolated from water because of the expanding capacity of water sources and changes in social and economic systems. These riparian zones, formerly the boundary between cities and the countryside, have been abandoned in both core and peripheral locations. This is a consequence of the expansion of city waterfronts, which were once in the countryside but are now part of the urban periphery. To control such occurrences, several communities have undertaken initiatives to revitalize vacant land by constructing waterfronts (Fumagalli et al., 2014). Bangladesh is a country with the broadest range of lifestyles. Ecosystem services are the operations of natural systems that, either directly or indirectly, benefit humans or enhance social welfare. Ecosystem services benefit people in several ways, either directly or by being used as materials for producing other goods and services. The benefits that ecosystems provide that make it possible and advantageous for people to survive are known as ecosystem services. Providing goods like food and water, preventing floods, soil erosion, and disease outbreaks, delivering non-material benefits like spiritual and recreational opportunities in natural settings, and enhancing the environment through natural resources are examples of ecosystem services (Turner et al., 2021).

Some of the criteria used in the analysis were: flat landscape slope, high population change of children per block group (standardized), low density of existing parks/recreational facilities, proximity to a water body, small cost-distance to the nearest existing water-based park or splash pads, and proximity to a water body. The resulting raster map was produced for each criterion using ArcMap software. The analytical hierarchy process (AHP) and geographic information system (GIS) were used to identify potential ecotourism spots in the Kullu District of Himachal Pradesh, India. Slope, topographic roughness, vegetation, accessibility to surface water, height, protected area, climate, visibility, road closeness, village proximity, soil, groundwater, and geology are just a few of the 13 variables considered for this research. (Ahmadi et al., 2015) set aside suitable areas in the province of western Iran for the growth of ecotourism. Digital elevation, slope, land cover and usage, mineral springs, and water resource maps were created to perform the necessary initial preparations. While existing studies have employed various methods like MCDA and AHP, this approach combines GIS and F-AHP, providing a more comprehensive assessment of physical, natural, environmental, and socioeconomic factors for ecotourism suitability. In contrast, this study's application of the GIS-based F-AHP approach can be adapted to diverse geographical contexts, making it a versatile tool for identifying suitable ecotourism sites globally. This research bridges the gap between theoretical concepts and practical implementation by addressing the growing demand for ecotourism and sustainable waterfront development. It also emphasizes the importance of prioritizing ecotourism management through land-use planning zoning, offering valuable insights for urban development in various regions worldwide.

Geographic Information Systems theory also provides the foundation for spatial analyses and mapping intrinsic to any sustainable waterfront development process by integrating spatial data layers to assess environmental, social, and economic factors in urban planning (Tobler, 1970; Burrough & McDonnell, 1998). A key concept that GIS purports in general is Tobler's First Law of Geography, which says, "everything is related to everything else, but near things are more related than distant things"; by their nature, GIS is an effective tool for analyzing localized spatial relationships in urban ecosystems (Tobler, 1970). This study also uses systems theory because urban ecosystems are perceived here as interdependent systems where any change in one constituent eventually affects others (Bertalanffy, 1969). Applying this approach within a systems framework of GIS can analyze the interplay of these factors in depth to identify how ecological and urban elements combine to form suitable development zones.

In this respect, the conceptual framework is underlined by ecological conservation principles, which are integrated within sustainable development goals, using GIS as a core analytical tool. These include key environmental, social, and infrastructural variables, including proximity to bodies of water, flora, fauna, and urban infrastructure, which identify sites suitable for waterfront development that balance urban growth with biodiversity conservation (Farber et al., 2006; Dyson & Yocom, 2014). By mapping the spatial relationship between the factors, the framework can provide planners and policymakers with visual insight into development areas where conservation and urban amenity coexist and support a holistic approach in waterfront planning (Zabihi et al., 2020; Sahani, 2019b). This study's framework integrates ecological conservation with the principles of sustainable development, with GIS as the core tool. Based on the analytical framework, the factors of proximity to water bodies, biodiversity, and urban infrastructure pinpoint locations where the growth of urban areas could coexist with ecological preservation. Therefore, it ensures that waterfront planning for biodiversity, sustainability, and community needs goes hand in hand.

RESEARCH METHOD

Study Area

Between 1960 and 2005, Dhaka rapidly expanded, with urban land rising from 11% to 34% by 2005 (Dewan et al., 2006). Bottom-up, demand-driven urbanization modifies the present environment without considering the possible repercussions or the need for environmental sustainability (Ishtiaque et al., 2014). Canals throughout the city formerly connected the rivers that ringed Greater Dhaka (Ahmed, 1986). Nevertheless, the neighboring canals, marshes, and depressions have been filled up as development has increased (Kamal & Midorikawa, 2004; JICA, 1991). The Sutivola Canal located in Badda Thanda Wards 37, 38, and 41, which are part of the Dhaka North City Corporation. The location and the nearby significant buildings led to the selection of this waterway as the research area. This location can be used as an essential recreational center that is open to everyone and is environmentally beneficial.

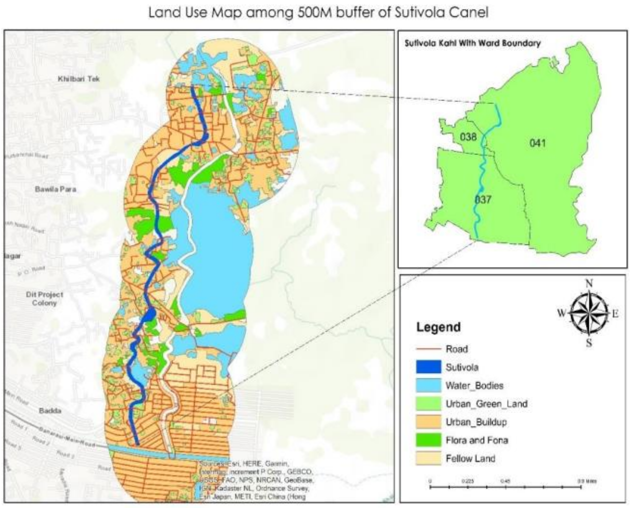

Figure 1. Study Area Map
(Source: Author, 2024)

Methodology

The AHP has not changed because of the use of numbers and numbers derived from numbers to display priorities, the AHP has not changed (Saaty, 1977). To create a list of priorities, we must compare items and create a numerical scale that indicates how essential one item is to another, based on the same criteria or quality. The AHP method evaluates items by contrasting them with one another. A scale of absolute judgments illustrates how much each item is superior to another when comparing two things using a particular method. The derived priority scales were created by dividing them by the priority of their parent nodes and adding all such nodes (Parry et al., 2018). The following steps include integrating the datasets and producing the derived data for further analysis. The data preparation and geographic analysis were performed with the help of ArcMap's spatial analysis extension. The distance to the water edge was calculated using the Euclidean distance computation feature (Ilhamdaniah, 2018). To identify appropriate areas, several investigations have been conducted in the literature (Njiru & Siriba, 2018; Mokarram & Hojati, 2017; Parry et al., 2018; Madurika & Hemakumara, 2017; Zabihi et al., 2020). OWA is a tool to implement these diverse combination concepts. The conditions under which the specific criteria are relevant provide further evidence for this method. MCDA and GIS provide decision-makers with more precise alternatives when assessing the actual components of environmental research

(Parvez, 2020). One of the most thorough techniques used in multi-criteria analysis is ordered weighted averaging (OWA) (Mokarram & Hojati, 2017). This study integrates a geographic information system (GIS) with a fuzzy-analytic hierarchy process (F-AHP) to evaluate the relative value of physical, natural, environmental, and socioeconomic variables for determining the suitability of ecotourism areas (Zabihi et al., 2020). Ilhamdaniah (2018) used a GIS-based suitability study to choose potential locations for building a waterfront park and recreational facility in Buffalo, New York. The final aim of this study was to identify suitable sites for a new waterfront leisure complex using various parameters from a GIS-based suitability analysis. Sridharan (2017) highlighted the significance of leveraging waterfronts for early trade and transportation in developing countries. This article examines the evolution of a notable waterfront region and analyzes the role of water in urban design, offering valuable insights into waterfront development.

Table 1. Arithmetical appearance and corresponding appropriateness scales

Order of importance	Suitability	Arithmetical appearance
Very lower significance	Very little suitable	1
Partial significance of one over another	Partly suitable	3
Mediocre importance or sturdy significance	Moderately suitable	5
High Level of significance	Mostly suitable	7
Very High Level of significance	Optimally suitable	9
	Intermediate values	2,4,6,8

Source: Zabihi et al. (2020)

The consistency of the pairwise comparison matrix is evaluated using a mathematical metric called the consistency ratio (CR).

$$CR = \frac{CI}{RI} \quad (1)$$

The CI is calculated as follows:

CI=

Here, n represents the number of impacts, max denotes the maximum value, and RI is the mean average consistency index (CI). The relevant index should be less than 0.10 to indicate that the AHP is suitable and that consistent results are being produced (Zabihi et al., 2020). The pairwise comparison provided as part of the AHP is employed to apply all the criteria on the fundamental scale. When criteria I and j are combined, criteria I is given the intensity of importance, and criteria j is given the joint value as the passion of rank. Equation (3) is used to calculate the weight of criterion I, which is used in the subsequent analysis for appropriateness analysis after comparing all possible criterion pairs (Parvez & Islam, 2020).

□□ = Σ Pij □□=1 / Σ □ □□=1 Σ P □□=1 □□ (3)

Here, in a pairwise comparison, comparative rank is shown. Comparing norms and criteria Connected to standards (Parry et al., 2018)

The RI cast-off pivots on the sum of the values (Njiru & Siriba, 2018). Here, the total number of variables is 6, which means n=6. From

Table **2**, the result was calculated as RI=1.24.

Table 2. Values of the RI mean average consistency index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

(RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Saaty (1977)

For this research, the literature was initially reviewed based on purpose and six criteria were determined. The six criteria and their weighting were finalized with the consultation of environmental and ecological experts (subject matter experts) to identify a suitable site for a sustainable waterfront that would conserve ecology. The GIS data were created by digitalizing the layers using Google Earth and ArcGIS and finalizing by visiting the site. Satellite image data were collected in August of 2024. Waterbodies, Flora and Fauna, Urban Green Space, Urban Build-up area, Urban Fellow Land, and Roads were determined. Both ecology and human perspectives were considered when considering these criteria. Waterbodies, green space, flora, and fauna were considered to conserve ecology. Fellow land was considered because land acquisition and land development are vital factors for any implementing agencies during the implementation stage. In this urban area, fellow land was considered, and this criterion will prevent the ecology from being disturbed during the construction phase. Finally, urban development and proximity to the road were taken for better communication and access, as the waterfront also has significant value in eco-friendly tourism. **Error! Reference source not found.** presents the criteria and justification for this study.

Table 3. Criteria identification with Justification

Criteria	Justification of the standards	Raw data	Derived data
Waterbodies	To accommodate the waterfront, the placement of the Waterfront should ideally be near the water (Sutivora lakefront)	Polygon data of Sutivora Lake, Ponds, and Lakes Around 500 m Buffer Around the Lake	Euclidean distance from Waterbodies
Flora and Fauna	The waterfront should preferably be located close to the Flora and Fauna to accommodate it (Sutivora Lakefront).	Polygon data of Flora and Fauna Around 500 m Buffer Around the Lake	Euclidean distance from Flora and Fauna
Urban Green Space	The waterfront should ideally be near the Green Space (Sutivora lakefront) to accommodate the waterfront.	Polygon data of Green Space Around 500 m Buffer Around the Lake	Euclidean distance from Green Space
Urban Buildup area	To accommodate the waterfront, the placement of the Waterfront should ideally be near the Buildup area (Sutivora	Human Settlement data Around 500 m Buffer Around the Lake	Euclidean distance from the Buildup area
Urban Fellow Land	The waterfront should ideally be near the Urban Fellow Land (Sutivora lakefront) to accommodate it.	Polygon data of Fellow Land Around 500 m Buffer Around the Lake	Euclidean distance from Fellow Land
Road	The Waterfront should ideally be near the Roads (Sutivora lakefront) to accommodate the waterfront.	Polyline Road Data is located 500 m around Sutivora Khal.	Euclidean distance from Road

Source: (Author, 2024)

The following Source: (Author, 2024)
illustrates the Methodological Framework of the Study. In the first stage of this research, data were sourced from data.humdata.org and then updated and corrected for accuracy and relevance.

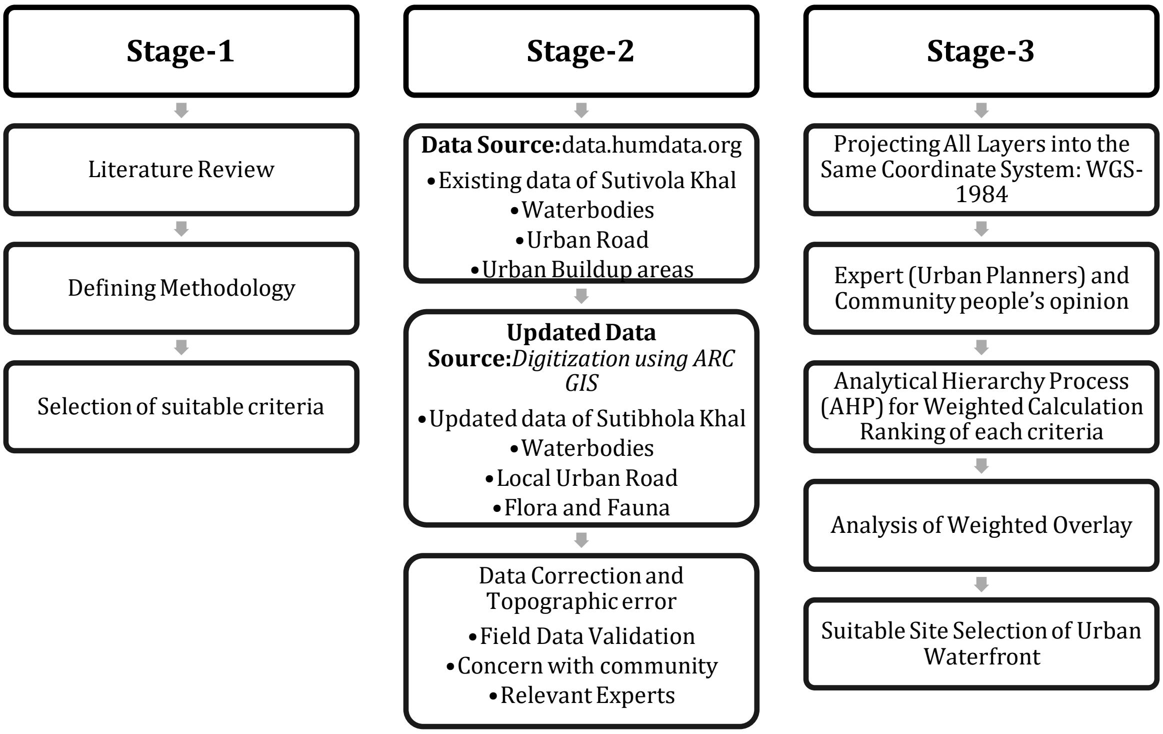

Figure 2. Methodological Framework of the Study
Source: (Author, 2024)

This involved digitizing the data using ARC GIS and addressing the topological errors to ensure the reliability of the information. The data categories included Sutibhola Khal, waterbodies, urban roads, urban build-up, flora and fauna, fellow land, and urban green spaces. The data were validated by field experts and the local community to confirm its accuracy. In the second stage, all data layers were projected into the same coordinate system, WGS-1984, to ensure consistency and compatibility. This stage also involved gathering opinions from urban planners and community members to understand their perspectives. The Analytical Hierarchy Process (AHP) was employed to calculate weighted rankings for each criterion considering the input from experts and the community. This process allowed for a comprehensive weighted overlay analysis that considered various factors and stakeholders. Finally, in the third stage, the research aimed to identify suitable sites for urban waterfront development. Combining the insights gained from data correction, expert and community input, and AHP rankings, this study aimed to provide a robust framework for selecting the most suitable sites for urban waterfront projects. This multi-stage approach ensures that site selection is based on a thorough and inclusive assessment, contributing to more informed urban planning and development decision-making.

FINDINGS AND DISCUSSION

A recent analysis revealed that several training locations are low-lying, somewhat favorable for urban growth, or very suitable. The linear aggregate technique's final suitability map displayed areas with distinct potential for urban expansion scored from one to five (Mohammed et al., 2016). As shown in Table 1, all layers are inputs to overlay, standardizing them into a scale of one to 5, with 5 being the most advantageous. Using the helpful arc-GIS weighted

Table **2**, each input raster was improved by applying a distinct weight. After categorizing all input raster layers into five suitability categories, all input raster layers were combined to form a suitability map in Table 4. The following are the projected weights for the study of

Table **5**, which is based on several weight calculations.

Table 4. Pair-wise assessment matrixes for considered standards weights for the study

Standards for Suitability	Proximity to urban Green Space	Proximity to Flora and Fauna	Waterbodies	Urban Build-up area	Urban Fellow Land	Proximity to Road	Weight Value
Proximity to Urban Green Space	0.4730	0.8050	0.6110	0.1810	0.2150	0.1670	0.4080
Proximity to Flora and Fauna	0.0531	0.0891	0.2620	0.3032	0.1280	0.1670	0.1670
Waterbodies	0.0670	0.0292	0.0880	0.4231	0.3860	0.2770	0.2110
Urban Build-up area	0.1572	0.0183	0.0130	0.0612	0.2140	0.1670	0.1060
Urban Fellow Land	0.0940	0.0294	0.0090	0.0130	0.0430	0.1670	0.0590
Proximity to Road	0.1561	0.0292	0.0170	0.0190	0.0140	0.0550	0.0490
Sum	1	1	1	1	1	1	1

Source: Author, 2024.

Table 5. Projected weights for the study

Criteria of Suitability	Proximity to urban Green Space	Proximity to Flora and Fauna	Waterbodies	Urban Build-up area	Urban Fellow Land	Proximity to Road
Proximity to urban Green Space	1	09	07	03	05	03
Proximity to Flora and Fauna	0.11	1	03	05	03	03
Waterbodies	0.14	0.33	01	07	09	05
Urban Build-up area	0.33	0.2	0.14	1	05	03
Urban Fellow Land	0.2	0.33	0.11	0.2	1	3
Proximity to Road	0.33	0.33	0.2	0.33	0.33	1

Sum	2.11	11.19	11.45	16.53	23.33	018

Source: (Author, 2024)

Table 6. Projected calculated AHP weighted effect

Standards for Suitability	Impact of weight on AHP (%)
Urban Green Space	41
Proximity Flora and Fauna	17
Waterbodies	22
Urban Build-up area	10
Urban Fellow Land	5
Proximity to Road	5

Source: Author, 2024

The map of site suitability for. **Error! Reference source not found.** shows the proximity to roads, water bodies, urban green space, urban build-up areas, urban fellow land, and proximity to flora and fauna. The Euclidean distance is determined for each example after a 500-m buffer, and the site is then categorized as the most appropriate or least suitable spot. A few areas on the map are considered acceptable for a potential sustainable waterfront, with most locations deemed unsuitable.

After integrating all maps, the entire coverage was published. The most significant places are those where a sustainable waterfront can readily grow and have all the amenities needed, including open enterprises and genuine land use. Some utilities, such as water supply, drainage, road networks, and changes in land use, are absent from less perfect and highly suited areas. There were 123 very few acceptable locations, 433 somewhat suitable sites, none moderately suitable, 1638 generally suitable sites, and 2122 very suitable sites in that order in Table 6 and

Table **7**. 10% of the 4316 places evaluated were considered just slightly acceptable, 10% somewhat appropriate, 0% moderately suitable, 37% predominantly suitable, and 50% entirely suitable.

Table 7. Sustainable Location Summary

Suitability levels	Number	%
Very Little Suitability	123	3
Partly Suitability	433	10
Mostly Suitability	1638	37
Optimally Suitability	2122	50

Source: Author, 2024

Creating a vision for an area, using skills and resources to make that vision a reality, and involving local consumers are all components of sustainable waterfront development. Creating places with distinctive identities and esthetic appeal also incorporates several policymaking strands, such as environmental responsibility, social equity, economic viability, planning, transportation, and architectural design. Waterfront development shapes the communities surrounding water bodies and demonstrates how effectively a city can adapt to shifting economic and social situations. To appropriately integrate human activities and agglomerations into the area's deteriorating and increasingly dangerous environment, it is imperative to enhance waterfront areas. Sustainable waterfront development may also improve local cities and regions' chances of competing globally.

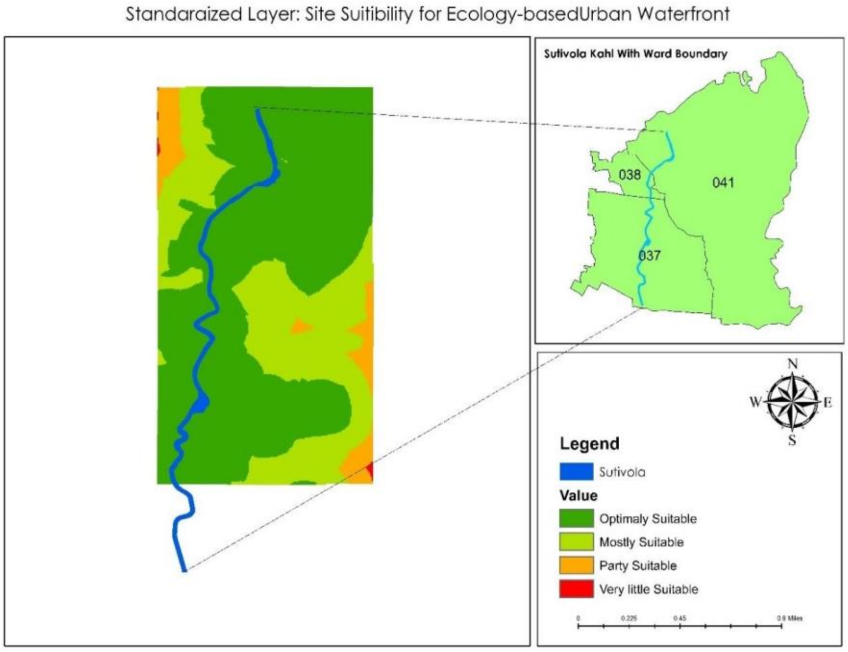

Figure 3. Standardized Layers for the Study
Source: (Author, 2024)

The results and discussion of this study on the Sutibhola Canal in Dhaka provide deep insights into the dynamics of urban waterfront development and its challenges. The results reveal a complex picture of potential and caution. Approximately 50% of the evaluated areas are highly suitable for sustainable waterfront development, offering a substantial opportunity to create environmentally harmonious and beneficial urban spaces. These findings suggest the strong potential for developing these areas in a way that balances urban growth with ecological sensitivity. However, the study also highlights areas of concern. Notably, approximately 3% of the regions are deficient in developmental suitability, highlighting the need for stringent conservation efforts in these regions. This is a crucial insight, underscoring the importance of preserving natural habitats and biodiversity in urban planning. Additionally, 37% of the areas are moderately suitable for development, indicating that they could be viable for sustainable projects with appropriate planning and interventions. The remaining 10% of partly suitable areas require more intensive management and strategic foresight to ensure that development does not compromise ecological integrity. Figure 4 shows urban build-up suitability in Sulibhola Khal, with color-coded zones ranging from highly suitable (green) to very unsuitable (red). The main map depicts urban areas in pink surrounded by varying suitability zones, while the inset map outlines specific wards. The Euclidean distance from urban areas affects suitability. Figure 5 shows the suitability of fallow land in Sulibhola Khal, with zones labeled from suitable (dark blue, value 1) to not suitable (light colors, value 5). The main map indicates fallow land areas with varying suitability, while the inset displays specific ward boundaries. The Euclidean distance from fallow land affects the suitability level.

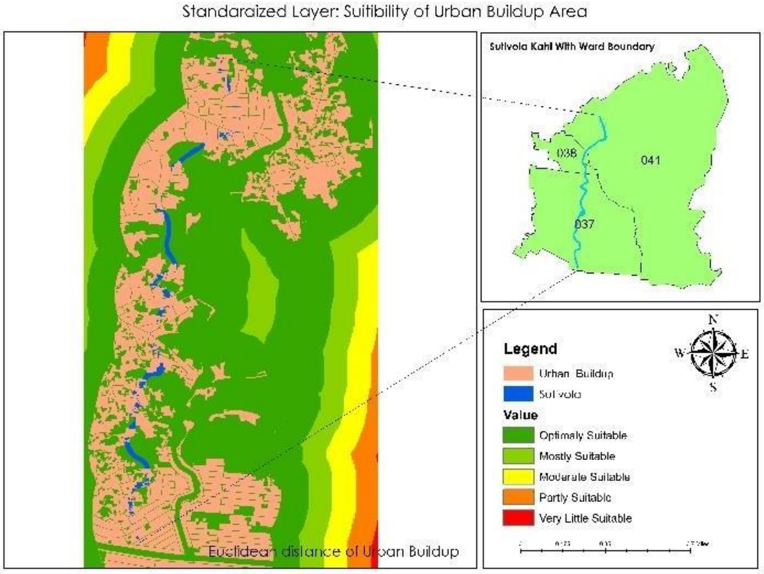

Fig rea

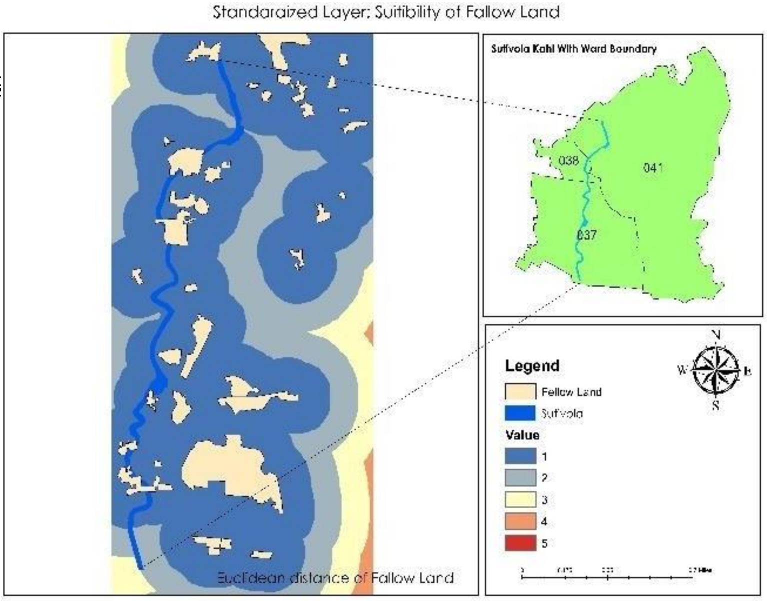

Figure 5. Standardization layer: Sustainability of Fellow Lands

Figure 6 represents the suitability of areas for flora and fauna in Sulibhola Khal, with zones ranging from optimally suitable (dark green) to mostly unsuitable (red). The main map highlights areas with different suitability levels, while the inset map outlines specific ward boundaries. The Euclidean distance from flora and fauna areas influences suitability. Figure 7 illustrates the suitability of areas for the road network in Sulivote Kaiti, with zones ranging from optimally suitable (dark green) to very little suitable (red). The main map shows roads and their surrounding suitability zones, while the inset shows specific ward boundaries. The Euclidean distance from the road network affects the suitability of each area.

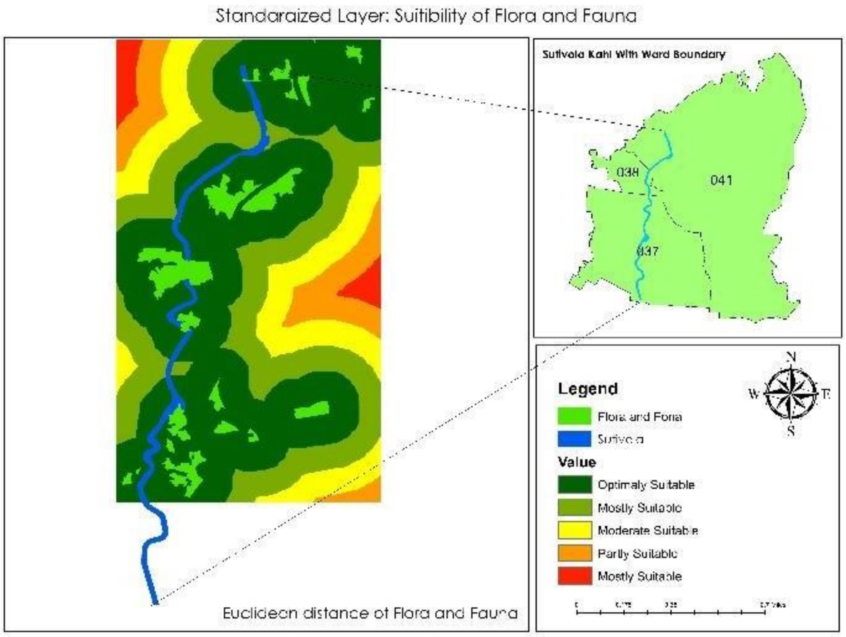

Figure 6. Standardization layer: Flora and Fauna

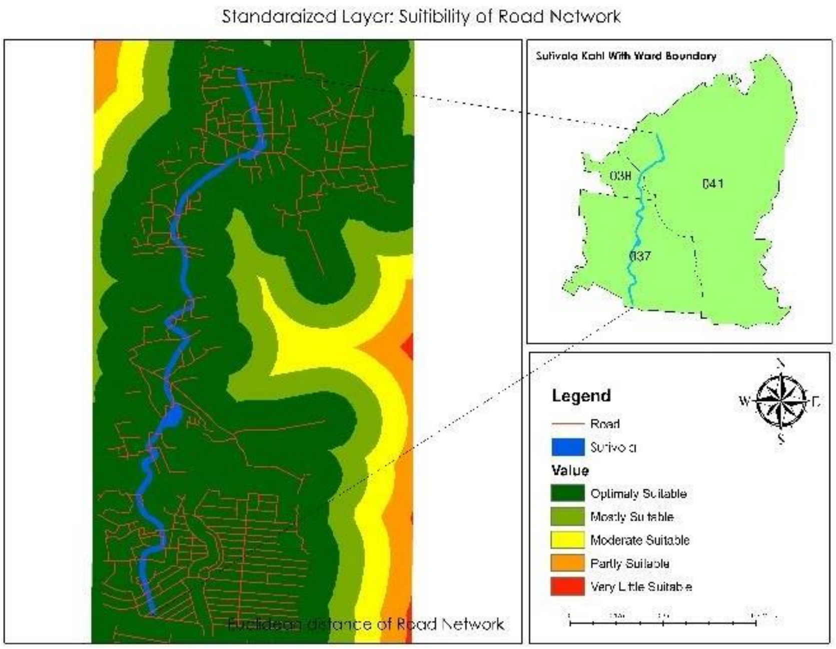

Figure 8. Standardization layer: Sustainable Road Network

Figure 8 illustrates the suitability of water bodies within the Sutibhola Khal area using a color gradient to denote suitability levels, where darker shades indicate areas that are optimally suitable based on proximity to water bodies. This visual representation helps identify regions in which development could best integrate with existing water resources. Figure 9 displays the suitability of urban green land, also within the Sutibhola Khal area, with warm colors like red and orange highlighting optimal suitability zones, which decrease in suitability as distance from green spaces increases.

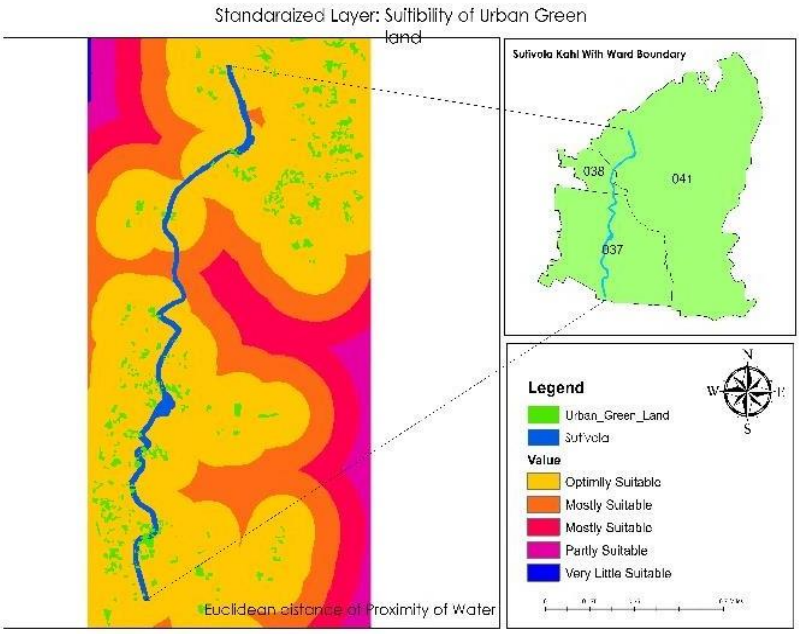

Figure 8. Standardization layer: Suitability of Urban Green

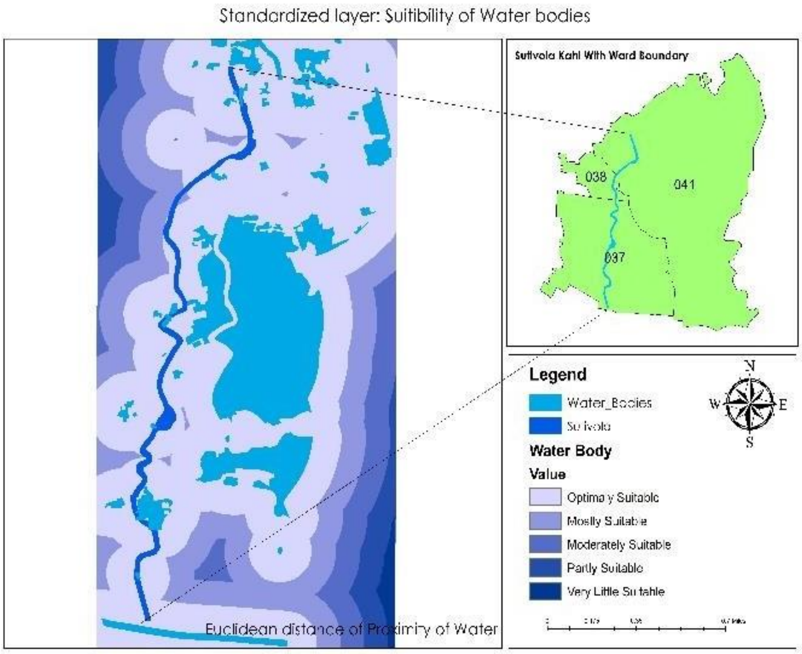

Figure 9. Standardized Layer: Suitability of Waterbodies

In the discussion section, the study emphasizes the crucial role of the Sutibhola Canal restoration in addressing various urban challenges, particularly flooding, which is a frequent and significant problem in Dhaka. The proposed sustainable canal development is a critical initiative that could serve as a model for other urban areas. This development is related to mitigating flood risks, enhancing waterway communication, and rejuvenating local ecosystems. Furthermore, the study sheds light on the importance of integrating a range of environmental and urban factors in the planning process, such as Urban Green Space, Proximity to Flora and Fauna, Waterbodies, Urban Build-up Areas, Urban Fellow Land, and Proximity to Roads. These factors are essential for balancing urban development needs and ecological preservation. This study provides critical scientific insights using GIS and AHP to investigate sustainable waterfront development, indicating that 50% of the 4,316 evaluated locations are appropriate. This method differs from prior research in that it focuses more on urban demands and highlights the benefits of incorporating ecological factors into a more balanced, resilient design framework. Compared with traditional site studies, this method's accuracy and adaptability highlight its importance in developing sustainable urban development.

The discussion also extends to the broader implications of the study. The insights and methodologies used in this research can be applied to other urban areas facing similar challenges. This study advocates water-based urban ecotourism as a sustainable approach that can enhance urban ecology without harming the environment, providing a template for urban planners and policymakers worldwide. Finally, the results and discussion offer a nuanced view of urban waterfront development. They highlight the potential to create sustainable, ecologically balanced urban spaces while also drawing attention to areas that require careful conservation and planning. This study provides a comprehensive framework for understanding and addressing the complex interplay between urban development and environmental conservation, making it a valuable resource for sustainable urban planning.

CONCLUSIONS

The study of the Sutibhola Canal in Dhaka offers a vital perspective on the challenges and opportunities in urban waterfront development. The study highlights the dire consequences of canal encroachment, such as increased flooding, declining groundwater levels, and biodiversity loss. These issues significantly impact the environment and the social and economic aspects of life in urban areas, particularly despite frequent peak flow and storm water runoff events. By employing advanced methods like the Analytic Hierarchy Process (AHP) and Ordered Weighted Averaging (OWA), along with Geographic Information System (GIS) technologies, this study delves into various critical factors needed for sustainable landscape development. This analytical approach provides a detailed and nuanced understanding of the balance between urban development and ecological preservation.

One of the study's most striking findings is the considerable potential for sustainable waterfront development, with about half of the evaluated areas being highly suitable for such projects. These findings indicate a promising pathway for developing waterfronts in harmony with the environment. However, the study also highlights areas of concern. Approximately 3% of the areas are deemed very low in developmental suitability, underscoring the need for focused ecological conservation efforts. Meanwhile, 37% of the areas were moderately suitable, suggesting that they could be developed with thoughtful planning and appropriate interventions. The remaining 10% are partly suitable and require more intensive management and strategic approaches to balance development and ecological care.

This study emphasizes the crucial role of restoring the Sutibhola Canal in addressing the city's flooding problems, enhancing waterway communications, and restoring environmental balance. The proposed canal development can continue to be a beacon for sustainable urban planning, offering opportunities for water-based urban ecotourism while reducing environmental pollution. Moreover, the research highlights the importance of considering a range of factors like Urban Green Space, Proximity to Flora and Fauna, Waterbodies, Urban Build-up Area, Urban Fellow Land, and Proximity to Roads in planning. These criteria are crucial for balancing urban development needs with ecological conservation.

The implications of this study are far-reaching and offer a blueprint for other cities facing similar challenges. This study presents a strategic framework for policymakers and urban planners, promoting the idea of water-based urban ecotourism as a means to enhance urban ecology without compromising the environment. Finally, this study presents a compelling case for a balanced, thoughtful urban development approach. The study integrates the need for environmental conservation with urban expansion, providing valuable insights and guidelines for sustainable urban planning relevant to Dhaka and any urban area facing similar ecological and developmental challenges. The research has effectively met its objectives by providing valuable insights into waterfront development and sustainable approaches. Practical implications based on the findings include suggestions for city planners to further extend waterfront projects to incorporate future priorities on environmental conservation, especially integrating ecological elements like proximity to green spaces, water bodies, and biodiversity. This could be further validated and widened to multisite analysis and community engagement in future research, strengthening sustainable urban planning and ecological balance in diverse city settings.

LIMITATION AND FURTHER RESEARCH

The research is limited in several ways, so this is probably the case for the results. Because this was a single-case study, the findings may not be generalizable to all sites. This study has some limitations. This study focused on only one case; thus, the findings might only fit some situations. In addition, the study used computer data, which might have missed some real-life details. In the future, researchers can use this research better by looking at more cases, talking to people to learn more about their experiences, and finding ways to apply our theories in real-life situations for sustainable waterfronts. Additionally, the data generated through a computer may have lost some crucial real-life factors that make the site unsuitable for sustainable waterfront development. In this regard, future research on a multi-site basis is recommended to broaden the insights and validate findings across different types of urban settings. The direct inclusion of local communities through feedback mechanisms in future studies would also provide a more detailed insight into the needs and concerns. In addition, practical application of the theoretical framework in various geographical and environmental conditions would be helpful for further refinement of methodologies for sustainable waterfront development, and it would ensure that the strategies are applicable in different contexts. Thus, it is conceivable that any holistic appreciation of ecological conservation and sustainable urban planning can be achieved through this approach, which can be applied to further global urban development practices.

REFERENCES

Ahmadi, M., Asgari, S., & Ghanavati, E. (2015). Land Capability Evaluation for Ecotourism Development in Ilam Province, A GIS Approach. *Boletim de Ciências Geodésicas, 21*(1), 107– 125. https://doi.org/10.1590/s1982-21702015000100008

Ahmed, S. U. (1986). *Dacca: A Study in Urban History and Development*. The Riverdale Company, Glenn Dale. https://doi.org/10.4324/9781351186759

Ali, S. M., Mohamed, A. N., & El Sohafi, N. (2020). Towards a Sustainable Waterfront Development" Case Study of Port Said City". *International Journal of Environmental Science*, *5*, 104-115.

Ayu, S. N., & Agustini, P. M. (2024). Digital marketing strategy analysis "Lagoon Avenue Mall" toward Sustainable Development Goal 5 (Case study at Lagoon Avenue Mall Sungkono Surabaya). *Humanities, Society and Community, 1*(2), 45–53. https://doi.org/10.31098/hsc.v1i2.2364

Baumgart, M., Weiland, U., & Höfer, R. (2022). Urban Waterfronts: New Perspectives on Sustainable Design. *Sustainability*, *14*(15), 9469. https://doi.org/10.3390/su14159469

Bertalanffy, L. V. (1969). *General System Theory: Foundations, Development*. George Braziller. http://hdl.handle.net/10822/763002

Burrough, P. A., & McDonnell, R. A. (1998). *Principles of Geographical Information Systems*. Oxford University Press. https://www.researchgate.net/publication/37419765_Principle_of_Geographic_Information_Systems

Dewan, A. M., Kumamoto, T., & Nishigaki, M. (2006). Flood Hazard Delineation in Greater Dhaka, Bangladesh Using an Integrated GIS and Remote Sensing Approach. *Geocarto International*, *21*(2), 33-38. https://doi.org/10.1080/10106040608542381

Dyson, K., & Yocom, K. (2014). Ecological Design for Urban Waterfronts. *Urban Ecosystems*, *18*(1), 189–208. https://doi.org/10.1007/s11252-014-0385-9

Farber, S., Costanza, R., Childers, D. L., Erickson, J., Gross, K., Grove, M., Wilson, M. (2006). Linking Ecology and Economics for Ecosystem Management. *BioScience*, *56*(2), 121–133. https://doi.org/10.1641/0006-3568(2006)056[0121:LEAEFE]2.0.CO;2

Fumagalli, N., Colombo, C., Ferrario, P. S., Senes, G., & Toccolini, A. (2014). Suburban Waterfront with Ecological and Recreational Function: Planning Based on Network Analysis. *Journal of Agricultural Engineering*, *44*(4), 141. https://doi.org/10.4081/jae.2013.183

Grêt-Regamey, A., Altwegg, J., Sirén, E. A., van Strien, M. J., & Weibel, B. (2017). Integrating Ecosystem Services into Spatial Planning—A Spatial Decision Support Tool. *Landscape and Urban Planning, 165*, 206–219. https://doi.org/10.1016/j.landurbplan.2016.05.003

Gu, M. C. and Liu, H., (2013). Sustainable Development of Tourism Choice - Eco-Tourism. *Applied Mechanics and Materials, 448*(453), 4445-4448. https://doi.org/10.4028/www.scientific.net/AMM.448-453.4445

Gunardi, E., & Meilasari-Sugiana, A. (2024). Building Teamwork in the Gotong Royong-Based Modern State: A Conceptual Investigation of Difficulties and Challenges. *Humanities, Society and Community, 1*(2), 54–64. https://doi.org/10.31098/hsc.v1i2.2265

Humaira, R., Choudhary, S., & Gupta, S. (2019). Study of Ecological Waterfront Development in India. *International Journal of Research in Engineering, Science and Management*, *2*(10), 618-620.

Hussein, R.M.R. (2014). Sustainable Urban Waterfronts Using Sustainability Assessment Rating Systems. *International Journal of Civil, Environment, Structural, Construction and Architectural Engineering*, *8*(4), 488–498.

Ilhamdaniah, I. (2018). GIS-based Suitability Analysis for Siting Waterfront Park in the City of Buffalo, New York. *IOP Conference Series Earth and Environmental Science, 145*(1), 012014. IOP Publishing. https://doi.org/10.1088/1755-1315/145/1/012014

Ishtiaque, A., Mahmud, M. S., & Rafi, M. H. (2014). Encroachment of Canals of Dhaka City, Bangladesh: An Investigative Approach. *GeoScape*, *8*(2), 48–64. https://doi.org/10.2478/geosc-2014-0006

JICA. (1991). *Master Plan for Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area)*. Japan International Cooperation Agency (JICA). Dhaka. https://openjicareport.jica.go.jp/pdf/10986875_01.pdf

Kamal, A. M., & Midorikawa, S. (2004). GIS-Based Geomorphological Mapping Using Remote Sensing Data and Supplementary Geoinformation: A Case Study of the Dhaka City Area, Bangladesh. *International Journal of Applied Earth Observation and Geoinformation*, *6*(2), 111-125. https://doi.org/10.1016/j.jag.2004.08.003

Keyvanfar, A., Shafaghat, A., Mohamad, S., Abdullahi, M. M., Ahmad, H., Mohd Derus, N. H., & Khorami, M. (2018). A Sustainable Historic Waterfront Revitalization Decision Support Tool for

Attracting Tourists. *Sustainability, 10*(2), 215. https://doi.org/10.3390/su10020215

Madurika, H. K. G. M. & Hemakumara, G. P. T. S. (2017). GIS Based Analysis for Suitability Location Finding in The Residential Development Areas of Greater Matara Region. *International Journal of Scientific and Technology Research, 6*, 96-105.

Mansour, S., Al-Awhadi, T., & Al-Hatrushi, S. (2019). Geospatial Based Multi-Criteria Analysis for Ecotourism Land Suitability Using GIS & AHP: A Case Study of Masirah Island, Oman. *Journal of Ecotourism, 19*(1), 1–20. https://doi.org/10.1080/14724049.2019.1663202

Mnini, P. & Ramoroka, T. (2020). Challenges of Ecotourism and Poverty Alleviation in South Africa. *International Journal of Economics and Finance Studies*, 12(2), 184-197. https://doi.org/10.34109/ijefs.202012205

Mohammed, K. M., Elhadary, Y. A. E., & Samat N. (2016). Identifying Potential Areas for Future Urban Development Using GIIS Based Multi-Criteria Evaluation Technique. *SHS Web of Conferences, 23*, 03001. https://doi.org/10.1051/shsconf/20162303001

Mokarram, M. & Hojati, M. (2017). Ordered Weight Averaging (OWA) Aggregation for Multi-Criteria Soil Fertility Evaluation by GIS (Case Study: Southeast Iran). *Computer and Electronics in Agriculture, 132*, 1-13. https://doi.org/10.1016/j.compag.2016.11.005

Mondino, E. & Beery, T. (2019). Ecotourism as a Learning Tool for Sustainable Development. The Case of Monviso Transboundary Biosphere Reserve, Italy. *Journal of Ecotourism*, *18*(2), 107-121. https://doi.org/10.1080/14724049.2018.1462371

Njiru, F. M., & Siriba, D. N. (2018). Site Selection for an Earth DAM in Mbeere North, Embu County-Kenya. *Journal of Geoscience and Environment Protection, 6*, 113-133. https://doi.org/10.4236/gep.2018.67009

Parry, J. A., Showkat, A. G., & Bhat, M. S. (2018). GIS-Based Land Suitability Analysis Using AHP Model for Urban Services Planning in Srinagar and Jammu Urban Centers of Jandk, India. *Journal of Urban Management, 7*, 46-56. https://doi.org/10.1016/j.jum.2018.05.002

Parvez, M. (2020). Solving Traffic Congestion Consequences Regarding E-Taxi Parking by Identifying a Suitable Location for the E-Taxi Station: Geo-Spatial and AHP Approaches. *Smart and Resilient Transportation*, *2*(2), 55-68. https://doi.org/10.1108/srt-07-2020-0005

Parvez, M., & Islam, S. (2020). Sites Suitability Analysis of Potential Urban Growth in Pabna Municipality Area in Bangladesh: AHP and Geospatial Approaches. *Journal of Geographical Studies*, *3*(2), 82–92. https://doi.org/10.21523/gcj5.19030204

Ragheb, A., & EL-Ashmawy, R. (2020). Urban Waterfront Development for Designing Space in Coastal Cities. *International Journal of Sustainable Development and Planning, 15*(3), 345–352. https://doi.org/10.18280/ijsdp.150311

Saaty, T. L. (1977). A Scaling Method for Priorities in Hierarchical Structures. *Journal of Mathematical Psychology, 15*, 234-281. https://doi.org/10.1016/0022-2496(77)90033-5

Sahani, N. (2019a). Application of Analytical Hierarchy Process and GIS for Ecotourism Potentiality Mapping in Kullu District, Himachal Pradesh, India. Environment, Development and *Sustainability, 22*(7), 6187–6211. https://doi.org/10.1007/s10668-019-00470-w

Sahani, N. (2019b). Assessment of Ecotourism Potentiality in GHNPCA, Himachal Pradesh, India, Using Remote Sensing, GIS, and MCDA Techniques. *Asia-Pacific Journal of Regional Science*, *3*(2), 623–646. https://doi.org/10.1007/s41685-019-00116-9

Sahani, N. (2023). Application of Analytical Hierarchy Process and GIS for Ecotourism Potentiality Mapping in Kullu District, Himachal Pradesh, India. *Applied Quantitative Research*, 3(1), 45–59. https://doi.org/10.31098/aqr.v3i1.2202

Saraf, M., & Dobariya, H. (2020). A Sustainable Approach to Waterfront Planning Against Environmental Hazards. *International Journal of Creative Research Thoughts (IJCRT)*, *9*(4), 3166–3172.

Siddika, T. (2020). Rethinking Urban Waterfront: A Case Study of Sylhet City Bangladesh. *Architecture Research*, *10*(4), 110–116. https://doi.org/10.5923/j.arch.20201004.03

Sridharan, N. (2017). *Globalisation, Productive Spaces and Small-Town Transformation: The Case of Machlipatnam and Pedana in Coastal Andra Pradesh*. Springer, New Delhi. https://doi.org/10.1007/978-81-322-3616-0_20

Syahrir, Y. (2021). Towards an Effective Participatory Process for a Sustainable Urban Waterfront Development. *Communications in Humanities and Social Sciences*, *1*(1), 1-6. https://doi.org/10.21924/chss.1.1.2021.6

Thoo, R. Y. X., Foong, S. S., & Chandran, G. (2024). Idleness as a Form of Resistance to Capitalism in Philip K. Dick's Piper in the Woods. *Humanities, Society and Community, 1*(2), 55–63. https://doi.org/10.31098/hsc.v1i2.1497

Tobler, W. R. (1970). A Computer Model Simulation of Urban Growth in the Detroit region. *Economic Geography, 46*(3), 234-240. https://doi.org/10.2307/143141

Turner, B. L., Lambin, E. F., & Verburg, P. H. (2021). From Land-Use/Land-Cover to Land System Science. *Ambio, 50*(7), 1291–1294. https://doi.org/10.1007/s13280-021-01510-4

Yocom, K. P., Andrews, L., Faghin, N., Dyson, K., Leschine, T., & Nam, J. (2016). Revitalizing Urban Waterfronts: Identifying Indicators for Human Well-Being. *AIMS Environmental Science, 3*(3), 456–473. https://doi.org/10.3934/environsci.2016.3.456

Zabihi, H., Alizadeh, M., Wolf, I. D., Karami, M., Ahmad, A., & Salamian, H. (2020). A GIS Based Fuzzy-Analytic Hierarchy Process (F-AHP) for Ecotourism Suitability Decision Making: A Case Study of Babol in Iran. *Tourism Management Perspectives, 36*, 100726. https://doi.org/10.1016/j.tmp.2020.100726

Zaki, S. K., & Hegazy, I. R. (2023). Investigating the Challenges and Opportunities for Sustainable Waterfront Development in Jeddah City. *International Journal of Low-Carbon Technologies, 18*, 809–819. https://doi.org/10.1093/ijlct/ctad062