Assessment of Ecosystem services, plant diversity pattern analysis in Guliakhali sea beach (Chattogram,Bangladesh).

By

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This Thesis Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science (B. Sc.) in Environmental Science and Disaster Management (ESDM)

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APPROVAL

This thesis report titled Assessment of **Ecosystem services, plant diversity pattern analysis in Guliakhali sea beach (Chattogram,Bangladesh)**, submitted by **Isteaque Ahmmed Chowdhury** to the Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU), has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Environmental Science and Disaster Management (ESDM) and approved as to its style and contents. The presentation has been held on 29th November of 2022.

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DECLARATION

I hereby certify that this research project has been done by me under the supervision of **Dr. Mahfuza Parveen, Associate Professor,** Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU). I also declare that neither this research project nor any component of this research project has been submitted elsewhere for the award of any degree.

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Dedication

This work is dedicated to

My beloved parents,

My family, friends &all of my teachers in my life

Who always support me.

Hasan ibn al Haytham,

Who was an early proponent of scientific method.

Muhammad ibn Musa al-Khwarizmi,

Father of algorithm.

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All glory and honor is due to Allah.

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Abstract

Bangladesh's coastal regions are frequently hit by cyclones. The Sundarbans' natural mangrove forests offer protection from storm damage, prompting government to launch a mangrove afforestation initiative in 1966. These first plantings were particularly effective in preserving and stabilizing coastal areas, which sparked a massive drive to reforest mangroves. In the current study, the ecosystem services and plant species diversity in Guliakhali are being identified. In Guliakhali, five distinct kinds of provisioning services are listed. Fish, fruits (plants), medicinal plants, ornamental resources, and fuels are among the known provisioning services. In Guliakhali, there are eleven regulated services and fifteen distinct types of cultural services. According to the study, Guliakhali is an important habitat for plants, fish, birds, and other life forms. Furthermore, it provides a habitat for 23 plant species and at least 15 fish species. From the identified plant species, four plant types are defined: trees (10 species), herbs (4 species), shrubs (2 species), and climbers (7 species).Salinity, distance, and among the species all exhibit positive and negative correlations. We can see that the amount of vegetation is gradually diminishing through the examination of the NDVI maps. This study will help social workers, researchers, and legislators work toward various sustainable goals.

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1 Introduction

1.1 Introduction

Bangladesh has one of the world's densest rural populations. In 1974, a 55,126-square-mile area housed 75 million people. A number of the world's biggest rivers flow through the country, which makes it the largest global delta. The Ganges-Brahmaputra river system creates a 25,000-square-kilometer delta in the Bengal Basin. Length of miles As a result, it goes without saying that monsoon rain, rising and declining river levels, floods, Alluvion, and Diluvion are all examples of natural calamities, and river course fluctuations are the substance of both cultural and natural history (Rashid, 2019).Surrounding the coast accounts for more than a third of the country's total farmable land. Its interior reaches a maximum distance of 150 kilometers from the coast. Arable lands cover approximately 0.83 million ha of the 2.85 million ha of coastline and near-shore areas, accounting for roughly 30% of Bangladesh's total cultivable land. The Sundarbans is located along the coast and is a protected natural mangrove forest covering about 4,500 square kilometers. The remaining coastal land is devoted to agriculture. Soil salinity has a significant impact on agricultural potential in coastal regions. Bangladesh's coastal and offshore territory includes the tides, estuaries, and river floodplains of the Bay of Bengal in the south. In these areas, agricultural land is used. Extreme poverty affects nearly half of the population nationwide (Haque, 2006).

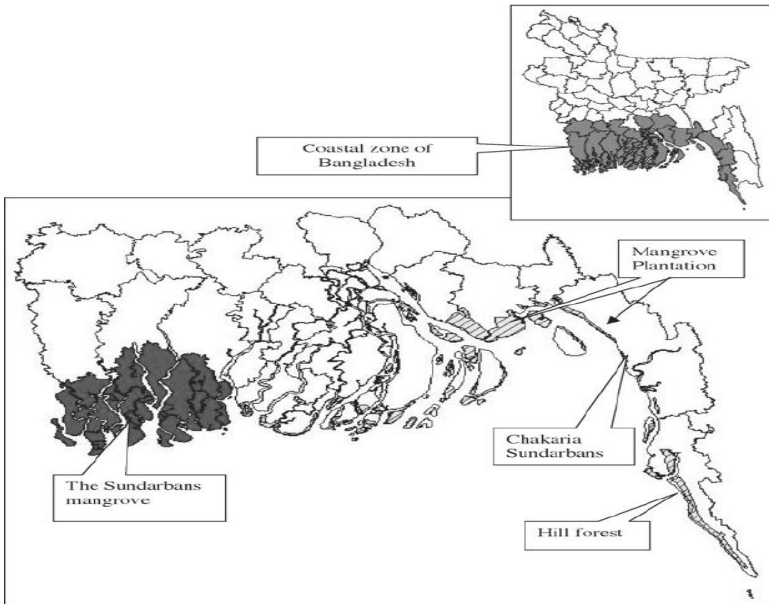


Figure 1: A map of Bangladesh's coastline that displays both natural and artificial mangrove forests (Iftekhar and Islam, 2004)

Bangladesh has 19 districts located in coastal regions that cover around 32% of the country's total territory. The negative impacts of climate change are amplified in the presence of other risk factors, like high population density, low income, and inadequate infrastructure, particularly in high population density, low income, and inadequate infrastructure, particularly in the areas of water and sanitation, electricity, and healthcare. Most South Asians do not have access to clean water, and over a quarter of the region's people are undernourished (Huq & Rabbani, 2014).

Coastal residents in Bangladesh rely heavily on natural resources, and it has potential appeal for ports, tourism, and other activities (Uddin et al., 2013). In addition to their aesthetic value, sandy beaches serve an important ecological and economic function by facilitating activities like biodiversity conservation and population maintenance. But these beaches are impacted by the anthropogenic reasons and climate change (Amaral et al., 2016). If we understand the importance of the beaches and its ecosystem services it will be better for us to maintain a beach. Because requirement of natural ecosystem is too high perhaps we cannot survive without it (Heal, 2000). South Asia has some of the top holiday spots in the globe. From lovely beaches to spectacular hill stations, fabulous backwaters, elaborately carved temples, and gorgeous heritage and culture, the position of tourism practice is not totally fulfilled.

As a result of humans occupying most of the biospheres, ecosystems have been severely altered, often to the point where they can no longer provide the vital ecological services we depend on. Unfortunately, our understanding of the ecological value of ecosystem services is extremely limited. While previous studies have mapped service provision, assessed risks, and estimated economic values, they have not quantified biodiversity's underlying contribution to service provision (Kremen, 2005).

Many studies on ecosystem services have been conducted around the world. The research study on ecosystem services in Bangladesh has a restriction. There has been no research on the ecosystem services of the Sitakunda area, in particular. No studies have focused on the Sitakunda region's ecosystem services yet. Sitakunda is a Chottogram district sub-district. The Guliakhali beach has grown in popularity as a tourist destination, and the government has designated it as a protected area. So far, no research has been conducted in the area. Therefore, I decided to conduct my research on this topic in order to learn about some previously unknown information and events, and to pave the way for further study in this field.

1.2 Objectives

- To learn about the ecosystem services which have been provided by the Guliakhali sea beach.
- To determine the types of plants that are present and the distribution patterns of those types.
- NDVI change detection in last five years

2 Literature review

2.1 Ecosystem services

We can easily define this term Ecosystem service by divide into two part one is ecosystem another is services. If we define these two terms specifically it would be better for us to understand the ecosystem service.

2.1.1 Ecosystem

An ecosystem is a natural habitat in a specific area where various living organisms (plants, animals, and microbes) coexist and interact with one another as a functional unit. An ecosystem might be either huge or extremely small. The variables or components that make up an ecosystem are referred to as its structure. As a result, the major factors or components of an ecosystem are classified as

- Biotic (plants, animals, microorganisms, etc.) and
- Abiotic (soil, air, water, sun, sunlight, etc.).

All of the aforementioned factors exist in an ecosystem. To maintain a food chain, all life interacts with or is dependent on one another. Abiotic variables, such as the sun, are critical in providing energy for food production. Microbes, on the other hand, perform an important function in decomposing the substance that is left behind.

2.1.2 Services

The word "service" contains a wide range of meanings. Because the concept can refer to an industry, an output or service, or a process, there is a lot of uncertainty when it is used in management literature (Johns, 1999). Service is a mechanism for meeting the requirements of the public, and the items provided are referred to as services. Such as transportation facilities, utility facilities (electricity, water), oxygen from trees, nature's photosynthesis process, and so forth. So,

A natural ecosystem and its inhabitants work together to produce, sustain, and meet human needs through a process known as ecosystem services. By following this process, the production of necessary goods and biodiversity are kept in balance. Examples of items produced as ecosystem services include energy, pharmaceuticals, fiber, and wood (Daily, 1997) or, Ecosystem services are the advantages (or necessities) provided to humans by the transformation of resources such as soil, water, biomass, and air (Costanza et al., 1998).

Ecosystem services are the benefits people receive from healthy ecosystems. Many of these are essential for maintaining life (controlling the weather, cleaning the air, and pollinating crops), while others are merely beneficial (aesthetics). Because of human interference in the biosphere, ecosystems have undergone rapid transformations in their composition, structure, and function (Vitousek et al., 1997).

2.1.3 Category of ecosystem services

To evaluate the state of the world's ecosystems, UN Secretary-General Kofi Annan proposed a framework known as the Millennium Ecosystem Assessment (MEA) (MA). Initiated in 2001, the project was finally wrapped up in 2005. Therefore, the evaluation criteria are typically referred to as the MA, 2005. Therefore, the field of environmental services can be broken down into four distinct subfields (Millennium ecosystem assessment, 2005)Which are:-

- Provisioning services.
- Regulating services.
- Cultural services.
- Supporting services.

Table 1: category of ecosystem services

Category	Examples of the ecosystem services provides
Provisioning services (products derived from the ecosystem)	Water, food, flowers, fiber, fuel, genetic resources, biochemical, medicine, etc.
Regulating services (benefits derived from ecosystem process regulation)	Climate regulation, water regulation, human disease regulation, pest control, air quality, etc.
Cultural services (nonmaterial benefits derived from an ecosystem)	Spiritual values, educational values, aesthetic values, tourism, recreation, etc.

Supporting services (ecosystem functions for ecosystem service production)	Habitat for the species, soil formation, and retention, nutrient cycling, water cycling, etc.

2.2 Plant species diversity

The amount of distinct species present within a single ecological community is represented by species diversity in a geographical area within a given time.

Species diversity consists of two elements:

1. Species richness refers to the number of species in a given area or the number of species or other taxa in a given collection of organisms.

Evenness refers to the proportional abundance of each species in a community or collection. Evenness can be determined by using any metric of abundance (biomass, number, or projective cover). The greater the evenness, the closer the abundance values of all species are to one another (Vasilevich, 2009).

2.3 NDVI

NDVI is a simplified image created by dividing near-infrared (NIR) minus red by NIR plus red (Kriegler et al., 1969).

NDVI was developed in the 1970s to simplify multi-spectral data. Imagery is now the most common vegetation index. An NDVI can be easily computed using any multispectral imaging system sensor with visible and near-infrared bands. Several studies have shown that the NDVI is effective for expressing vegetation status and quantifying vegetation attributes (Huang et al., 2021).

2.4 Related study

"Ecosystem Services of the World Largest Mangrove Forest Sundarban in Bangladesh" To better understand the Sundarban Mangrove Forest's ecosystem services, researchers (Hossain et al., 2016) first cataloged all of the different ones that exist there. Quantitative and qualitative research techniques were used to compile this report. Indicators of ecosystem services were selected in light of study objectives, data availability, measurability, and pressing environmental concerns. Three protected

areas in the Sundarbans were the focus of a month-long field survey in the dead of winter in January 2016.People whose lives are directly affected by Sundarban's ecological services were the primary subjects of direct observation, photography, and formal and informal community discussions. Discussions with Forest Service representatives shed light on the difficulties of the investigation. The data were analyzed to compile a catalogue of ecosystem services, uses, and prospects. Resources such as timber, fish, thatching, fuel wood, crab, honey, and wax came from the Sundarban. The Sundarbans act as a buffer zone for the cities along the coast. The Sundarban helps protect Bangladesh's coastline from the effects of natural disasters like cyclones and tidal surges. Sundarban offers many cultural services, such as tourism, education, a world heritage site, ethnic festivals, and local worship.

"Environmental Services of Beaches and Coastal Sand Dunes as a Tool for Their Conservation" The ES of the shores and dunes along the coast of the Baja California Peninsula has been the subject of research (Rodríguez-Revelo et al., 2018). The ES was found through a search of both global and regional scientific literature databases. The beaches and coastal dunes of the Baja California Peninsula have been documented as a source of ES in the literature. After reading the abstracts of a thousand studies found through literature searches, three hundred and fifty papers were selected and thoroughly reviewed because they dealt with ES in some way, shape, or form. They give so that their worth can be measured against competitors worldwide. When applied to the management of beaches and coastal dunes, the method outlined here can be used to inform discussions about environmental conservation, unearth gaps in knowledge, and inspire targeted studies. In total, 22 of the 25 ES that had been reported were identified. Six are transportation services, nine are government regulatory, two are administrative, and five are cultural.

"Valuing beaches to develop payment for ecosystem services schemes in Colombia's Sea flower marine protected area" (Castaño-Isaza et al., 2015). An investigation has been carried out. The worth of ecosystem services, functions, and benefits has been measured using a variety of approaches. Contingency valuation (CV), a survey-based strategy for the economic valuing of non-market resources, is a prominent way for quantifying ecosystem value. This study presents socioeconomic information about visitors to SAI and evaluates the economic worth of beaches to help build a Payment for Ecosystem Services strategy for beach conservation within

the area. Furthermore, it emphasizes the importance of economics Ecosystem service value for developing and implementing alternate finance structures to safeguard the region's economic health.

"Community dependency on the ecosystem services from the Sundarbans mangrove wetland in Bangladesh" (Islam & Hossain, 2017).This research looks at how the Sundarbans benefit the surrounding area and the country of Bangladesh as a whole through the services they provide to the local ecosystem. The mangrove ecosystem of the Sundarbans offers the same four benefits that are common to other wetland types. Among these are regulatory (carbon sequestration), cultural (mangrove tourism), and provisional (fish, shellfish, forests, honey) (e.g., soil formation). When all other options have been exhausted, the Sundarbans can be relied on to provide a steady stream of income, work, and food. Natural and anthropogenic risks and stressors continue to affect the flow and quality of ecosystems due to overuse and degradation. This research argues that in order for ecosystem services to be provided sustainably, wetland management must be both socially equitable and ecologically sound.

"An Impact Assessment of Beach Wrack and Litter on Beach Ecosystem Services to Support Coastal Management at the Baltic Sea" (Robbe et al., 2021).They took a two-pronged approach to get ready. They developed four hypothetical beach environments after settling on a suite of ecosystem services with which to evaluate sandy beaches in the southern Baltic. As a result of these data, two expert-based assessments of beach ecosystem services and the effect of beach wrack and litter were carried out. When making management and policy suggestions for the beach, they split the recommendations into three categories: general service provision, prospective (potential supply), and flow (actual use or real supply). They picked 21 services pivotal to the care and regulation of the Baltic's sandy beaches. Our foundation is the Common International Classification of Ecosystem Services. Four plausible beach scenarios were developed to represent common Baltic management strategies for a comparative ecosystem services assessment. They used data analysis tools like spreadsheets, workshops, and an online survey to compare 39 outside specialists. Cultural (52.2%), regulatory and maintenance (37.3%), and service-oriented (10.4%) resources are available. The effect scores showed that cleaning up

the beach resulted in a decrease in the availability of ecosystem services.Simplifying service by picking up litter.

"Ecosystem Services and Human Well-Being: a Participatory Study in a Mountain Community in Portugal"(Pereira et al., 2005)**.** In it, they detail the Millennium Ecosystem Assessment's investigation into the environment of the tiny town of Sistelo in northern Portugal. The team's primary objective was to examine how people in the area value environmental protection and health services. Methods such as direct observation, getting to know people, familiarization, semi-structured interviews, trend lines, well-being ratings, and ranking and scoring were used. There are over 40 indicators of success that were established. Using the Millennium Ecosystem Assessment's components of well-being, they sorted the most frequently used criteria (Millennium Ecosystem Assessment, 2003).

"Revealing marine cultural ecosystem services in the Black Sea" (Fletcher et al., 2014).The Black Sea town of Sile and the Istanbul metropolitan area were both parts of the research. Human-marine interaction could be better understood by analyzing public responses to an open question about the sea in Turkey. CES topics included things like beauty, fun, creativity, and history. Some of the other topics discussed included seafood, air quality, and global warming. An explanation of the intangible and environmental aspects of the four CES is provided, as well as their relationships.

"Social media-based analysis of cultural ecosystem services and heritage tourism in a coastal region of Mexico"(Ghermandi et al., 2020)**.** As a region rich in biological and cultural diversity, the Usumacinta floodplain is the focus of this investigation into the cultural services offered to visitors from near and far. They analyze pictures posted on social media and use high-resolution maps to find connections between cultural services and the ecosystems and land uses that support them. Places that attract a lot of tourists from all over the world are usually very well-known and easy to get to. Cultural ecosystem services, such as those provided by places for non-extractive recreation (such as hiking, walking, birdwatching, and boating) and for large-scale aesthetic benefits, are the primary focus of environmental research based on social media data. A few examples of possible uses are in the areas of ecotourism and traveler interest. Residents have a 2.2–2.5 point advantage over tourists in their appreciation of the arts and ornithology. Lagoons, mangroves, beaches, and the ocean continue to dominate the photo submissions from locals.

“Coastal ecosystem services in Bay of Bengal and efforts to improve their management”(Mozumder & Shamsuzzaman, 2018)**.** This study analyzes the current state of the Bay of Bengal's surrounding coastal ecosystem services as well as their contribution to the effort to improve their management. This study relies on secondary data gathered from scientific research articles and journals. They discovered numerous services such as fisheries, coral reefs, mangrove forests, and coastal tourism.

“Willingness to pay for Beach Ecosystem Services: The case study of three Colombian beaches”(Enriquez-Acevedo et al., 2018)**.** This paper discusses the findings of a WTP study conducted on three beaches in the Caribbean region of Colombia. Seventy-plus percent of those polled at the three beaches valued the continuation of Beach Ecosystem Services (BES) even after tourism had died down. The monthly fee at two beaches was $3.40, while at the third it was $6.80. The payout could be impacted by the state of the beach's environment. WTP on beaches was unaffected by socioeconomic factors like income and employment. Environmental concerns and the decline of ecosystem services determined the value placed on BES. The findings presented here may give policymakers useful quantitative insight into public preferences for beach renovation initiatives.

“Scale and ecosystem services: how do observation, management, and analysis shift with scale lessons from Québec” (Raudsepp-Hearne & Peterson, 2016)To identify the effects of the social-ecological scale on ecosystem service assessment, researchers looked at how the distribution, trade-offs, and bundles of ecosystem services varied across different spatial scales. In this study, researchers looked at a case study in Québec, Canada, to analyze the production, consumption, and management of 12 ecosystem services, as well as the changes in interactions among 7 of these services, across three different observational scales (1, 9, and 75 km2). Even though the patterns and interactions of ecosystem services were stable across all scales of observation, the researchers did find four scale mismatches in the production, consumption, and management of these services. In light of these results, they proposed four scale factors for evaluating ecosystem services.

“Quantification and assessment of changes in ecosystem service in the Three-River Headwaters Region, China as a result of climate variability and land cover change” (Jiang et al., 2016)**.** This study quantified and assessed changes in ecosystem

services in China's Three-River Headwaters Region from 2000 to 2012. This study assessed the historical flow of regulating services, such as soil conservation, water yield, and carbon sequestration, and provisioning services, such as food provision, using biophysical models such as the Integrated Valuation of Ecosystem Services and Trade-Offs, the Revised Wind Erosion Equation, and the Carnegie-Ames-Stanford Approach. Both soil conservation and water yield showed growing spatial homogeneity in the ecosystem. Net primary productivity and food output rose between 2000 and 2012. Inter-connected ecosystem services. Correlation studies found a synergy between soil conservation and carbon sequestration and a trade-off between water yield and carbon sequestration. Congruence was found across pasture, meat, and grain. Ecosystem services depend on climate variability and vegetation restoration. The temperature increased NPP (P 0.1), while increased precipitation increased water yield and soil erosion. The TRHR's ecological rehabilitation and changes in essential ecosystem services showed the benefits of environmental legislation and the importance of adaptive management.

"Defining and classifying ecosystem services for decision making"(Fisher et al., 2009)**.** Ecosystem services are a theoretical framework that connects environmental health and human well-being. When making a choice, it's essential to grasp this connection. There has been a lot of work put into trying to categorize ecosystem services, but as of yet there isn't a single, universally accepted definition. In this work, they define ecosystem services and present numerous taxonomic frameworks. They propose a system of classifying ecosystem services that take into account both the ecosystems of interest and the decision environment in which the concept is put into practice. No single taxonomy will be adequate for the wide variety of uses to which research on ecosystem services could be put. They investigate how ecosystems, ecosystem services, and the circumstances surrounding decisions affect classification approaches.

(Millennium ecosystem assessment, 2005) Kofi Annan proposed the Millennium Ecosystem Assessment in 2000. Three international conventions endorsed the 2001 assessment. The Millennium Ecosystem Assessment investigated the consequences of ecosystem change on human well-being and developed the scientific basis for enhancing the conservation and sustainable use of ecosystems. The MA responds to government information requests through four international conventions—the

Convention on Biological Diversity, the UN Convention to Combat Desertification, the Ramsar Convention on Wetlands, and the Convention on Migratory Species—and meets the needs of other stakeholders such as the business community, the health sector, nongovernmental organizations, and indigenous peoples. Sub global assessments met regional user demands. "Ecosystem services" link ecosystems to human well-being. Plant, animal, and microbial communities interact in an ecosystem. The MA includes natural forests, managed farmland, and urban areas. Ecosystem services benefit humans. Provisioning, regulating, cultural, and sustaining services include food, water, timber, and fiber. Despite culture and technology, humans need ecological services.

“Mangrove Ecosystems of Asia”(Faridah-Hanum et al., 2013)**.** The scope, current practices, and future challenges of environmental management are discussed in relation to Asia's mangroves. The risk to mangrove ecosystems prompted the creation of this scientific compilation. The contributors to this volume are ecologists and biologists specializing in mangroves from a variety of countries and regions, including India, Bangladesh, China, Japan, the Philippines, Timor-Leste, Indonesia, Australia, New Zealand, Thailand, and Malaysia. Instead of rehashing previous studies and surveys on mangrove ecology, the authors were tasked with offering novel ideas for the conservation and management of Asia's rich Pacific and its valuable resources. The first part of the book is dedicated to mangrove ecology in a variety of different countries, including Timor-Leste, New Zealand, Bangladesh, the Philippines, Thailand, Iran, Indonesia, and Malaysia. Organic carbon storage and turnover in the mangrove ecosystem, climate change effects on mangrove communities, and adaptation options are discussed in the second section, along with other topics such as economic sustainability, mangrove deforestation, GIS and remote sensing applications, and economic development. In the final section, we take a look at the economic viability of halophytes and the current state of sustainable management studies. When all is said and done, it is recommended that mangroves in the Asia-Pacific region be the subject of further discussion and study.

“Phytosociology and biodiversity of roadside herbs in a salinity-affected coastal area of Bangladesh” (Selim et al., 2021). This paper describes phytosociology, herbaceous plant diversity, and soil salinity gradients in Shyamnagar, Bangladesh. 25 roadside quadrants were studied for herbaceous plant diversity and soil parameters.

EC and moisture levels increase from north to south. The salinity hot spots are near the river or aquaculture and low-lying. There were 1116 herbaceous plants of 11 types. The main species, Croton *Bonplandianum baill*, is more adaptable to soil EC. In four of the 25 high EC, moisture, and elevation quadrants, no plants grew. The diversity of herbaceous plants decreases with increasing soil salinity as you move southeast. The area has a concentrated population, contagious plant species, and four prominent clusters. Roadside herbs have medicinal value and provide cooking fuel to fuel-scarce coastal communities. The study's results shed light on herbaceous plant diversity and soil salinity. Overall, the study's findings help us understand how environmental stressors affect the distribution of shoreline herbaceous plants.

"A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya"(Saxena & Singh, 1982)**.** This study analyzes the Gola River's northwest basin in the Kumaun Himalaya. *Pinus roxburghii*, mixed, *Quercus leucotrichophora*, *Quercus lanuginosa,* and *Quercus floribunda* were among the forest types found at 14 sites and 56 stands between 1,200 and 2,523. Slope and orientation affected ground cover composition. *Q. lanuginosa's* roots were the thickest. Depending on the slope's position and aspect, tree and shrub species and seedling numbers varied. The richness of mixed forest species increased as total basal area increased. Cooler (and wetter) and warmer (and drier) exposures favored shrubs and seedlings, but intermediate conditions favored trees, saplings, and herbs. *P. roxburghii* and mixed forests had a positive relationship between shrubs plus seedlings and trees plus saplings. In low-diversity communities, tree dominance-diversity curves progressed geometrically. *Q. lanuginosa* regenerates better than *Q. leucotrichophora.*

3 Methodology

3.1 Study area

Guliakhali Sea Beach is situated in Sitakunda upazila of Chittagong district. Locals call this beach as Muradpur Beach. This beach is only 5 km away from Sitakunda Bazar. Its Latitude is 22º3689399 N and Longitude is 91º83522E.The natural beauty of Guliakhali has made it different. One does not have to go Sundarbans to see Swamp forest and mangrove because they can find it here

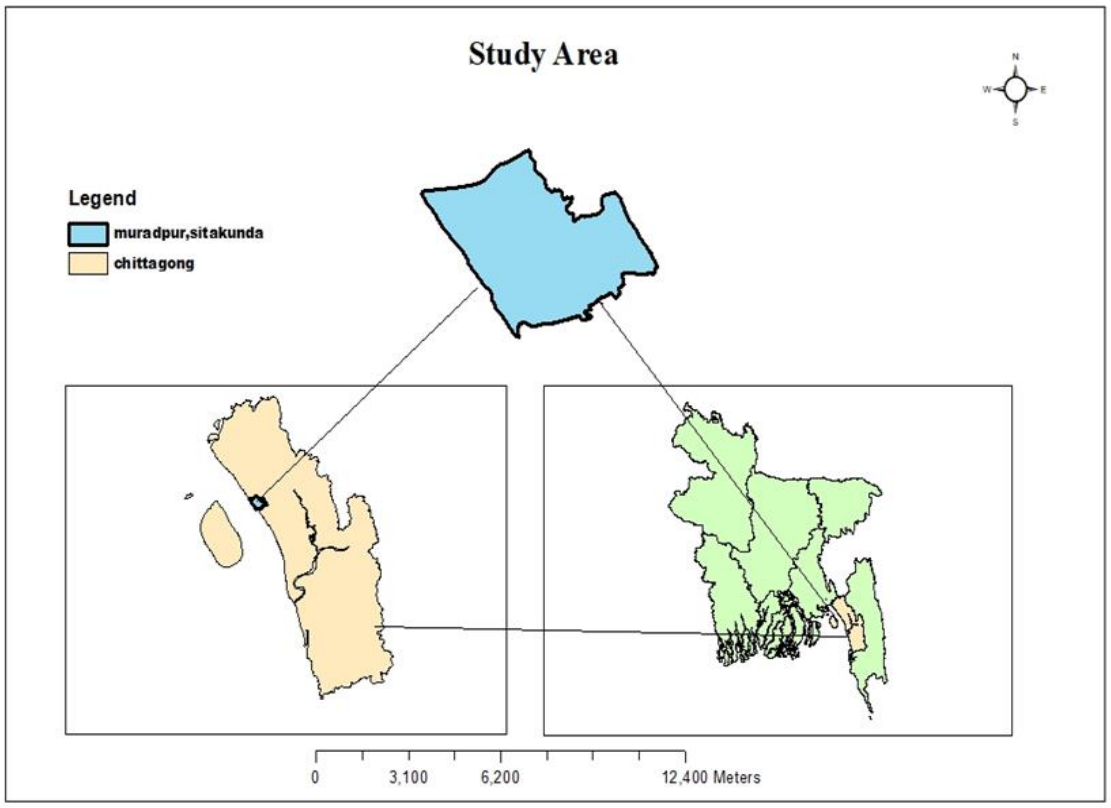


Figure 2: Study area map Guliakhali, Chottogram (own illustration).

3.2 Data collection procedure

Quantitative and qualitative methods of analysis have been used interchangeably in this investigation. However, since primary data collection via direct observation formed a central part of the study's design, it was inevitable that this method would be favored. (Enriquez-Acevedo et al., 2018).Sample quadrat estimation (Biswas et al., 2007) and interview. Secondary information was collected by analyzing various books, scientific journal, news report etc. which is already done by the researcher regarding the topic. So data collection process was done by the following framework.

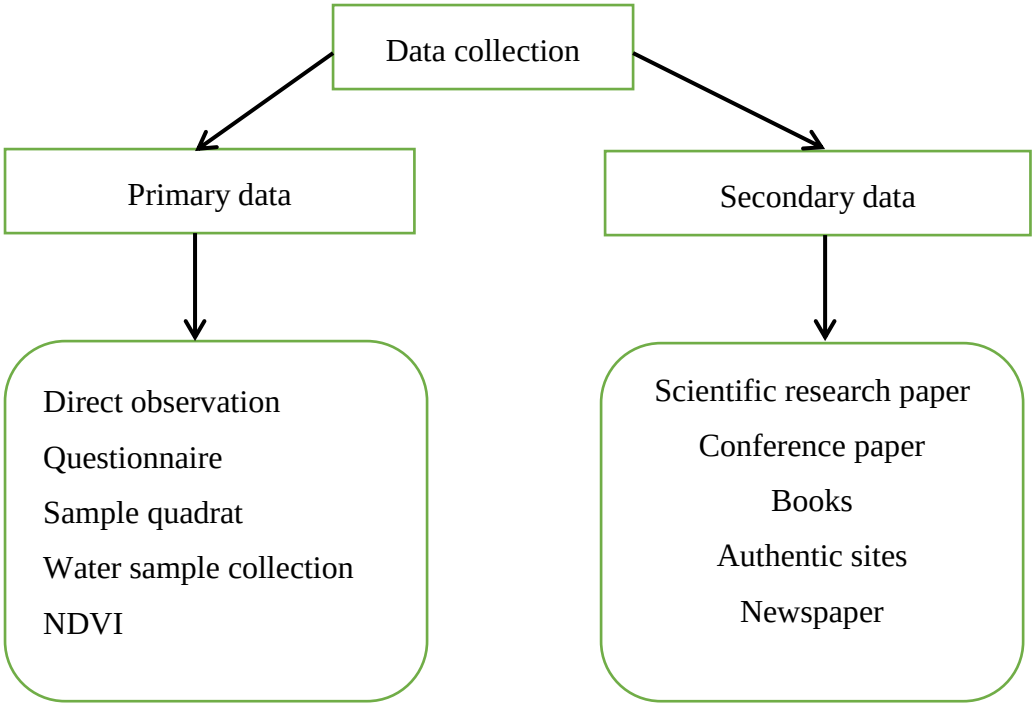


Figure 3: Data collection process.

3.2.1 Direct observation

Direct observation is the ancient and usual the instrumental method till yet. Direct observation method has been used in conditions which are free, partially controlled or manipulated. By going to the study region allowed for in-depth observations of each and every ecosystem service. In addition to fish and animal species, every sort of plant species was listed. Single observation may take less than one minute to many hours(Jersild & Meigs, 1939).The basic method and the scale of observation both have an impact on the model of ecosystem services. (Raudsepp-Hearne & Peterson, 2016).It was attempted to evaluate and classify Guliakhali Beach's ecosystem services

3.2.2 Questionnaire

Different sets of the question were asked to the local people in different prospect when the get from the beach what benefit them and what kind of benefit do they get from it. Typically, a questionnaire is used for gathering quantitative primary data. Using a questionnaire, quantitative data can be gathered in a consistent format that is easier to analyze. Questionnaires must be related to the study purpose(Roopa & Rani, 2012). A set of matrix question, open ended question as well as close ended question

was asked to the local people as well as tourist for the assessment of the ecosystem services.

3.2.3 Sample quadrat

14 quadrats had been selected in the study area for getting data. Each quadrat was 10m×10m (Saxena & Singh, 1982).Basically quadrat is a definitely enclosed area. Quadrat is used for gather the massive knowledge of vegetation (Gleason, 1920).Due to the increase of the ecological study use quadrat become more popular(Weaver, 1918).Then species have been identified within the quadrat and counted. Then process has been repeated again and again for the every quadrat. Following data sheet (table 2) was used to collect data from the every plot.

Figure 4: During the sample quadrat estimation.

Table 2: Tabulation Example for Estimating Quadrants

Sampling Quadrat ($10m^2$)	
Plant Species	n (Number of Individuals)
Sonneratia apetala	| **(1)**
Avicennia officinalis	𝍸 || **(7)**
Excoecaria agallocha	| **(1)**

3.2.4 Water sample collection

Throughout the study area, ocean water was sampled at regular intervals of half kilometers. And then water was collected from inland bodies, then from groundwater sources such as tubewell and pumps. The water sample was then kept in the sampling bottle, and each container was leveled. After that, it was stored safely for future scientific investigation of the material.

Figure 5: Water sample collection from the sea

3.3 NDVI

The abbreviation "NDVI" means "normalized difference vegetation index." Spectral radiance (or reflectance) measurements in the red (visible) and NIR (near-infrared) regions are referred to as "red" and "NIR," respectively (Kriegler et al., 1969).

$$\text{NDVI} = \frac{IR-R}{IR+R}$$

No matter whether radiance, reflectance, or DN is used as inputs, the normal distribution of the NDVI is 0 to 1. Surfaces made of rock, sand, or concrete have values close to zero; bodies of water have values in the negative; and surfaces covered

in plants, including trees, shrubs, grasses, and bushes, have values in the positive (Jones & Vaughan, 2010). NDVI has been performed in between 2017 to 2022.

3.4 Data analysis

After collecting data it was analyzed as per our requirement. Data analyzing process was according to the following frame work.

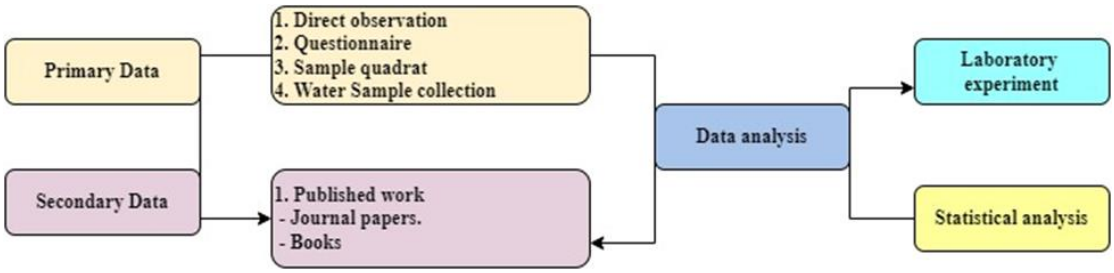


Figure 6: Structured Framework for Data Analysis.

In this particular instance, certain perimeters were measured in the laboratory of the university, which was also the location where the salinity, Total Dissolved Solid (TDS), and Electric Conductivity (EC) of the collected water were determined.

3.4.1 Simpson Diversity index

One way to evaluate diversity is with Simpson's Diversity Index (D). It is frequently employed in ecology to assess a site's level of biodiversity. It considers both the diversity of species and the relative abundance of those species.

Simpson Diversity Index =1- $\frac{\sum n(n-1)}{N(N-1)}$

Here,

n = Total number of people from all species.

N = Total number of organisms, across all species

After the computation is complete, the Simpson Diversity Index (D) yields a value between 0 and 1. Again, this index's value can be anywhere from 0 to 1, with a higher number indicating a more diverse sample.

Table 3: A technique for evaluating diversity based on Simpson's index (D).

Species name	**n**	**(n-1)**	**n(n-1)**
Sonneratia apetala	1	0	0
Avicennia officinalis	7	6	42
Excoecaria agallocha	1	0	0
			∑n(n-1)= 42
	N=9 (N-1)= 8	(N-1)= 8	N(N-1)= 72
D= 1- $\frac{\sum n(n-1)}{N(N-1)}$		**D= 1-0.583**	**D=0.416**

3.4.2 Instrumental techniques

The calculation of the data has been accomplished using a wide variety of resources. Water salinity, total dissolved solids, and electrical conductivity have all been measured using their own specialized equipment. Cartography was performed using Google Earth Pro and ArcGIS 10.8. We used modeling software like ArcGIS 10.8 to generate the required maps and image classification data.

Table 4: The Study Equipment, Tools, and Programs Used.

Category	**Parameters**	**Name or Model**
Instruments	Water Salinity	Portable Salinity Refractometer
	TDS	HANNA P^H/EC/TDS/Temperature Meter (HI9814)
	EC	EC HANNA EC Tester (HI98304)
Tool	Navigation	Garmin Etrex® 10 (GPS Navigation Device)
		Google Earth Pro
Software		Arcgis 10.8

The following is a list of the instruments, measures, and analysis tools that were used to compile the study's findings.

4 Results and discussions

4.1 Ecosystem services

This part just attempts to demonstrate the study's outcomes or results. The identified ecosystem services were initially categorized as provisioning services, regulatory services, cultural services, and habitat services. The section illustrated the plant diversity pattern found on Guliakhali Beach and created a list of the recognized plant species. Finally, ecosystems were valued using the Millennium Ecosystem Assessment and Total Economic Value frameworks.

4.1.1 Provisioning service

Guliakhali beach has seven distinct sorts of provisioning services. Fish, fruits (plants), medicinal plants, ornamental resources, and fuels have been identified as providing services. The Guliakhali beach was home to seventeen (17) different types of fish, four (04) different types of fruit (plant), ten types of vegetable species, one type of grain species, two (02) different types of medicinal plants, and two types of decorative resources. Guliakhali beach produces a lot of dried leaves, twigs, and dead objects due to its dense forest cover. The identified services were frequently obtained directly from Guliakhali beach by local people or guests. As a result, these various sorts of ecosystem services are classified as provisioning services in the study.

Table 5: Categorization of identified provisioning services.

Section: Fish		
Local name	**English name**	**Scientific name**
Ilish	Hilsha	*Tenualosa ilisha*
Nuna Tengra	Long whiskers catfish	*Mystus gulio*
Chingri	Indian prawn	*Penaeus indicus*
Loitta	Bombay Duck	Harpadon nehereus
Poa	Pama croaker	*Otolithoides pama*
Chiring or Chewa	Mudskipper	*Pseudapocryptes elongates*
Baila	Scribbled Goby	*Awaous guamensis*
Rupchada	Chinese silver pomfret	*Pampus chinensis*
Surma	Indo-Pacific king mackere	*Scomberomorus guttatus*l
Pangas	Yellowtail catfish	*Pangasius pangasius*
Topse	Mango fish	*Polynemus paradiseus*
Kachki	Ganges river sprat	*Corica soborna*
Katla	Indian Carp	*Catla catla*
Rui	Rohu	*Labeo rohita*
Mrigel	The mrigal carp	*Cirrhinus cirrhosus*
Section: Fruit		
Local name	**English name**	**Scientific name**
Khejur	Date	*Phoenix sylvestris*

Narikel	Coconut	*Cocos nucifera*
Kola	Banana	*Musa acuminate*
Peyara	Guava	*Psidium guajava*
Section: Medicinal plant		
Local name	English name	Scientific name
Shishu	Indian rosewood	*Dalbergia sissoo*
Lal Jhau	Athel pine	*Tamarix dioica*
Section: Vegetables		
Local name	**English name**	**Scientific name**
Sheem	Bean	*Lablab niger*
Barbati	String bean	*Vigna sesquipedalis*
Misti Kumda	Sweet Gourd	*Cucurbita maxima*
Chal Kumda	Wax gourd	*Benincasa hispida*
Khira	Cucumber (short)	*Cucumis anguina*
Begoon	Brinjal	*Solanum melongena*
Tomato	Tomato	*Lycopersicon esculentum*
Dhedosh	Okra	*Lycopersicon esculentum*
Dhundul	Sponse gourd	*Luffa cylindrical*
Karala	Bitter gourd	*Momordica charantia*
Section: Food Grain		
Local name	**English name**	**Scientific name**
Dhan	Rice	*Oryza sativa*
Section: Ornamental resources		
Local name	**English name**	**Scientific name**
Jhinuk	Cowrie	*Cypraea tessellata*
	Ark Shell	*Anadara corbuloides*
Section: Fuel		
Dry leaves of trees	Dry dead trees	Dry twigs of trees

4.1.2 Cultural service

Through participant observation and surveys, this research catalogs the cultural offerings at Guliakhali Beach. Guliakhali beach has fifteen (15) distinct forms of cultural service. Cultural services were identified and classified into four (04) sections. The part is divided into four sections: recreation, relaxation, spirituality, social interactions, economics (companies), and academics (Table no 6). Tourists are asked to fill out a survey in order to gain insight into their experiences and opinions of the area. These intangibles are what the region offers to its residents.

Table 6:Classification of the cultural ecosystem services that have been identified.

Section: Recreation, relaxation and spiritual		
Walking and exercise	Playing (beach football)	Boat riding
Cycling	Physical and mental health	Aesthetic beauty

Section: Social relation		
Birthday celebration	Hangout and meeting	Get together
Picnic		
Section: Economic (Businesses)		
Selling commodities	Restaurant and mini restaurants	Mini tea stall
Section: Academic		
Group study, drawing and research	Architectural planning and design	

4.1.3 Regulating service

Guliakhali beach has eleven (11) different types of regulated services. There are many regulatory services provided by Guliakhali Beach, including photosynthesis, carbon sequestration and storage, temperature regulation, air flow regulation, noise level regulation, water quality regulation, soil salinity reduction, erosion regulation, soil retention, waste management, pollination, and seed dispersal (Table 7). These services are classified as regulating services because people frequently benefit from them as a result of the dynamic environmental processes that occur on Guliakhali beach.

Table 7: Categorization and detail description of identified regulating services.

Section: Photosynthesis, carbon sequestration, and storage, air quality regulation
Carbon dioxide (CO2) depletes the ozone layer (GHG). CO2 is causing air unpredictability in urban areas. CO2 is the primary component of photosynthesis (Manteghi et al., 2015) . Massive mangrove flora grew all around the beach, constantly absorbing CO2 to direct their photosynthetic process. Guliakhali is teeming with amphibian little fishes in the water bodies, which are surrounded by vegetation Microorganisms and plants have also found ways to store CO2 in their tissues. But the Guliakhali plants are constantly releasing extra oxygen (O2) into the atmosphere, so they must be helping to improve air quality.
Section: Erosion control and soil retention
Guliakhali beach has many mangrove plants and grass that cover the beach like a green carpet. Plant life is essential for keeping the soil in place. Reduce soil erosion by boosting plant cover, root biomass, and rock and soil biota conservation.
Section: Soil salinity regulation
Coastal areas contain saline soil due to the penetration of saline water from the

ocean, but studies show that soil salinity was much higher in bare land, whereas forested land had increased soil organic matter, organic carbon, potassium nitrogen, and phosphorus (Mamun et al., 2021).
Section: Pollination, and seed dispersal
Fertilization moves dust from male to female plant parts, while seed dispersal transports seeds (Calviño-Cancela et al., 2012). Fertilization occurs on Guliakhali beach on a regular basis, primarily by flying creatures and wind. Seed distribution is also commonly accomplished by wind, water, and winged species (Howe & Miriti, 2004). For seed transportation from one location to the next, ocean waves assumed an important role in Guliakhali Beach. The abundant plant variety example of Guliakhali beach demonstrates the dynamic fertilization and seed dispersal patterns that occur there.
Section: Water quality control, and waste management
Although Guliakhali is a common source of contamination in fresh water, it can also be used to remove and break down organic wastes that have been flushed into coastal or marine ecosystems. Relationships exist between the timing and magnitude of runoff, flooding, and aquifer recharge.

4.1.4 Supporting service

Guliakhali beach is a vast environment for flora, avifauna, fish, and a variety of other animal species. The Guliakhali beach has a wide variety of habitats for fish (Table 5), birds, and plants (Table 5) species. In the water bodies of Guliakhali beach, fifteen (15) fish species have been identified. It is home to several mangrove species, including Keora (Sonneratia apetala), Gewa (Excoecaria agallocha), Blind-your-eye mangrove, and Bain (Avicennia officinalis), Gray Mangrove.

Table 8: Categorization and detail description of identified supporting services.

Section: Habitat supporting	Guliakhali beach has a diverse habitat for flora, avifauna, fish, and other animal species.
Section: soil formation	Soil is a complex natural body generated from its parent material by the impact of plants, bacteria, soil animals, water, and air (Van Breemen & Buurman, 2002). With these conditions, Guliakhali beach is ideal.
Section: water cycle	Guliakhali helps recycle water. Because The ocean contains 97% of the Earth's free water, making it a key player in the global water cycle. Despite this, oceans

	account for 86% of global evaporation and 78% of world precipitation (Schmitt, 1995) .
Section: nutrient regulation	Guliakhali is involved in fertilizer transportation, storage, and recycling.

4.2 Plants species diversity

During the course of this investigation of the Guliakhali beach area, a total of 23 plant species were documented. These species are divided into four plant categories. Each species has a local name, an English name, a scientific name, and a plant type (Table 5). Plants has been classified as climbers, herbs, shrubs, or trees. The majority of the 23 plant species are tree species. We discovered 10 tree species, 2 shrub species, 4 herb species, and 7 climber species in total (Table 9). Mangrove species dominate the Guliakhali beach. At Guliakhali beach, four different types of mangrove species were detected. At Guliakhali beach, four different types of mangrove species were recognized. At Guliakhali beach, four distinct types of fruit (plant) species were detected. Guliakhali beach also has two distinct sorts of medicinal (plant) species.

Table 9: Categorization of identified plant species

Local name	English name	Scientific name	Plant types
Khejur	Date	*Phoenix sylvestris*	Tree
Narikel	Coconut	*Cocos nucifera*	Tree
Kola	Banana	*Musa acuminate*	Herb
Peyara	Guava	*Psidium guajava*	Tree
Shishu	Indian rosewood	*Dalbergia sissoo*	Tree
Lal Jhau	Athel pine	*Tamarix dioica*	Shrub
keora	Mangrove apple	*Sonneratia apetala*	Tree
Gewa	Blind-your-eye mangrove	*Excoecaria agallocha*	Tree
Bain	Gray mangrove	*Avicennia officinalis*	Tree
Bilati Jhau	She oak	*Casuarina equisetifolia*	Tree
Akashmoni	Earleaf acacia	*Acacia auriculiformis*	Tree
Kata mandar	Coral bean	*Erythrina fusca*	Tree
Sheem	Bean	*Lablab niger*	Climber
Barbati	String bean	*Vigna sesquipedalis*	Climber
Misti Kumda	Sweet Gourd	*Cucurbita maxima*	Climber
Chal Kumda	Wax gourd	*Benincasa hispida*	Climber

Khira	Cucumber (short)	*Cucumis anguina*	Climber
Begoon	Brinjal	*Solanum melongena*	Herb
Tomato	Tomato	*Lycopersicon esculentum*	Herb
Dhedosh	Okra	*Lycopersicon esculentum*	Shrub
Dhundul	Sponse gourd	*Luffa cylindrical*	Climber
Karala	Bitter gourd	*Momordica charantia*	Climber
Dhan	Rice	*Oryza sativa*	Herb

4.3 Plant diversity assessment

Though salty and sandy beaches do not support much vegetation. In this case it show

Guliakhali Beach is covered in moderate mangrove vegetation. Table 9 depicts the flora diversity of Guliakhali Beach. Guliakhali Beach had patchy but high plant diversity for mangrove species. The Simpson Diversity Index value for plant diversity was D=0.274 and it was achieved using plant species from Guliakhali Beach. High levels of diversity are indicated by a Simpson Diversity Index (D) value close to one (D).The study discovered a value of D=0.274, which is very close to zero, indicating a low amount of plant variety in the Guliakhali beach region; however, keep in mind that beaches are sandy and salty in nature, which may not support diverse species of vegetation.

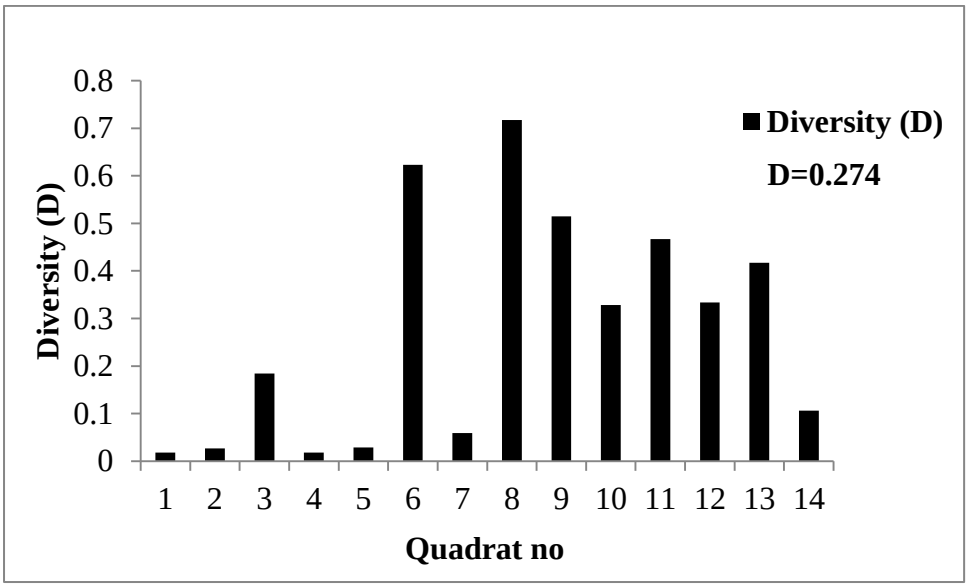


Figure 7 Plant species diversity of Guliakhali sea beach.

4.4 Vegetation pattern analysis:

Launched in 1965–1966, Bangladesh's innovative afforestation program is making use of the newly formed land along the Bay of Bengal. Currently, four Coastal Afforestation Divisions Chittagong, Noakhali, Barisal, and Patuakhali—are in charge of managing the coastal plantations that have been established in the coastal regions. These divisions are further divided into 28 forest ranges and 198 beats. 170,000 ha of coastal area were planted up until 2010, but there were significant plantation failures throughout (Papry, 2014).Bangladesh is home to about 27 different species of mangroves and a number of related species, the majority of these species are either uncommon or have little economic significance. To support silviculture, only 10 or fewer species are present frequently enough. Early plantations relied on trial and error, which is why only two species, *Sonneratia apetala* and *Avicennia officinalis*, showed promising survival rates and now predominate as monospecific stands in the mangrove plantations. The timber from these species, which is of medium quality, is used in building materials, furniture, and construction. and *Ceriops decandra*, made up the remaining areas (Saenger & Siddiqi, 1993) .

Mangrove species *Sonneratia apetala* and *Excoecaria agallocha*, with some *Avicennia officinalis*, predominate in the study area in the Sitakunda range of the Chittagong Division. It was discovered during sample collection that *Sonneratia apetala* is more numerous in areas close to the shore, while the absence of *Excoecaria agallocha* was observed in deeper waters. It's a different story once ones get inland. Salinity and the distance from the sample site to the coast are two variables that have been adapted for this purpose.

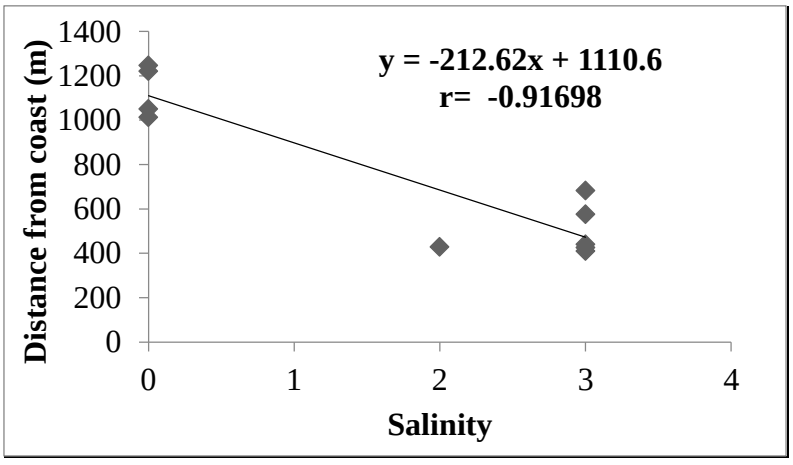
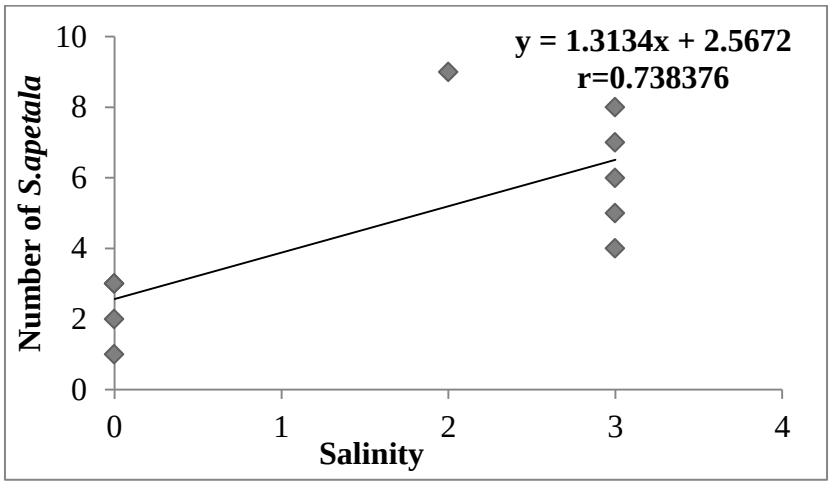
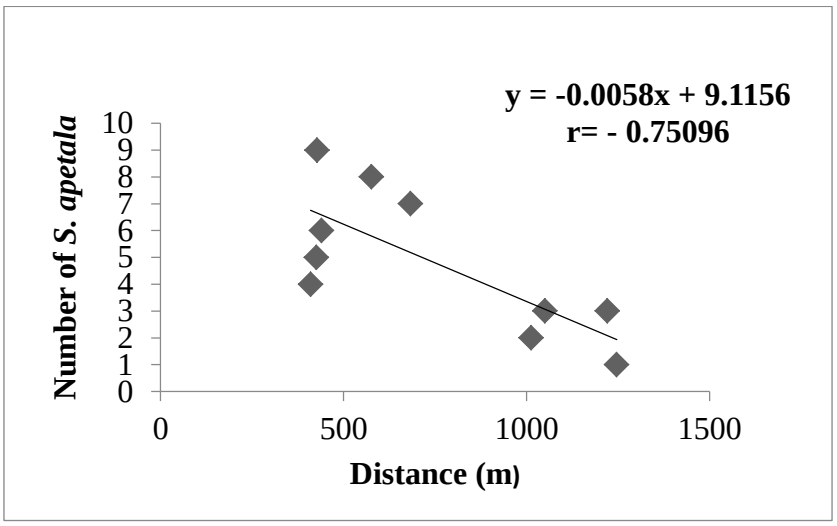


Figure 8: Correlation between salinity and coastline distance.

Figure 8 clearly show, there is a negative correlation of -0.91698 between distance and salinity. Which implies a strong negative correlation and simply conveys that salinity decreases as distance increases.



(a)



(b)

Figure 9: Relationship of number of *S. apetala* with salinity (a) & distance (b).

The correlation between *S. apetala* and salinity in this instance is 0.738, indicating that more *S. apetala* have been discovered in areas with salinity. On the other hand, the value of r=-0.75096, which shows a negative correlation between the distance from the shore and the number of *S. apetala,* simply shows that the species' abundance decreases with increasing distance.

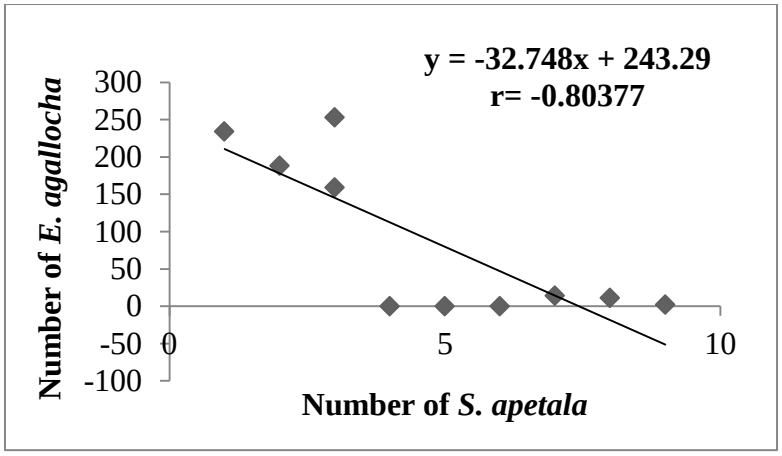
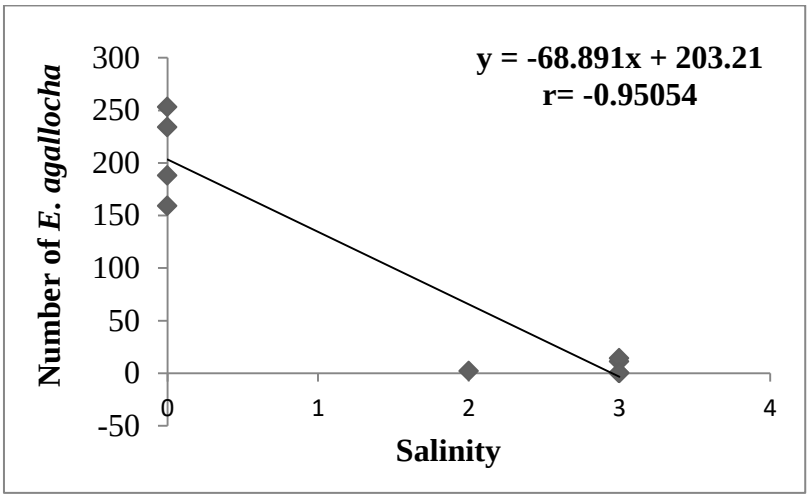
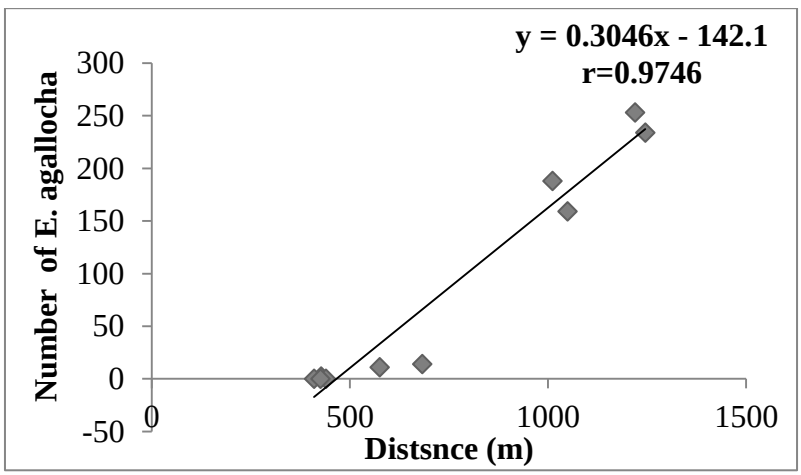


Figure 10: Relationship between *E. agallocha* & *S. apetala.*

The figure shows that the two species have a negative correlation or r=-0.80377. Where *E. agallocha* numbers are high, *S. apetala* numbers are low.



(a)



(b)

Figure 11: Relationship Salinity (a) and distance (b) with *E. agallocha*.

A negative correlation between *E. agallocha* and salinity is evident from the figure. With an increase in salinity, *E. agallocha* numbers decreased. Contrarily, There is a highly significant positive relationship between distance and *E. agallocha* population size. A large number of *E. agallocha* were discovered far from the coast.

4.5 NDVI change:

Little shift was observed in the spatial distribution of the major land use and land cover classes over the study's time period (Figure 11).Changing land use categories resulted in a decrease in the spatial extent of those categories.

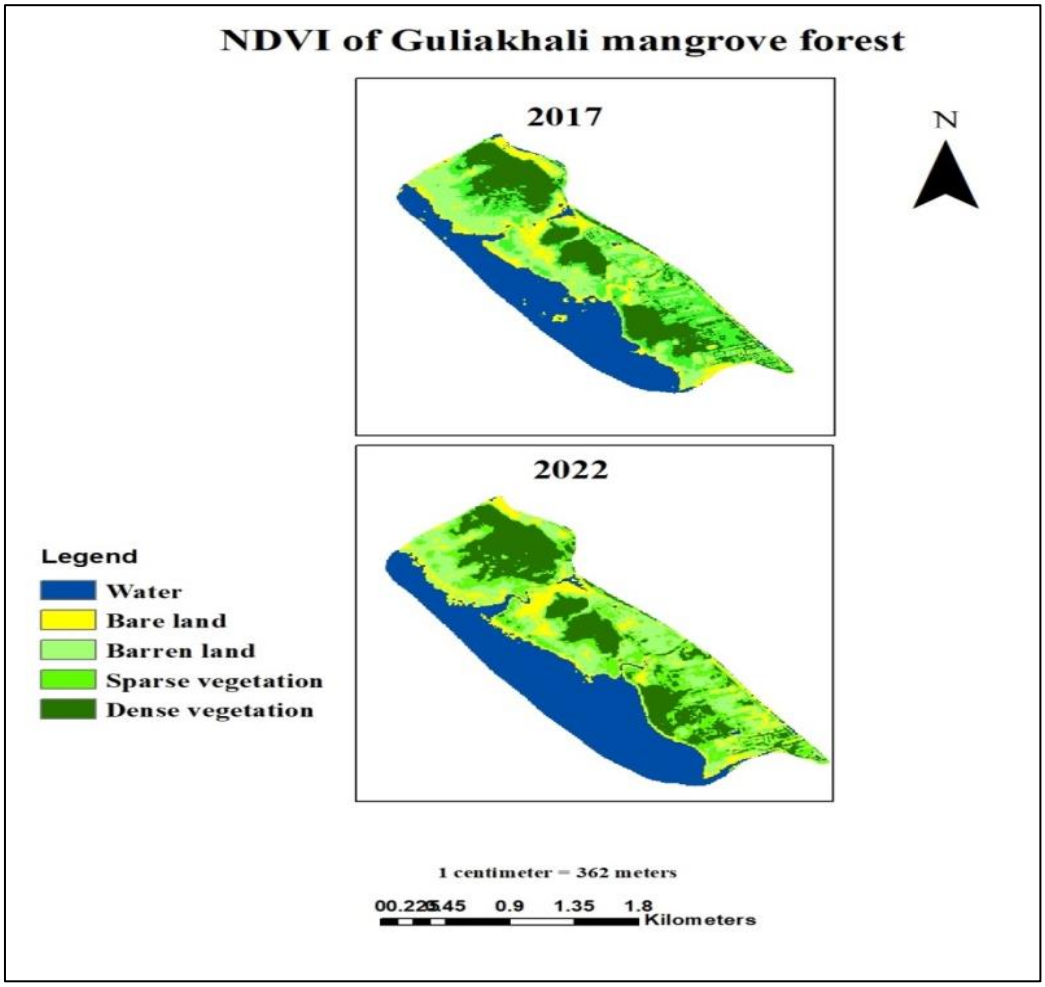
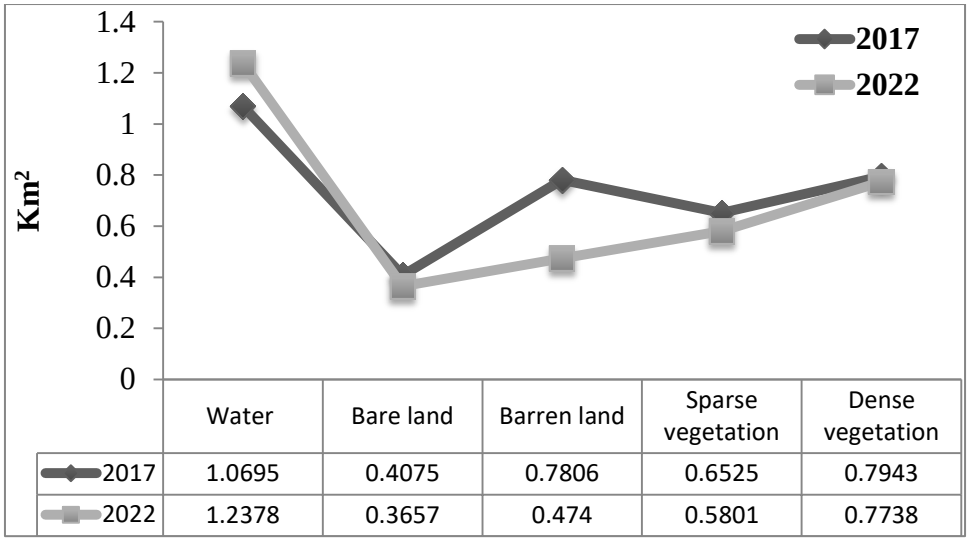


Figure 12: NDVI map of Guliakhali sea beach over the last 6 years.

Between 2017 and 2022, the water bodies showed a slight increase. The expansion of fisheries led to an increase in water bodies. On the other hand, a slight deterioration of bare land suggests that agriculture is being increased.



	Water	Bare land	Barren land	Sparse vegetation	Dense vegetation
2017	1.0695	0.4075	0.7806	0.6525	0.7943
2022	1.2378	0.3657	0.474	0.5801	0.7738

Figure 13: NDVI change over 2017- 2022

Furthermore, grasslands gradually shrank. Sparse vegetation is shrinking from 0.6 km2 to 0.5 km2 in the five years between 2017 and 2022. We can also see that the amount of dense vegetation will diminish, albeit gradually.

5 Recommendations & Conclusion:

5.1 Recommendations:

The mangrove forest and biodiversity of the Guliakhali region have been endangered in various ways due to recent increases in tourism. It reduced the security of the land and quickly altered the pattern of land use, potentially resulting in a natural disaster. Few recommendations have been offered to lessen the detrimental effects of an abrupt change in land use in the study area.

- Ecotourism must be managed sustainably due to its popularity and daily visitors. Land zoning decisions should involve locals.
- More research needs to be done to determine potential strategies for reclaiming the saline-affected soils for future plantations.
- Thorough land-use regulations that give the coastal area's environmental concerns top priority should be created and put into place.
- A GIS (Geographical Information System)-based monitoring system should be developed.
- A project for the reclamation of agricultural land ought to be started.
- More research should be done to find economically advantageous saline-tolerant species.
- The local population should be made aware of unauthorized land use activities through a widespread awareness campaign.

5.2 Conclusion:

It is now widely acknowledged that Guliakhali Sea Beach is one of Sitakunda's most visited locations, making it a convenient getaway for the region's economic growth. From the discussion above, This paper argued that the economic growth and environmental sustainability of the region depend on Guliakhali's wide range of ecosystem services. The ecosystem services are currently threatened by anthropogenic influences and the impacts of climate change on natural resources, as observed and discussed in both formal and informal settings with community members and forest officials. Therefore, the responsible authority should quickly implement a policy to ensure their safety while taking advantage of the Guliakhali's services. Therefore, the responsible authority should quickly implement a policy to ensure their safety while taking advantage of the Guliakhali's services. The authority should pay special attention to this issue in an urgent manner as it may be a key factor in the

socioeconomic growth of the nation given the cultural service's great potential for promoting ecotourism. This paper concludes that the Guliakhali ecosystem services can provide a cornerstone for sustainable development by combining our natural resources for nature and people with the increasing demands of a growing human population.(Manteghi et al., 2015)

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Appendix1

Quadrat 1			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**2**	**1**	**2**
Geoa (*Excoecaria agallocha)*	**228**	**227**	**51756**
			∑n(n-1)= 51758
	N= 230		**N(N-1)= 52670**
D = 1-(∑n(n-1))/(N(N-1)) = 0.018			

Quadrat 2			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**4**	**3**	**12**
Geoa (*Excoecaria agallocha)*	**279**	**278**	**77562**
			∑n(n-1)=77574
	N=283		**N(N-1)=79806**
D = 1-(∑n(n-1))/(N(N-1)) =0.027			

Quadrat 3			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**1**	**0**	**0**
Geoa (*Excoecaria*	**247**	**246**	**60762**

agallocha)			
Lal Jhau (***Tamarix dioica)***	**27**	**26**	**702**
			∑n(n-1)=61464
	N=275		**N(N-1)=75350**
D = 1-(∑n(n-1))/(N(N-1)) =0.184			

Quadrat 4			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**1**	**0**	**0**
Geoa (*Excoecaria agallocha)*	**221**	**220**	**48620**
			∑n(n-1)=48620
	N=222		**N(N-1)=49506**
D = 1-(∑n(n-1))/(N(N-1)) =0.018			

Quadrat 5			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**3**	**2**	**6**
Geoa (*Excoecaria agallocha)*	**189**	**188**	**35532**
			∑n(n-1)=35638
	N=192		**N(N-1)=36672**
D = 1-(∑n(n-1))/(N(N-1)) =0.029			

Quadrat 6			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	2	1	2
Lal Jhau (***Tamarix dioica)***	2	1	2
Khezur (*Phoenix sylvestris*)	6	5	30
			∑n(n-1)= 34
	N=10		N(N-1)=90
D = 1-(∑n(n-1))/(N(N-1)) =0.623			

Quadrat 7			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	4	3	12
Geoa (*Excoecaria agallocha)*	130	129	16770
			∑n(n-1)=16782
	N=134		N(N-1)=17822
D = 1-(∑n(n-1))/(N(N-1)) =0.059			

Quadrat 8			
Species name	**n**	**(n-1)**	**n(n-1)**
Coconut (Cocos nucifera)	4	3	12
Geoa (*Excoecaria agallocha)*	17	16	272

Bilati Jhau (*Casuarina equisetifolia*)	10	9	90
Akashmoni (*Acacia auriculiformis*))	16	15	240
			∑n(n-1)=614
	N=47		N(N-1)=2162
D = 1-(∑n(n-1))/(N(N-1)) =0.717			

Quadrat 9			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**8**	**7**	**56**
Geoa (*Excoecaria agallocha)*	**11**	**10**	**110**
			∑n(n-1)=166
	N=19		**N(N-1)=342**
D = 1-(∑n(n-1))/(N(N-1)) =0.515			

Quadrat 10			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**9**	**8**	**72**
Geoa (*Excoecaria agallocha)*	**2**	**1**	**2**
			∑n(n-1)=74
	N=11		**N(N-1)=110**
D = 1-(∑n(n-1))/(N(N-1)) =0.328			

Quadrat 11			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**7**	**6**	**42**
Geoa (*Excoecaria agallocha)*	**14**	**13**	**182**
			∑n(n-1)=224
	N=21		**N(N-1)=420**
D = 1-(∑n(n-1))/(N(N-1)) =0.467			

Quadrat 12			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**1**	**0**	**0**
Bain (*Avicennia officinalis)*	**5**	**4**	**20**
			∑n(n-1)=20
	N=6		**N(N-1)=30**
D = 1-(∑n(n-1))/(N(N-1)) =0.334			

Quadrat 13			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**1**	**0**	**0**
Geoa (*Excoecaria agallocha)*	**1**	**0**	**0**
Bain (*Avicennia officinalis)*	**7**	**6**	**42**
			∑n(n-1)=42
	N=9		**N(N-1)=72**
D = 1-(∑n(n-1))/(N(N-1)) =0.417			

Quadrat 14			
Species name	**n**	**(n-1)**	**n(n-1)**
Keora *(Sonneratia apetala)*	**3**	**2**	**6**
Geoa (*Excoecaria agallocha)*	**139**	**138**	**19182**
Lal Jhau (Tamarix dioica)	**5**	**4**	**20**
			∑n(n-1)=19208
	N=147		**N(N-1)=21462**
D = 1-(∑n(n-1))/(N(N-1)) =0.106			

Table 10 Checklist for identified Ecosystem services.

Category	Services	Yes	No
Provisioning	Food	√	
	Fresh water	√	
	Fiber	√	
	Medicinal resources	√	
	Ornamental resources	√	
Cultural	Recreation	√	
	Aesthetic	√	
	Spiritual	√	
	Social relation	√	
	Economic	√	
	Educational	√	
Regulating	Air quality regulation	√	
	Erosion control	√	
	Soil salinity regulation	√	
	pollination	√	
	Water quality control	√	
	Pest control		√
	Waste management	√	
	Climate regulation	√	
Supporting	Habitat supporting	√	
	Soil Formation	√	
	Water cycle	√	
	Nutrient regulation	√	

7 Appendix 2

Photographs: