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Assessing Ecotourism Potentiality of Sundarbans, Bangladesh, Using GIS and AHP Techniques

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[**Abstract:** Tourism has recently been one of the main industries in Bangladesh that generates foreign cash. This study's main goals are to identify and evaluate possible ecotourism locations using GIS and the Analytic Hierarchy Process (AHP), as well as to construct acceptable ecotourism locations in the Sundarbans mangrove forest using the suitability analysis method of GIS. This study identifies community characteristics, terrain, accessibility, wildlife, and landscape/naturalness as indicators of appropriateness within terrestrial ecosystems. Four factors were taken into consideration while evaluating ecotourism locations: proximity to a wide variety of species, elevation, distance from rivers, and distance from current tourist destinations. According to the AHP results, approximately 23.03%, 48.39%, 28.55%, and 0.03% of the area were highly prospective, moderately potential, marginally potential, and no potential zones for ecotourism development, respectively.]

Keywords: AHP, ecotourism, ecotourism potentiality, GIS, suitability analysis, Sundarbans.

1. Introduction

When someone takes willful tour to interact with the beauty of nature and to enjoy the local communities' culture then that tour is called ecotourism (Jafar & Bozorgnia, 2011). At present, among fast growing tourism sectors, ecotourism is one of the vital one (Bhaya & Chakrabarty, 2016). Recently among foreign currency earning sectors tourism is a vital one in Bangladesh (Sarker & Huibin, 2018). Mangrove forests are great attraction places in the world thus Sundarbans is a wonderful attraction place for tourist attraction in Bangladesh (Khan, 2020). Sundarbans is the largest mangrove ecosystem of the world and UNESCO has declared Sundarbans as a world heritage site in 1987 (Sarker & Huibin, 2018; Biswas *et al.*, 2007; Gopal & Chauhan, 2006). Sundarbans is famous for its natural beauty of thousands meandering rivers, estuaries, Royal Bengal tigers, spotted deer, crocodiles different types of birds, golpata, honey the famous tree sundari and many other species (Islam & Gnauck, 2009; Manna et al., 2010). A great number of tourists visit

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Sundarbans thus it plays a great role in the national economy. In 2014, Sundarbans had a direct contribution of USD 3.80 billion in the Bangladesh's GDP which was 1.9% of total GDP. Sarker and Huibin (2018) forecasted that in the year 2025 the contribution will be USD 16.08 billion which will be 4.4% of total GDP. Annually, Bangladesh earns about TK. 20 million from Sundarbans tourism and the tourists are increasing by 30000 every year (A. R. Khan, 2020). Sundarbans has a great potentiality as an ecotourism spot. Bangladesh is a country of forest dependent livelihood (Haque et al., 2016; Das and Siddiqi, 1985; Das, 1985). About one million people rely on the Sundarbans for their livelihood in Bangladesh (Sohela, 2013). So, an alternative livelihood can be provided through an ecofriendly tourism system which will reduce the pressure on flora and fauna of Sundarbans (Haque et al., 2016). It is important to make Sundarbans as a suitable ecotourist spot so that the over exploitation of Sundarbans will reduce due to the work opportunities of the local community in this sector (Haque et al., 2016). GIS is quite useful in locating unexplored places (Rahman, 2010) . To develop any tourism, it needs to be proper planned thus Geographic Information System (GIS) can be great tools to take proper decision in the planning process (Rahman, 2010). GIS-based multi-criteria decision-making (MCDM) approach can be used to evaluate priorities from different indicators to make proper decisions (Ahmadi et al., 2015). However, determining the relative weights of the criteria is a fundamental issue with decision theory for suitability or potentiality analysis. The Analytical Hierarchy Process (AHP) is a popular weight assessment technique (Bunruamkaew & Murayama, 2011; Dashti et al., 2013; Taye et al., 2019; Mobaraki et al., 2014). Specifying the hierarchical structure, finding the relative weights of the criterion and sub-criteria, allocating preferred weights to each alternative, and calculating the final score are all processes in this procedure (Abidin, 1999). In Thailand's Surat Thani Province, Bunruamkaew & Murayama (2011) used Geographic Information System (GIS) and the Analytical Hierarchy Process (AHP) to identify and rank suitable ecotourism sites. Indicators of appropriateness within terrestrial ecosystems were identified by his research as landscape/naturalness, wildlife, topography, accessibility, and community traits. Species richness, elevation, slope, proximity to cultural sites, separation from roads, settlement size, and land use/cover were among the nine criteria used to evaluate ecotourism locations. Gourabi and Rad (2013) assessed prospects and ecotourism potentials in Boujagh utilizing AHP to promote the growth of centralized and widespread tourism while assisting in environmental preservation technique based on the AHP model and hybrid descriptive and analytical methodologies. The findings indicated that due to the preference criteria in the development of centralized ecotourism, an area of 713.58 hectares, or roughly 21%, has desired power, an area of 237.38 hectares, or roughly 7%, has average power, and an area of 2329 hectares, or roughly 67 percent, has unfavorable power. According to the study index, the entire region was suitable for broad ecotourism. There are some previous studies that focus on the status of ecotourism in Bangladesh and the economic valuation of Sundarbans as a tourism industry alongside trying to identify sustainable ways to develop Sundarban's ecotourism (Mohammad et al., 2021; Sarker & Huibin, 2018; Afroz & Mahmud, 2017; Haque et al., 2016; Rahman, 2010). The ecotourism potentiality of Sundarbans was not quantified in those studies. Therefore, this study will fulfill the knowledge gap.

1.2 Aim and objectives

This study aims to illustrate the ecotourism potentiality in Sundarbans, Bangladesh and to produce some potential spots for the development of ecotourism in Sundarbans.

1. To identify ecotourism potential zones of Sundarbans by using GIS and AHP method.
2. To generate a suitable location map for ecotourism spots.

2. Study Area

The Sundarbans, previously known as the Sunderbunds, are a huge tract of saltwater swamp and forest that make up the lower Padma-Brahmaputra River delta in southeast West Bengal, northeastern India, and southern Bangladesh. The tract runs inland for roughly 50 miles (80 km) at its widest point and spans about 160 miles (260 km) along the Bay of Bengal from the Indian Hugli River estuary to Bangladesh's western Meghna River estuary (M. A. R. Khan et al., 2013). It is a system of flat, heavily vegetated, marshy islands that are surrounded by estuaries, tidal rivers, and creeks that are cut through by multiple channels. Three-fifths of the Sundarbans' total area, which includes both land and water, is in Bangladesh, or around 3,860 square miles (10,000 square km). Sundarbans is lying between latitude 21° 27′ 30″ and 22° 30′ 00″ North and longitude 89° 02′ 00″ and 90° 00′ 00″ East and with a total area of 10,000 km^2, 60% of the property lies in Bangladesh and the rest in India (Hussain et al., 2017). The vegetation, which is primarily of the mangrove type, is made up of a variety of trees, shrubs, grasses, epiphytes, and lianas. They have largely identical physiological and structural adaptations because they are primarily evergreen. For airborne respiration, the majority of trees have pneumatophores. Sundari (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) are the two most common species. 334 species were listed under 245 genera by Prain (1903). Of these, 87 are monocotyledons and the remaining are dicotyledons; 17 of these are pteridophytes. Among the plant species are 18 euphorbias, 29 grasses, 19 sedges, and 35 legumes. The Sundarbans alone include 35 of the 50 real mangrove plant species that have been identified. Nearly all mangrove plant species are evergreen, diminutive, towering trees, or shrubby plants that spread gregariously without leaving any room on the ground (Ovi, 2016).

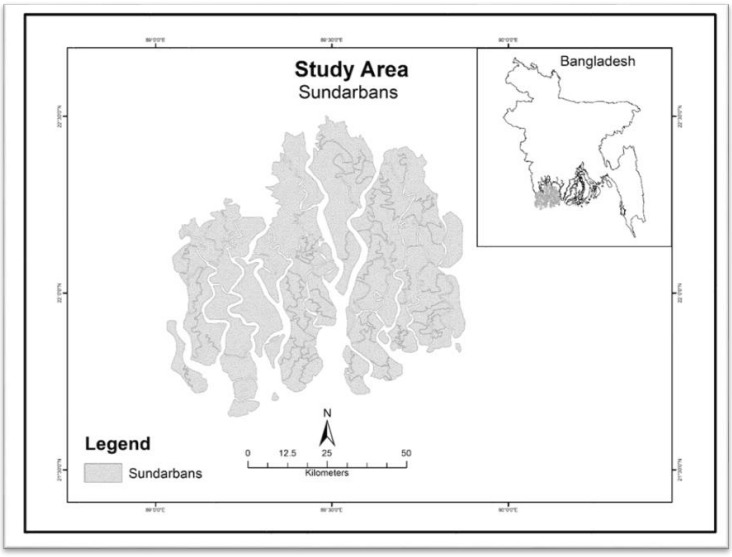

Figure 1 : Study area map (Sundarbans located in Satkhira, Khulna, and Bagerhat districts of Bangladesh); Source: Compiled by author, 2022

3. Materials and Methods

3.1 Data Sources

A variety of data were collected from different sources (Table 1). The Shuttle Radar Topography Mission (SRTM) data was extracted from https://earthexplorer.usgs.gov/ to find the elevation of the studied area (Table 2). The ecological rich biodiversity spots were collected from Banglapedia (https://en.banglapedia.org/index.php/Sundarbans). Present ecotourist spots and major river data was generated from Google Maps and Google Earth Pro software, respectively.

Table 1: List of data used in this study along with their sources.

Data	Sources
Boundary Map	Local Government Engineering Department (LGED)
DEM	SRTM, DEM, U.S. Geological Survey (USGS).
Ecological Rich Area	Banglapedia.org
Location of River	Google Earth Pro
Present Tourist Spots	Google Maps

Source: Compiled by author, 2022

Table 2: The details about SRTM DEM data collected from USGS.

Entity ID	**Acquisition date**	**Spatial Resolution**
SRTM1N22E089V3	2000-02-11	1-ARC (30 m)
SRTM1N21E089V3	2000-02-11	1-ARC (30 m)

Source: Compiled by author, 2022

3.2 Methods

The suitability map was created using the AHP weights derived with ArcMap 10.5 and Microsoft Excel. To create a site suitability map for ecotourism, there were four essential phases. These are: 1. finding appropriate elements for the study, 2. assigning factor priority, weight, and class weight (rating) to the relevant criteria, 3. creating an ecotourism land suitability map, and 4. identifying ecotourism potential regions. The suitable tourist spots were generated using suitability analysis with ArcMap 10. 5 by taking the above-mentioned criteria into consideration with specific values as suitability scores.

The consistency ratio was measured by the following equation;

$$CR = \frac{CI}{RI} \quad \text{..... (1) (Bunruamkaew \& Murayama, 2011)}$$

Where, CR – Consistency ratio, CI = Consistency index and RI = Random consistency index.

3.3 Identifying the Factors and Sorting the Criteria

Within the context of the terrestrial ecosystems of Sundarbans, this study identified the following elements as indicators of suitability: topography, naturalness, wildlife, and accessibility.

The four selected criteria—viz., elevation, ecologically rich area, river distance and proximity to the present spots were used to evaluate ecotourism locations (Table 3). The values which were taken to calculate was generated from experts' opinions, extensive literature reviews and the characteristics from already established ecotourism spots as they are successfully operating the Sundarbans' tourism industries. The values which were used to generate the table 3 are given in the table 6.

Table 3: Factors and criteria and their potentials with weights to analysis ecotourism potentiality of Sundarbans

Factors	Criteria	Unit	Class	Potentials	Rating	Weights (%)
Topography	Elevation	meter	(-22) – (-10.4) (-10.4) – 1.2 1.2 – 12.8 12.8 – 24.4 24.4 - 36	Very low Low Moderate High Very High	5 4 3 2 1	39
Accessibility	Distance from River	meter	0 – 2897 2897 – 5794 5794 – 8691 8691 – 11589 11589 - 14485	Very low High Very high Moderate Low	5 2 1 3 4	30
Wildlife	Proximity to ecological sites	meter	0 – 5804 5804 – 11607 11607 – 17410 17410 – 23214 23214 - 29017	Very high High Moderate Low Very low	1 2 3 4 5	21
Naturalness	Proximity to present Spots	meter	0 - 10551 10551 - 21103 21103 – 31654 31654 – 42206 42206 - 52758	Very low Low Moderate High Very high	5 4 3 2 1	10

Source: Compiled by author, 2022

The values of class were generated from APH analysis in which the nearer the location from river is considered as the higher potential values because the river is the only transportation system. The closer the ecological site implies the more attraction for the tourist and the present spot is vice versa. While higher elevated surface is considered as the minimum potentiality to be affected by flood as the total area of Sundarbans underly in flood prone zone, thus, higher elevation comprise a higher potential value and lover elevation comprise lower potential value for tourism development in Sundarbans.

3.4 Creating and Classifying Criteria Maps

The relevant elements and standards listed in Table 3 were made into and stored as GIS layers. First, a digital elevation model was used to construct a visibility factor, with high values representing the zones with the most potential and low values representing the

zones with the least potential. By using Euclidean analysis, the ecologically rich places, river locations, and present tourist spots were categorized.

Map layers that contain attribute values for each pixel in raster data are used in the GIS database to represent the attribute factors. Regarding the information gathered, there were four key criteria for ecotourism represented by four GIS-based layers (Fig. 2). During this process, each factor's data was maintained, displayed, and controlled separately. For the study area's final assessment as suitable for ecotourism, these criteria maps were superimposed together to generate suitable tourism spots by using ArcMap 10.5 software.

3.5 Determination of Weight Value for each Criterion using AHP

Analytical Hierarchy Process (AHP) methods by (Goepel, 2018) and geographic information systems GIS have been utilized to ascertain the natural regions' ideal capacity for concentrated and extensive ecotourism. Hierarchy analyses simplify complex and challenging problems before offering solutions. The desired components are first organized into a hierarchy as part of the AHP process, after which the components at each level are compared in pairs using higher level criteria. These comparisons go on until the right weights are determined and combined. Then, these factors' compatibility and relationship are evaluated. The environmental resources of the area were mapped using GIS, and digital elevation, river, and current tourist locations maps were created using simple maps utilizing the same UTM coordinate system in the ArcMap 10.5 environment.

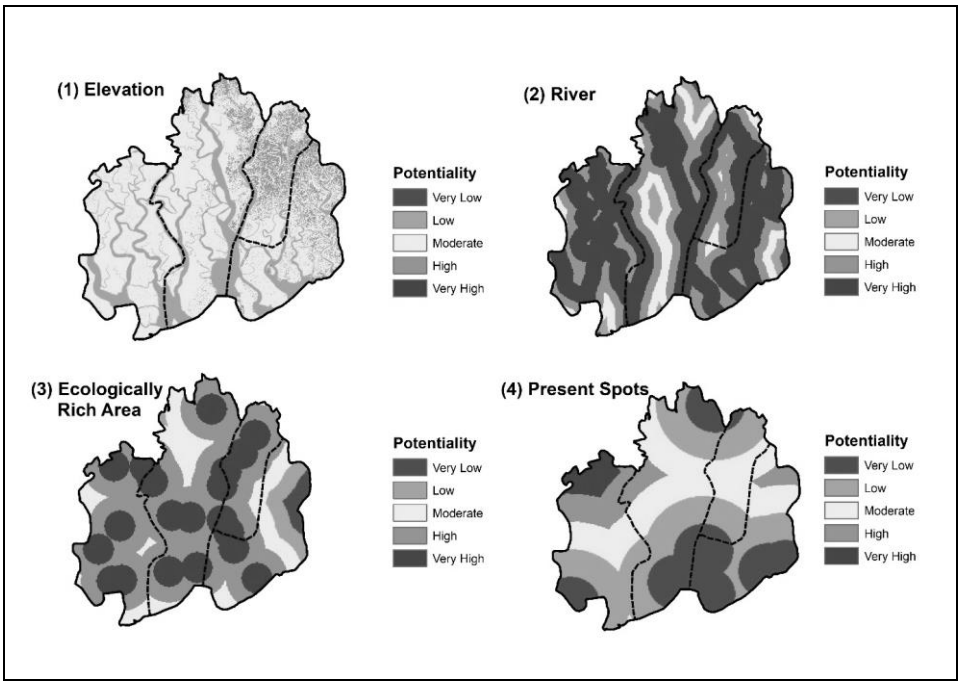

Figure 2: Criteria maps for ecotourism potentiality analysis of Sundarbans, where (1) representing the elevation map, (2) representing the suitable river distance map, (3) representing the suitable ecological rich area map and, (4) representing the distance from present tourist spot map; Source: Compiled by Author, 2022

In figure 2, (1) illustrate that the north-eastern part of Sundarbans has a relatively higher elevation thus, the area is highly potential for tourism development than other parts in consideration to flood susceptibility, (2) illustrate the closeness to the river make it more accessible for tourist to visit the area so the closer areas implie higher potential values, (3) tourist will travel shorter distance form ecologically rich areas thus the nearest area from the areas are taking high potential values, and (4) present spots already have a influence on their surroundings thus it will be wise to develop a spots keeping standard distance from present spots so, the neatest areas from present tourist spots are comprising lowest potential values for tourism development.

AHP additionally offers tools to identify mathematical judgment discrepancy in order to guarantee the validity of the relative significance utilized. It is possible to construct the consistency ratio index (CR), as stated in Equation (1), based on the characteristics of reciprocal matrices. According to Saaty (1987), the degree of consistency is generally satisfactory if the CR is less than 0.10. However, if it is greater than 0.10, the evaluation process is inconsistent, and the AHP approach might not produce accurate results.

In this procedure, the opinions of experts were sought in order to determine the relative weights of the relevant elements and criteria. Ecotourism's CR was likewise determined to be 0.04, which is suitable for use in the appropriateness analysis. Tables 4 and 5 show the results of the pair-wise comparison matrix and consistency ratio calculations, respectively.

Based on the linear combination of the suitability scores for each of the factors employed in this method the land suitability map for ecotourism has been developed. The AHP approach was used to assess the relative weight of each chosen element. The linear combination of the suitability scores acquired for each component and criteria involved was used to determine the overall suitability score for each land unit (i.e., each raster cell on the map).

Table 4: The pair-wise comparison matrix; Source: Compiled by author, 2022

Matrix		Elevation	River	Ecologically Rich	Present Spot	**Normalized Principal Eigenvector**
		1	2	3	4	
Elevation	1	1	1	3	3	**39.41%**
River	2	1	1	1	3	**29.46%**
Ecologically Rich	3	1/3	1	1	2	**20.49%**
Present Spot	4	1/3	1/3	1/2	1	**10.65%**

Table 5: Estimation of the consistency ratio and computation of the factor weights; Source: Compiled by author, 2022

	Criterion	Weights	+/-
1	Elevation	39.4%	14.1%
2	River	29.5%	7.6%
3	Ecologically Rich	20.5%	6.5%
4	Present Spot	10.6%	1.4%
			CR = 0.043

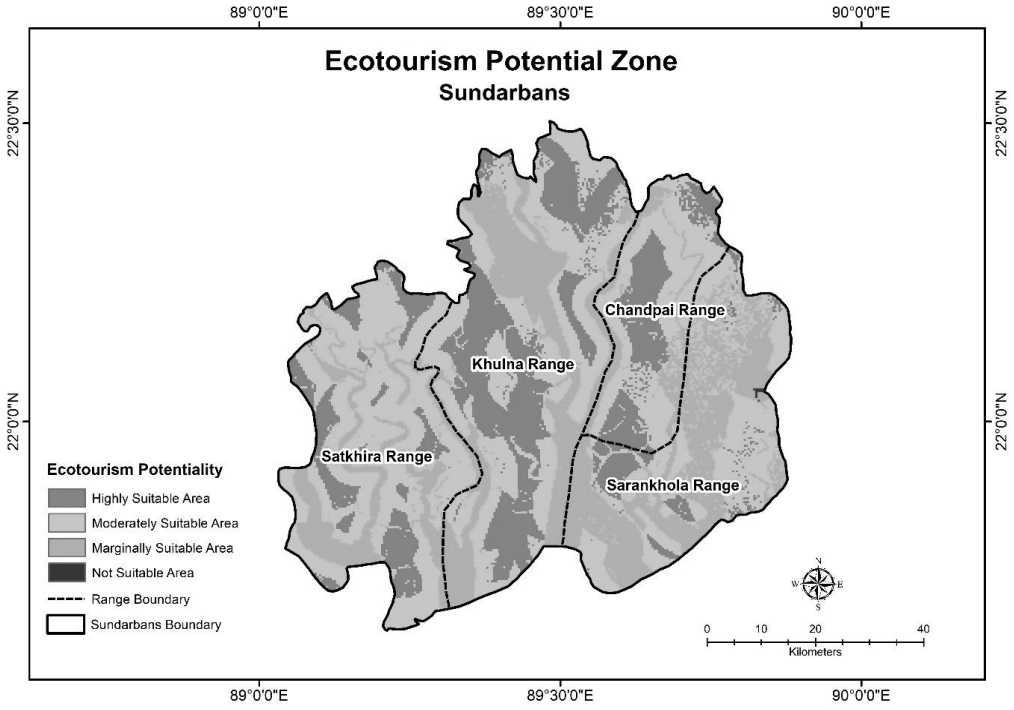

Figure 3: Ecotourism potential zones of Sundarbans*;* Source: Compiled by author, 2022

3.6 Suitability of the area for tourist attraction

In this study four criteria have been taken to generate suitable ecotourism spots: elevation, distance from river, natural attributes and established ecotourism spots (Table 6).

Table 6: The criteria chosen for suitability analysis for selecting suitable sites in Sundarbans for ecotourism development with their values and reason to choose the values; source: Compiled by author, 2022

Criteria	Value	Comment
Suitable Elevation Map	>10 meters	Higher elevation will reduce the risk of coastal flooding.
River Map	• Distance more than 400 meters • Distance Less than 500 meters	Closer to the river may increase the vulnerability of flooding, while more distance can discourage the tourist to visit the place as no vehicle occupies there.
Ecologically Rich Area	Buffer within 1 Kilometer	Far from the ecologically rich area can discourage the visitors to travel the spot.
Present Tourist Spots	Distance more than 3 Kilometers	The closer the spots are the lesser possibilities to generate proper outcome.

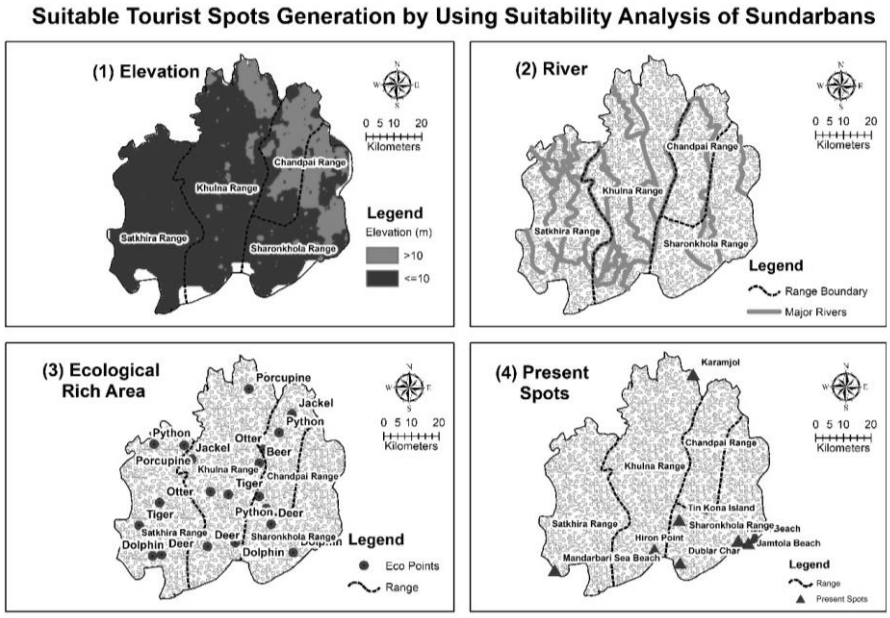

Figure 4: The criteria maps for suitable tourist spots generation. (1) Representing the suitable elevation map, (2) representing the major river map, (3) representing the ecological rich area, and (4) displaying the present tourist spots map; Source: Compiled by author, 2

The north-eastern part of Sundarbans is elevated above 10 meters from the sea level (figure 4[1]) which was taken for the suitability analysis, because below 10 meters elevated surface highly vulnerable for flood susceptibility. There are several rivers in Sundarbans only the high navigable river (figure 4[2]) was taken in consideration for the analysis. The ecologically rich area with biodiversity (figure 4[3]) has been collected for suitability analysis as the third important criteria. And finally the already established area

(figure 4[4]) was also included for suitability analysis as, the shorter distance among spots will reduce the impact of the spots.

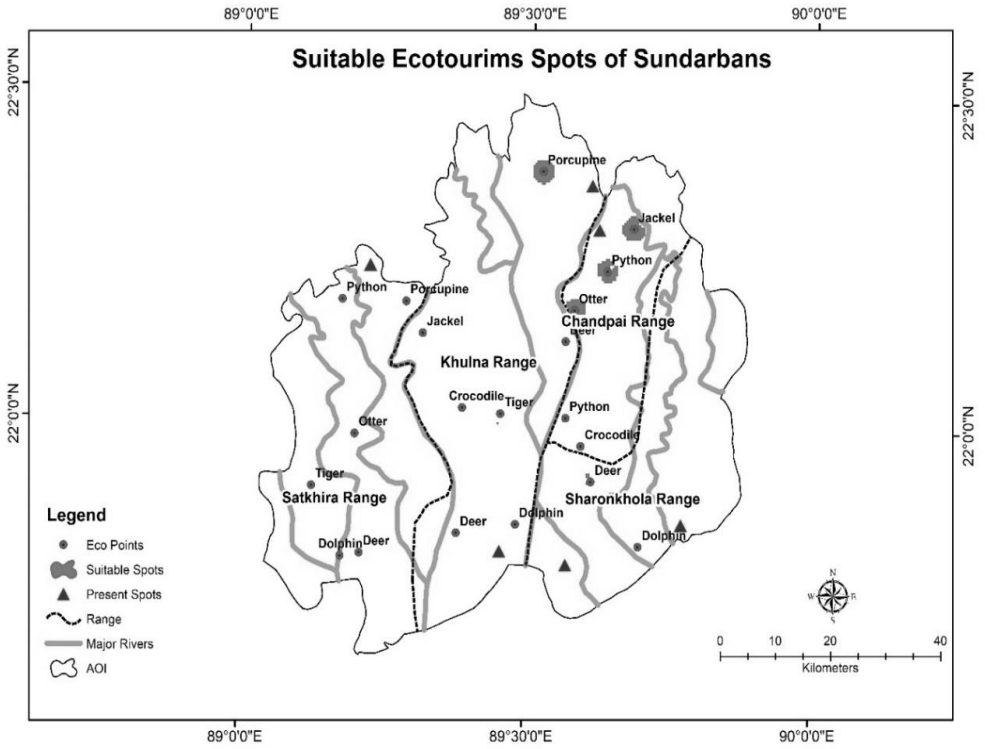

Figure 5 : Suitable ecotourism spots map; Source: Compiled by author**, 2022**

Figure 5 illustrates the suitable locations for the tourism development in Sundarbans where AOI implies Area of Interest and the green marked areas are the final outcome of the suitability analysis where tourist spot can be developed but any residential or commercial activities cannot be operated there because they will hinder the biodiversity.

4. Result and Discussion

According to the FAO framework for land evaluation (Tienwong, 2008; Baniya, 2008), the data in the maps are categorized into four suitability classes: highly suitable, moderately suitable, marginally suitable, and not suitable. According to the suitability map for ecotourism shown in Table 7, there are approximately 48.39% moderately suitable areas, 28.55% marginally suitable areas, and 23.03% highly suitable areas. Only a little portion (0.03%) of the land was deemed unsuitable. According to suitability values, there is no precise pattern for how suitable areas are distributed; instead, many patterns are used throughout the entire area.

Table 7 : The area and percentages of ecotourism potentiality of Sundarbans; Source: Compiled by author, 2022

Potentiality	Area (Sq.Km)	Percentage (%)
Highly Suitable (S1)	1228.11	23.03
Moderately Suitable (S2)	2580.76	48.39
Marginally Suitable (S3)	1522.54	28.55
Not Suitable (N)	1.68	0.03
Total	**5333.106556**	**100**

According to the results analysis and ecotourism requirements, the usual locations that are suggested are categorized into 4 categories (Yaakup et al., 2006). (1) The S1 "strong ecotourism potential" category recommends that ecotourism can be developed largely in that region, as it is the most elevated and biologically diverse area but could be endangered by tourism development. With the application of specific restrictions and procedures, it might function as the primary ecotourism attractions. The proper management and code of conduct is an illustration of a rule that should be used to restrict the quantity and length of entry to the place. The recommended activities for these regions include site-seeing and activities relating to education and research. (2) The S2 category, which has a moderate potential for ecotourism, permits modest development with careful consideration given to building activities and detailed assessments of the effects on the environment. Due to passive tourist activities like camping, hiking, animal watching, sightseeing, and other activities with little growth or influence on the site, these sites can nevertheless be considered ecotourism attractions. (3) The S3 category, which denotes regions "suited for tourism industry," comprises accessible, low-sensitive locations. Even yet, it is important to undertake development in a way that minimizes its negative effects. To encourage ecotourism in these locations, it is necessary to build physical structures such eco-friendly lodgings, motels, restaurants, and public restrooms. (4) The N " not suitable" category comprises regions that have experienced several development-related consequences and environmental degradation. The suitability analysis produced roughly 3 spots (Figure 5) to develop ecotourism, which are mainly the north-eastern part of the study area. This area is more accessible and best fitted with the selected criteria of the study. Thus, if we want to develop fewer tourist spots we have to firstly taken these spots in our consideration.

Limitations:

As my research work was not funded by any organizations or people, there is some limitations to obtaining the baseline data of ecologically rich area, where I used Banglapedia data. Due to the lack of funding I cannot collect ecologically rich data by ground-truthing techniques.

5. Conclusion

Among the world, Sundarbans is the largest mangrove forest which was declared as the world heritage site in 1987 by the UNESCO. Every year thousands of tourists are increasing to visit Sundarbans. Besides, Bangladesh is earning a huge amount of money from Sundarbans just from the tourism sector of it. There are numbers of ecotourism

spots established in Sundarbans of which only a few are well planned and organized. Thus, in this study I proposed some potential zones with some suitable ecotourist spots by taking some vital criteria in consideration to develop ecotourism in Sundarbans. The result will help the authorities which are concerned about the ecotourism development in Sundarbans to develop the ecotourism sector of this places.

Data and code availability statement
The dataset and codes can be downloaded from https://megaup.net/folder/42876/Data.

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[**সার-সংক্ষেপ :** পর্যটন সম্প্রতি বাংলাদেশের অন্যতম প্রধান শিল্প যা বিদেশী নগদ অর্থ উৎপন্ন করে। এই অধ্যয়নের প্রধান লক্ষ্য হল GIS এবং Analytic Hierarchy Process (AHP) ব্যবহার করে সম্ভাব্য ইকোট্যুরিজম অবস্থানগুলি চিহ্নিত করা এবং মূল্যায়ন করা, সেইসাথে GIS-এর উপযুক্ততা বিশেষণ পদ্ধতি ব্যবহার করে সুন্দরবনের ম্যানগ্রোভ বনে গ্রহণযোগ্য ইকোট্যুরিজম অবস্থানগুলি নির্মাণ করা। এই অধ্যয়নটি সম্প্রদায়ের বৈশিষ্ট্য, ভূখণ্ড, প্রবেশযোগ্যতা, বন্যপ্রাণী এবং ল্যান্ডস্কেপ/প্রাকৃতিকতাকে পার্থিব বাস্তুতন্ত্রের মধ্যে উপযুক্ততার সূচক হিসাবে চিহ্নিত করে। ইকোট্যুরিজম অবস্থানের মূল্যায়ন করার সময় চারটি বিষয় বিবেচনা করা হয়েছিল: বিভিন্ন প্রজাতির সান্নিধ্য, উচ্চতা, নদী থেকে দূরত্ব এবং বর্তমান পর্যটন গন্তব্যস্থল থেকে দূরত্ব। AHP ফলাফল অনুসারে, আনুমানিক ২৩.০৩%, ৪৮.৩৯%, ২৮.৫৫%, এবং ০.০৩% এলাকা যথাক্রমে অত্যন্ত সম্ভাবনাময়, মাঝারি সম্ভাবনাময়, প্রান্তিক সম্ভাবনাময় এবং ইকোট্যুরিজম বিকাশের জন্য কোন সম্ভাব্য অঞ্চল ছিল না।

মূলশব্দ : এএইচপি, ইকোট্যুরিজম, ইকোট্যুরিজম সম্ভাবনা, জিআইএস, উপযুক্ততা বিশেষণ, সুন্দরবন।]