IMPACT OF WATER SALINITY ON LOCAL PLANT DIVERSITY OF THE SANGU RIVER ESTUARY ZONE, CHATTOGRAM

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This Thesis Report Presented in Partial Completion 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 **"Impact of Water Salinity on Local Plant Diversity of The Sangu River Estuary Zone, Chattogram",** submitted by Rafiul Azad Chy. (ID: 163-30-152) to the Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU) has been accepted as satisfactory for the partial completion 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 17th February of 2021.

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DECLARATION

I hereby declare that this research project has been done by me under the supervision of **Dr. A. B. M. Kamal Pasha, Ph.D., Associate Professor and Head, Department of Environmental Science and Disaster Management (ESDM),** Daffodil International University (DIU). I also declare that neither this research project nor any part of this research project has been submitted elsewhere for the award of any degree.

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DEDICATION

To,

my loving parents

Shamsul Azad Chowdhury

Sajeda Begum

my younger brother and sister

Hafizul Azad Chowdhury

Tasnim Chowdhury

Tanjina Chowdhury

Sanjida Chowdhury

Bokul Chowdhury

my respected teachers

Dr. A. B. M. Kamal Pasha, PhD

Md. Azharul Haque Chowdhury

Dr. Mahfuza Parveen

Mrs. Zannatul Ferdaus

Dr. Hasibur Rahman

and

to the loving memory of my beloved seniors, juniors, coordination officers and staffs from the **Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU)** with whom I was spent a single second of my undergrad life in the last four year (8th Oct 2016 to 17th Feb 2021).

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ABSTRACT

Bangladesh is a deltaic land with hundreds of rivers. Many of them flow through and fall into the Bay of Bengal. Changing climate leads to the SLR and rising sea level causes the salinity in river water. The increasing salinity of river water directly affects the local ecosystem and plant diversity. In this study, we tried to assess the status of water salinity and existing plant diversity of the Sangu river of Chattogram. We also tried to observe the impact of water salinity on the local plant diversity of the Sangu river. In order to meet with the objectives, we directly measured the water salinity in eleven (11) sampling locations, we collected plant diversity information from all sampling locations and estimated the status of plant diversity using both Simpson (D) and Shannon (H) Diversity Index Formula. Then statistically we observed the impact of salinity on the plant diversity on the riverside. We also collected water samples from sampling locations to measure the level of TDS and EC of the river water. We conducted our data from Kodom Rosul to Rasulabad of the Sangu river. In the study area, the highest salinity (10 ppt) was found in Kodom Rosul (transition point of Sangu river with the Bay of Bengal). In the upstream zone, salinity gradually decreases (10 ppt to 1 ppt) from Kodom Rosul to Majhir-ghat. We observed almost zero salinity level in the river water of the upstream zone. The salinity level remains the same throughout the upstream zone. In the study area, the plant diversity value of both indexes increases with the increase of distance from the Kodom Rosul to Rasulabad. The range of plant diversity value is D = 3.906 to 9.434 and H = 1.467 to 2.309. All values of plant diversity are almost the same and close to each other. The highest plant diversity was also estimated in Rasulabad, D = 9.434 and H = 2.309. From the statistical analysis of all the findings above, we reach into a conclusion that in the downstream zone, as salinity increases, plant diversity tends to decrease towards the Bay of Bengal.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol or Unit	Name of the Symbol or Unit
'	Second
º	Minute
ºC	Degree Celsius
µS/cm	Micro Siemens Centimeter
mS/cm	Milli Siemens Centimeter
dS/cm	Deci Siemens Centimeter
ppt	Parts Per Thousand
ppm	Parts Per Million
m	Meter
m^2	Meter Square
km	Kilometer
sq.km	Square Kilometer

Abbreviation	Full-Form of the Abbreviation
BoB	Bay of Bengal
CCC	Climate Change Cell
CCZ	Central Coastal Zone
CLD	Causal Loop Diagram
COP	Conference of the Parties
DAE	Department of Agricultural Extension
DIU	Daffodil International University
EC	Electrical Conductivity
ECA	Environmentally Critical Areas
ECZ	Eastern Coastal Zone
EPA	Environmentally Protected Areas
ESDM	Environmental Science and Disaster Management
GBM	Ganges-Brahmaputra-Meghna
GIS	Geographic Information System
GPS	Global Positioning System
KII	Key Informant Interview
MoEF	Ministry of Environment and Forest
NAPA	National Adaptation Programs of Action
SAARC	South Asian Association for Regional Cooperation
SL	Sampling Locations
SLR	Sea Level Rise
SMRC	SAARC Meterological Research Centre
SRDI	Soil Resourece Development Institute
TDS	Total Dissolved Solids
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WCZ	Western Coastal Zone

CHAPTER 01: INTRODUCTION

The introduction chapter describes the introductory information of the research study. Those include a discussion about the background, statement of the problem and objectives of the study.

1.1. Background

Bangladesh, the world's biggest deltaic nation, comprises of a level and low laying actual geography aside from the upper east and southeast locale. That plane scene, dynamic delta framework, and dynamic morphology of Bangladesh assume a fundamental part in the weakness of this nation because of environmental change and rising ocean levels. Bangladesh had an enormous coastline at the edge of the Inlet of Bengal. This gigantic coastline comprises 19 locales. Among them, twelve regions are known as the uncovered coast and seven are chosen as the inside coast. This enormous coastline covers 32% of the land region of Bangladesh. Bangladesh is a place where there is a stream, that comprises hundreds (in excess of 700 waterways) of waterways. The Ganges, the Brahmaputra, and the Meghna are the three significant streams of our nation. There are 57 trans-limit waterways that are experiencing Bangladesh. Among them, the nation imparts 54 to India and 3 with Myanmar (Huq and Rabbani, 2014; Parven and Hasan, 2018).

1.2. Statement of the Problem

Over the most recent few decades, the dirt and water saltiness have expanded at a disturbing rate. Sea Level Rise (SLR) because of environmental change and far and wide shrimp cultivating close to the coast is the most powerful factor for the expansion of both soil and water saltiness in the beach front locale of Bangladesh. Sea Level Rise (SLR) consequently influence the common environment and biodiversity of the beach front zones. Saline water interruption towards the inland is causing a serious effect on the nearby plant species and its variety. Because of the saltiness, cultivable grounds close to the coast are not being utilized for rural creation. The expanded saltiness is the fundamental limitation for the development of yields and plants. That restricts the general horticultural creation and plant development in the seaside territory and makes the dirt fruitless for the yields and plants. Thus, expanded saltiness close to the coast is a significant issue that restricts the food grain creation in our seaside locales. Expanded saltiness because of the saline water interruption towards the inland causes the adjustments in the harvest and plant design in the seaside belt of Bangladesh. There is a critical distinction between the harvest creation of saltiness influenced beach front terrains and non-saline inland regions. Because of the saltiness, there is a limitation for typical harvest creation and ordinary plant development. There is a major distinction between saltiness inclined territory and other non-saltiness inclined zones. In a saltiness inclined territory, creation of the harvest, the force of trimming, level of creation, and nature of individuals' work are a lot of lower than the non-saline territories of our nation. Chattogram, a southern coastal area of Bangladesh. The Sangu is a stream that experienced South Chattogram and falls into the Bay of Bengal. The areas close to the Bay of Bengal of that Sangu stream is an exceptionally saltiness influenced territory. Because of the gigantic saltiness, the nearby natural framework is straightforwardly compromised. Particularly the plant species example and plant variety of the Sangu stream (Ahsan and Bhuiyan, 2010; Basar, 2012; Mahmuduzzaman et al., 2014).

1.3. Justification of the Study

A lot of research work has had done at the western and central coastal region of Bangladesh about the salinity and its impact on various factors (such as mangrove forest, agriculture, biodiversity, etc.). There is a limitation of research study about the river water salinity and its impact on the coastal regions of Bangladesh. Especially there is no research work have had done on the rivers of the Chottogram division.

Sangu river is an important river of Chattogram. No research work has been done on the Sangu river, its water salinity and water salinity impact on the surrounding. So, I have selected this topic as my research project in order to explore some new facts and phenomena about that region.

1.4. Objectives

This study is focusing on three specific objectives. Here we want to explore these three specific facts. We tried –

- **To assess the status and variation of river water salinity level between the downstream sampling locations of the Sangu river.**
- **To assess the status and variation of plant species diversity between the downstream sampling locations of the Sangu river.**
- **To assess the impact of river water salinity on the plant species diversity or pattern around the Sangu river.**

1.5. Structure of the Study Report

This research project report is divided into five (05) separate chapters. The introduction chapter describes the introductory information about the research project. Those include a brief discussion about the background, problem statement, and objectives of this research project. This chapter also demonstrates and briefly explain the structure of this research project report. The literature review chapter provides a detailed description of four sections. This chapter discusses the river water salinity, saltwater intrusion, the causes and factors that are responsible for the saltwater intrusion into the coastal rivers of Bangladesh, and discuss the related study done in Bangladesh. The methodology chapter mainly provides a detailed description of the study area and discuss the various systematic techniques that are used to conduct this study. The result and discussion chapter broadly discuss the findings and results of our study in a different form. At the beginning of this research project, we have assumed three different objectives and we worked on it. Here, in this chapter, we tried to get a well-organized understanding of the objectives by analyzing the collected data and findings in different ways. In the recommendation and conclusion chapter of the study, I tried to assemble all study points from the literature review, data collection, data analysis, results, and discussions. Here, we also tried to justify the objectives of the study. Recommendations are also given for the researchers in order to better understanding of the future study.

CHAPTER 02: LITERATURE REVIEW

This part gives a detail portrayal in four segments. This part examines the stream water saltiness, saltwater interruption, the causes and factors that are answerable for the saltwater interruption into the beach front waterways of Bangladesh and talk about the connected investigation done in Bangladesh. This part isolated into four (04) segments. That is –

2.1. Water Salinity

Saltiness is the general extent of salt in soil or water. It is normally estimated in ppt (parts per thousand). Water saltiness is the general extent of the salts that are broken up into the water. At the point when the saline water from the sea advances toward the land through the stream, the waterway water gets pungent and it's called stream water saltiness. In this way, saltiness occurs or increment due to the landward development of saline water from the ocean, known as the saline water interruption. Because of the variety of thickness and weight between saline water and new water, saline water moves towards the inland and it called the saline water interruption. Saline water contains a high level of broke down minerals and salts than freshwater. In this way, saline water has significantly more weight than freshwater in the conditions of a similar volume of water. Therefore, saline water consistently will in general push toward the inland underneath the freshwater (Gain et al., 2014).

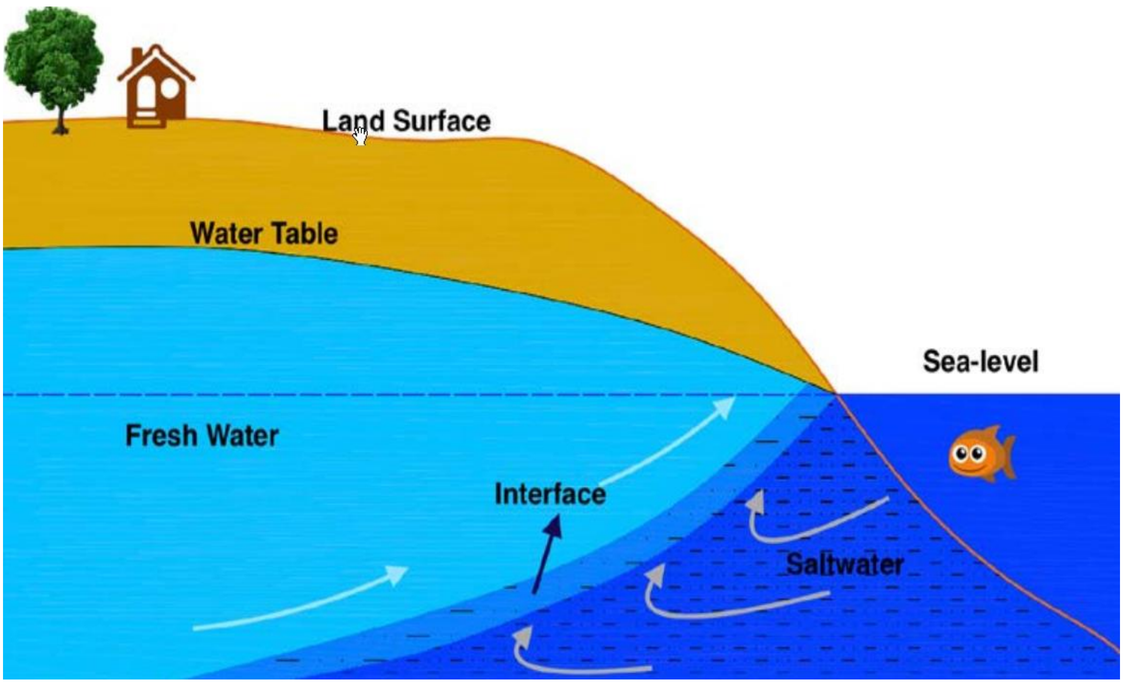


Figure 2.1: Conceptual Diagram of Salinity Intrusion Towards the Land.

2.2. Causes of Salinity in the Rivers of Coastal Bangladesh

Stream water saltiness essentially relies upon three significant marvels:

- **The volume of freshwater releases from the upstream zone of a stream**
- **The saltiness of the sea close to the coast**
- **The dissemination example of waterfront water instigated by the sea flows and solid flowing flows**

In Bangladesh, 80% of the nation is floodplain, that has an extremely low height over the degree of ocean water. The normal height of the southeast seaside territories are 4-5 m and the southwest beach front zones are 1-2 m (Dasgupta et al., 2015).

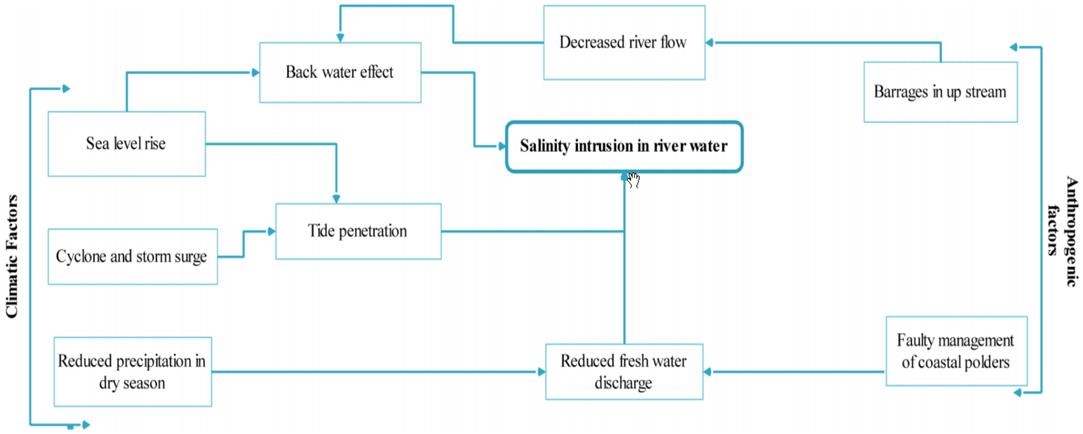


Figure 2.2: Causes of salinity intrusion in river water.

Followings are the main reasons for saline water intrusion in the coastal rivers of Bangladesh:

1. **Natural**
   - **Geographic location**
   - **Sea level rise**
   - **Natural hazard and disaster**
   - **Back water effect**
2. **Human Induced**
   - **Shrimp farming**
   - **Salt cultivation**

2.2.1. Geological Area

The southern locale of Bangladesh is one of the most profitable environments of the world and this is a piece of our beach front zone. Various waterways are experiencing that district, including the Ganges-Brahmaputra-Meghna (GBM) stream framework. Aside from this southern area of our nation, all different areas of our nation are plain land with a gigantic waterway network framework and scorch land (Sarwar, 2005). As indicated by (Islam, 2001), Seaside zone of Bangladesh has isolated into three fundamental areas:

- **Eastern Waterfront Zone (ECZ)**
- **Central Waterfront Zone (CCZ)**
- **Western Waterfront Zone (WCZ)**

The Eastern Waterfront Zone (ECZ) of Bangladesh is a tight district with a progression of little slopes that are run corresponding to this part. This waterfront zone begins from Bodormokam (the southern tip of the territory to the estuarine region of the Feni stream). The Karnafully, Matamuhury, Naf and Sangu stream experiencing that area and falls into the Sway. Bangladesh and Myanmar are partitioned by the Naf stream. The lowered sand shaped a 145 km long sandy ocean sea shore from Cox's Bazar to Teknaf. Patenga and Cox's Bazar ocean sea shore are the nation's two most significant ocean sea shore from a travel industry point of view. This beach front zone is generally significant for its travel industry exercises. However, salt development, fishing and fish cultivating is likewise the other major monetary exercises of this waterfront zone (Islam, 2001; Sarwar, 2005).

2.2.2. Sea Level Rise (SLR)

Bangladesh is a thickly populated nation. The waterfront areas of our nation are likewise thickly populated and that is entirely defenseless against the ocean level ascent. As indicated by Joined Countries Climate Program (UNEP), Ocean level will rise 1.5 m. in 2030 that will overpower around 16% of absolute land and impact around 15 million individuals of Bangladesh. Another examination extended the ocean level will rise 10 cm by 2020, 25 cm by 2050 and 1 m by 2100 that will overpower around 2%, 4% and 17.5% place where there is our nation separately (Seal and Baten, 2012).

Table 2.1: Intensity of impact due to climate change on different sectors.

	Physical vulnerability							
		Sea-level rise			Flood			
Sectoral vulnerability	Extreme temperature	Coastal inundation	Salinity intrusion	Drought	River flood	Flash flood	Cyclone and storm surges	Erosion and accretion
Crop agriculture	+++	++	+++	+++	+	++	+++	
Fisheries	++	+	+	++	++	+	+	
Livestock	++	++	+++			+	+++	
Infrastructure	+	++			++	+	+	+++
Industries	++	+++	++		++	+	+	
Biodiversity	++	+++	+++		++		+	
Health	+++	+	+++		++		++	
Human settlement							+++	+++
Energy	++	+			+		+	

Note: +++ high, ++ moderate, + lower impact.

In the reaction to the choice of UNFCCC's (Joined Countries Structure Show on Environmental Change) seventh Meeting of the Gathering of the Gatherings (COP7), Service of Climate and Woodland (MoEF), Bangladesh, has arranged Public Transformation Program of Activity (NAPA). In 2003, South Asian Relationship of Provincial Collaboration (SAARC) Meteorological Exploration Community (SMRC) watched the yearly flowing check from 1977-1998 and found that the flowing level in three-purpose of Bangladesh (Hiron Point, Roast Changa, and Cox's Bazar) rose (Table 02). The flowing degree of the Eastern Waterfront Zone (ECZ) is a lot higher than the flowing degree of the Western Seaside Zone (WCZ). Along these lines, saline water enters the waterfront locales of Bangladesh because of the ascending of ocean level (Seal and Baten, 2012). An investigation shows that 88 cm ocean level ascent impacts the 5 ppt saline water interruption towards 40 km inland of Tentulia freshwater waterway in Meghna estuary (Shamsuddoha and Chowdhury, 2007)

2.2.3. Natural Hazard and Disasters

Bangladesh is one of the most common risks and debacle inclined territory on the planet. Consistently we should adapt up to these wonders. There are different sorts of regular risk and calamity that are likewise liable for the interruption of the saline water towards the inland. For example, typhoon, storm flood, flowing flooding, and so forth. In Bangladesh, we encountered probably the deadliest typhoons in different time. Bhola Twister (1970) and Bangladesh Typhoon (1991) is the significant case of them (Ali 1996). During typhoon Sidr (2007) and twister Aila (2009), saline water meddles in horticultural land, lakes, trenches and waterways of the seaside zone that are as yet debased by the saline water. The people groups of the seaside zone are as yet experiencing that issue. The waterfront zone of Bangladesh is a level and low-lying district with a tallness of less than 3 m over the mean ocean level. Because of the unmistakable more elevated reach galactic tide and ocean level ascent, typhoon and tempest flood is probably going to be regular in the seaside Bangladesh (Seal and Baten, 2012). Recurrence of hurricane and tempest flood would increment with the higher pinnacle wind speeds and generous precipitation because of the environmental change in the waterfront zone of Bangladesh (Khan et al., 2010). With six hours of the continuous time stretch, Bangladesh faces two flood tide and two ebb tide in a day. Metropolitan regions of waterfront Bangladesh faces flooding because of the water logging during the rainstorm due to the hefty precipitation and flood tide. Thus, because of the weighty precipitation and elevated tide during storm, saline water grows practically everywhere on the beach front district (Mahmuduzzaman et al., 2014).

2.2.4. Back Water Impact

Backwater impact happens at the mouth of the stream (progress zone). Backwater impact is an exceptional kind of saline water development towards the waterway from the ocean. It happens when freshwater isn't satisfactory to partner moving tidewater (Seal and Baten, 2012). There is different explanation that is answerable for the backwater impact in the mouth of the waterway. The reasons are (Ali, 1999):

- **Southwest storm wind**
- **Astronomical tides**
- **Storm flood**

(Ali, 1999) likewise expressed that the ocean level ascent is the non-dynamic and long-haul explanation behind the backwater impact.

2.2.5. Shrimp Farming

Shrimp development is likewise answerable for the saline water interruption. Shrimp development raises a genuine disturbing circumstance to the horticultural land in the seaside locale of Bangladesh. Shrimp development needs saline water as a contribution to the gher (lake). Along these lines, saline water interruption is additionally expanding step by step with the development of shrimp development practice in the new agrarian land. Because of the huge shrimp cultivating, the saltiness of soil is expanding, and the accessibility of farming area is diminished. Penaeus monodon is a bitter water shrimp that has a gigantic interest in the worldwide market. Because of the colossal interest in the global market, this shrimp cultivating has occurred the nearly the entire seaside locale of our nation (Flaherty et al., 2000; Mahmuduzzaman et al., 2014).

2.3. Effect of Saltiness in the Streams of Waterfront Bangladesh

For the most part, saline water interruption is a typical danger to freshwater sources like springs. Likewise, the over the top substance of salt and minerals of saline water can negatively affect the creature species and to the numerous sorts of plant species additionally (Thompson 2014).

- **Water supply and security**
- **Agriculture**
- **Fisheries**
- **Biodiversity and biological system**

2.3.1. Water Supply and Security

Water is an image in Chinese culture. They accept that water can carry imperativeness and abundance to them. The thickly populated seaside areas of our planet demonstrated that accept of the Chinese culture. Individuals consistently attempt to move or move towards the coast for humankind so as to get the incredible profitability of the waterfront areas. Coordinated human exercises with some hydrological issues, (for example, tainting of groundwater through saline water interruption) degree the issue of drinking water shortage step by step in the seaside areas (Duan, 2016).

The expanded huge weight of saline water on the freshwater zone diminishes the accessibility of the new water in the waterfront zone. Individuals drink sullied water and became ill on water-borne illnesses, (for example, cholera, looseness of the bowels, and so on) because of the inaccessibility of new water, ailing health issue additionally expanded because of the diminishing of food creation (Sarwar, 2005).

2.3.2. Agricultural

As far as different factor, for example, lessening of harvest creation, hampering of mechanical creation, expanding of wellbeing peril and decreasing the efficiency of woods products and backwoods species, saline water interruption in stream water may cause huge financial misfortune. Saline water lessens the plants to develop through salt obsession in the plant's root and causes supplement lopsidedness. Because of that, farming creation is diminished when length. At the point when ventures utilized the saltwater from the stream to cool the condenser and keep the turbine running, at that point the mechanical creation is decreased naturally. Saltwater not just restricts the ease of use of the stream water yet additionally motivations spillages in the supplies. Along these lines, creation misfortune is occurring and cost creation is expanded. In 1993, Pakshi Paper Plant shut for the saltwater interruption in north Khulna (Mirza, 1998).

The expansion of water saltiness in the streams limits the development of the timberland species at the waterway channels. The abatement of freshwater and interruption of saline water exhaust the nature of soil that restricts the plant development and reduction the efficiency of the plants. Along these lines, the entire thing places an antagonistic effect on the encompassing untamed life and biodiversity (Seal and Baten, 2012). Essentially, saline water interruption prompted an adjustment in the dirt or water condition that builds the botanical infection and bug intrusion in the dirt. These components hinder the plant's development and diminishing plant species variety (Gain et al., 2014).

2.3.3. Fisheries

As per CLD (Haraldsson, 2004) - Easygoing Circle Graph between ocean level ascent and waterfront fisheries of Bangladesh (a reason sway relationship model between two wonders), beach front fisheries assets are predominantly influenced by the ascent of ocean level in three unique manners (Sarwar, 2005). These ways are:

- **Saltwater interruption**
- **Coastal flooding, and,**
- **Increase the power of the tornado**

In our waterfront Bangladesh, these three marvels individually answerable for the abatement of seaside fisheries assets that are the primary protein wellspring of beach front individuals. Individuals of Bangladesh admission around 60-80% of their creature protein interest from the utilization of fish (Alam and Thomson, 2001).

Because of the enormous increment of saltiness and expanding the force of other marvels diminished the beach front fisheries and cause shortage of protein into the mass individuals of the nation. This shortage of protein inevitably expands the chance of general wellbeing peril. The helpless status of general wellbeing will expand neediness among the seaside zones. Then again, the expansion in destitution will equip the wellbeing danger (Sarwar, 2005). In Bangladesh, the solidified food industry is one of the biggest unfamiliar trade procuring area that is incredibly reliant on the creation of fisheries assets from the waterfront districts. Thus, the lessening in beach front fisheries will diminish the acquiring of unfamiliar trade. Because of that, destitution will build that will make us search out unfamiliar guides (Sarwar, 2005).

2.3.4. Biodiversity and Biological system

Biological systems are generally known for its few significant natural or environmental capacities. For example, supplement cycling, a home for the botanical and faunal species, etc (Fretwell et al., 1996).

Followings are the ecologically protected areas of coastal Bangladesh:

- **Reserve Forest** - Bagerhat, Barguna, Bhola, Chottogram, Cox's Bazar, Feni, Khulna, Lakshmipur, Noakhali, Patuakhali, Satkhira
- **National Park** - Himchari, Cox's Bazar
  Nijhum Dweep, Noakhali
- **Eco-park** - Sitakunda, Chattogram
- **Wildlife Sanctuaries** - Sundarban East, Bagerhat
  Sundarbans South, Khulna
  Sundarban West, Satkhira
  Char Kukri Mukri, Bhola
  Chunati, Chattogram
- **Game Reserve** - Teknaf, Cox's Bazar
- **Ramsar Site** - The Sundarban (Bagerhat, Khulna, Satkhira)

An inconsequential change in the dirt saltiness because of the saline water interruption can cause water pressure of the plants and can make fatal outcomes them. Along these lines, when the environments of a biological system will get disintegrated than the biodiversity of that encompassing will decrease naturally (Duan, 2016).

Followings are the environmentally critical areas (ECA) of coastal Bangladesh:

- **Sonadia, Cox's Bazar**
- **Teknaf beach, Cox's Bazar**
- **St. Martin Island, Cox's Bazar**

Considering the higher biodiversity estimation of our seaside Bangladesh, a couple of territories are announced as an Earth Ensured Zone (EPA) so as to spare the normal natural surroundings for the species and spare them from the elimination (Islam 2004).

Many compromised creature types of our nation carrying on with a free from any potential harm life in these Earth Secured Territories (EPA).

Followings are the world heritage site of coastal Bangladesh:

- **Sundarban Wildlife Sanctuaries -** Bagerhat, Khulna, Satkhira
- **Shaat Gombuz Mosque -** Bagerhat

Along these lines, expanding saltiness in the beach front zones of our nation will hamper the environments and their biodiversity.

Followings are the marine reserve and fish sanctuaries of coastal Bangladesh:

- **Marine Reserve -** Bay of Bengal
- **Fish Sanctuaries -** Barisal, Bagerhat, Bhola, Narail, Jessore, Khulna, Lakshmipur, Patuakhali, Feni.

CHAPTER 03: METHODOLOGY

This chapter mainly provides a detailed description of the research project area (study area) and discuss the various systematic techniques that are used to conduct this research project. This chapter is divided into five (05) major components.

3.1. Study Area

Banshkhali Upazila is located in Bangladesh under Chattogram Division. It is located between 22°1.5′ north latitudes and 91°57.3′ east longitudes. It is surrounded by other Upazilas of Chattogram district on the north, south & east side and by the Bay of Bengal on the west. Banskhali Upazila contains around 20 km from the total length of the Sangu river.

Bangladesh is a land of the river. Chottogram division is divided into 5 hilly districts. The districts are Chottogram, Cox's Bazar, Bandarban, Rangamati and Khagrachhari. It is bounded by the Bay of Bengal on the south and west, the Naf river with Myanmar on the southeast, and India on the east. The total area is approximately 19,956 sq km with a hilly area of 1,300 sq km (BBS, 2016).

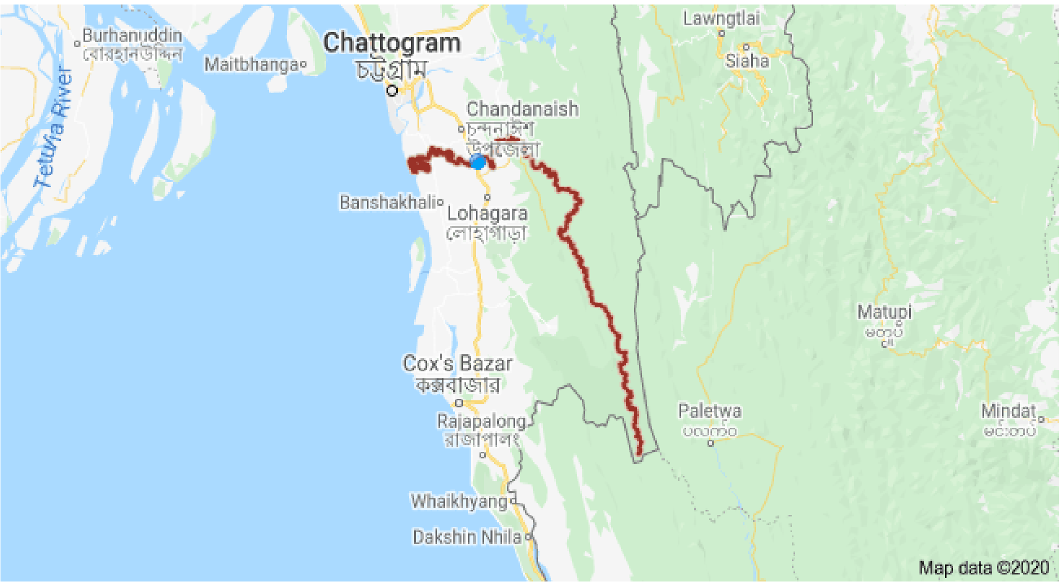


Figure 3.1: Map of Sangu River in Banskhali Upazila, Chattogram.

Some water flows down and enters Bangladesh from the west hilly region of Mizoram, India. From the Remakri point, the Sangu River goes through Bandarban Sadar Upazila and Satkania Upazila, then fall at the Banshkhali channel. The river is almost 270 kilometres in length and goes through like a snake.

The Sangu River is a river in Myanmar and Bangladesh. Its source is in the North Arakan Hills of Myanmar, which form the boundary between Arakan and the Chottogram hill tracts. It follows a northerly circuitous course in the Hill Tracts up to Bandarban. It enters the district from the east and flows west across the district and finally falls into the Bay of Bengal. The Sangu river is 270 km in length and went through like a snake. But, we covered almost 53 km of the Sangu river (from the Kodom Rosul, Banshkhali to Rasulabad, Satkania) after went to the field data collection. That means we also covered some portion (around 13km) of the Sangu river from Satkania Upazila.

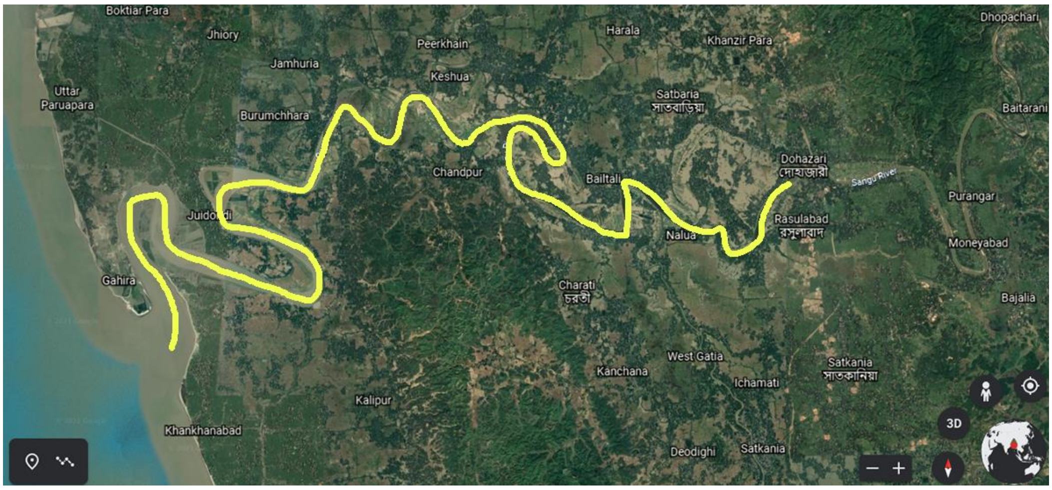


Figure 3.2: The 53.54km long Study Area of the Sangu River (own illustration)

3.1.1. Sampling Locations

From the 53.54 km long study area of the Sangu River, randomly selected 11 locations were used to collect data. So, we selected a total of 11 locations throughout the study area.

We started this data collection process from the Kodom Rosul of the Bay of Bengal (BoB) and ended it at the Rasulabad. This zone consists of eleven (11) sampling locations.

Due to some inconvenience, we couldn’t maintain the exact distance between the sampling locations. Although, we tried to keep a distance between the sampling locations that are not too far or not too close.

Table 2: Sampling Locations and their Latitude and Longitude

No.	Sampling Location	Latitude	Longitude
01	Kodom Rosul	N22°05'51.7"	E91°51'47.0"
02	Pharmacia-ghat	N22°07'22.6"	E91°51'35.0"
03	Moloipara	N22°07'48.3"	E91°51'23.6"
04	Majhir Ghat	N22°07'44.2"	E91°52'04.3"
05	Lachara	N22°07'24.5"	E91°53'16.0"
06	Issorbabur Hat	N22°07'09.9"	E91°53'57.6"
07	Toilardip Bridge	N22°10'26.8"	E91°54'34.6"
08	Sarwar Bazar	N22°08'31.1"	E92°00'30.9"
09	Naluwa	N22°08'11.3"	E92°02'21.8"
10	Morfola Bazar	N22°08'12.4"	E92°02'56.3"
11	Rasulabad	N22°09'13.2"	E92°03'29.6"

3.2. Data Collection Techniques of the Study

To collect and analyze the data here we implemented both qualitative and quantitative tactics on this study. Although, the study widely focuses on primary data collection through various data collection techniques in the eleven (11) sampling locations. The secondary data mainly has been assembled by evaluating various research papers or scientific research papers. So, the data collection techniques of this study have been structured according to the following framework:

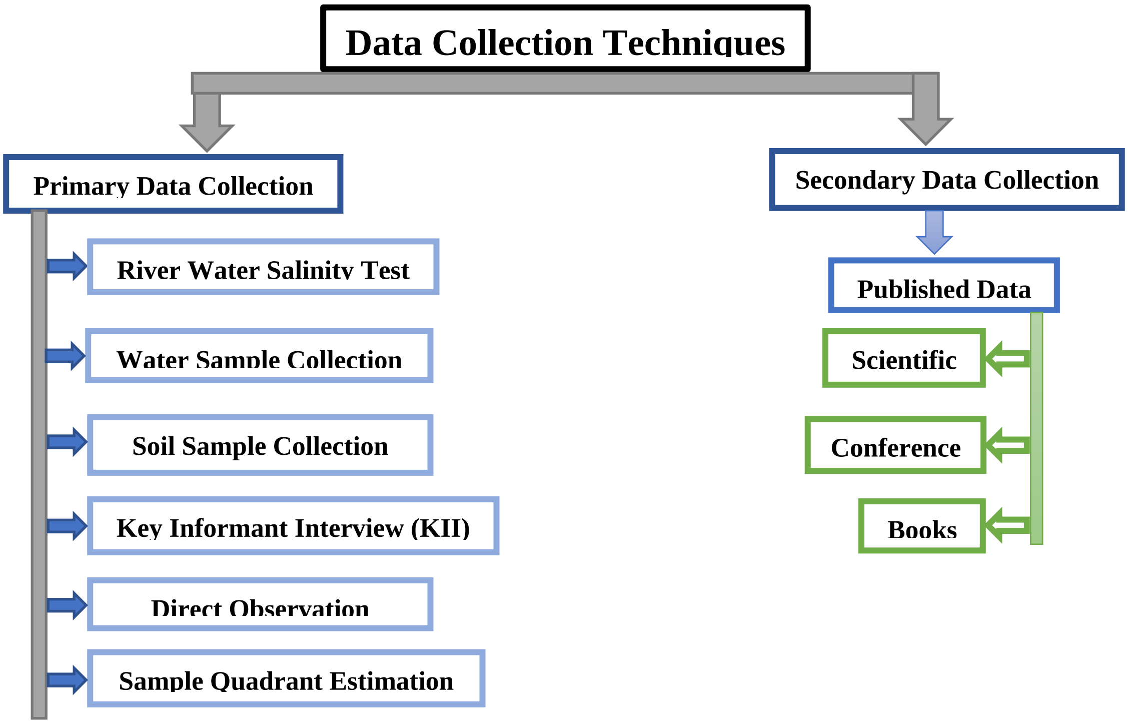


Figure 3.1: Data Collection Techniques of the Study.

The literature review of the secondary data sources helps us to understand the present salinity status of the coastal rivers of Bangladesh. It also helps us to identify the causes and impacts of river salinity on coastal Bangladesh.

3.2.1. River Water Salinity Test

In a specific sampling location, we collect water from four different spots of the river. Then we mixed these collected waters and measured the salinity of that water directly in that location using the portable salinity refractometer. We repeated the procedure in every 11 sampling locations to measure the water salinity of the Sangu river.

3.2.2. Water Sample Collection

In a specific sampling location, we separately collected 50 ml of water from four different spots of the river. Then we mixed these collected waters in a 250 ml water collection bottle. We repeated the procedure in every 11 sampling locations of the Sangu river.

We labeled the 11 sample water bottles and safely kept them for further analysis in the laboratory. Finally, we brought the water samples to the Environmental Science and Disaster Management (ESDM) Laboratory of Daffodil International University (DIU).

3.2.3. Key Informant Interview (KII)

KII is a qualitative approach of data collection with the experts or peoples who exactly know about an issue (Taylor & Renner, 2003). Here, we used this technique to collect some rigorous information about salinity and its impact on local plant diversity throughout the study area. We selected two key informants from those local government organizations that are related to our study. We also selected two local people who consist of rigorous information about the local surrounding of the study area. The age of the two local people is above 45 years.

The interview was taken face to face as a discussion based on a semi-structured questionnaire. The informative comments of them also taken into consideration.

Table 3: List of Selected Individuals for the Key Informant Interviews (KII).

Category	Organization / Village	Individuals
Local Government	Department of Environment, Chattogram	**Muktadir Hasan** Assistant Director
	Forest Department, Chattogram	**Afroza Begum** Research Officer
Local People	Kodom Rosul, Banshkhali, Chattogram	**Md. Saiful Islam** Controller, Age – 46
	Rasulabad, Satkania, Chattogram	**Mrs. Sajeda Begum** Age – 67

3.2.4. Direct Observation

With the test of water salinity of the Sangu River, we also tried to observe the environmental condition of every place around the sampling locations. We walked almost the whole study area throughout the Sangu river. We tried to observe the surrounding environment of the study area to identify any consequences or issues that are important for our study and tried to find out some issues that could be an issue for further work particularly.

We also tried to capture the existing environmental surroundings, the identified consequences or issues and other important phenomena that are important in terms of our study. In every sampling location, we also talked with the local people to understand their approach to the water salinity and its impact on local plant diversity throughout the study area of the Sangu river.

3.2.5. Sample Quadrat Estimation

In a sampling location, we selected a $4m^2$ plot in the riverside, within the range of 50 m from the river water salinity test spots. The plot is known as a quadrat (Odum, 1969). Now, we identified the existing plant species in the plot. Then we estimated the number of individuals for one plant species in the plot. We separately repeated the technique for all 11 sampling locations. We implemented the technique using the following table:

Table 4: Sample Tabulation Sheet for Sample Quadrat Estimation.

Sampling Quadrat ($4m^2$) Location 01: **Kodom Rosul**	
Plant Species	**n (Number of Individuals)**
Tamarix Dioica	XIV (14)
Cocos Nucifera	VIII (8)
Acacia Auriculiformis	VIII (8)
Alstonia scholaris	IV (4)
Vachellia Nilotica	II (2)
Ficus Benghalensis	II (2)

3.3. Data Analysis

We measured the river water salinity, estimated the sampling quadrat, collected water samples and conducted four key informant interviews. So, the collected data have been analyzed according to the following framework:

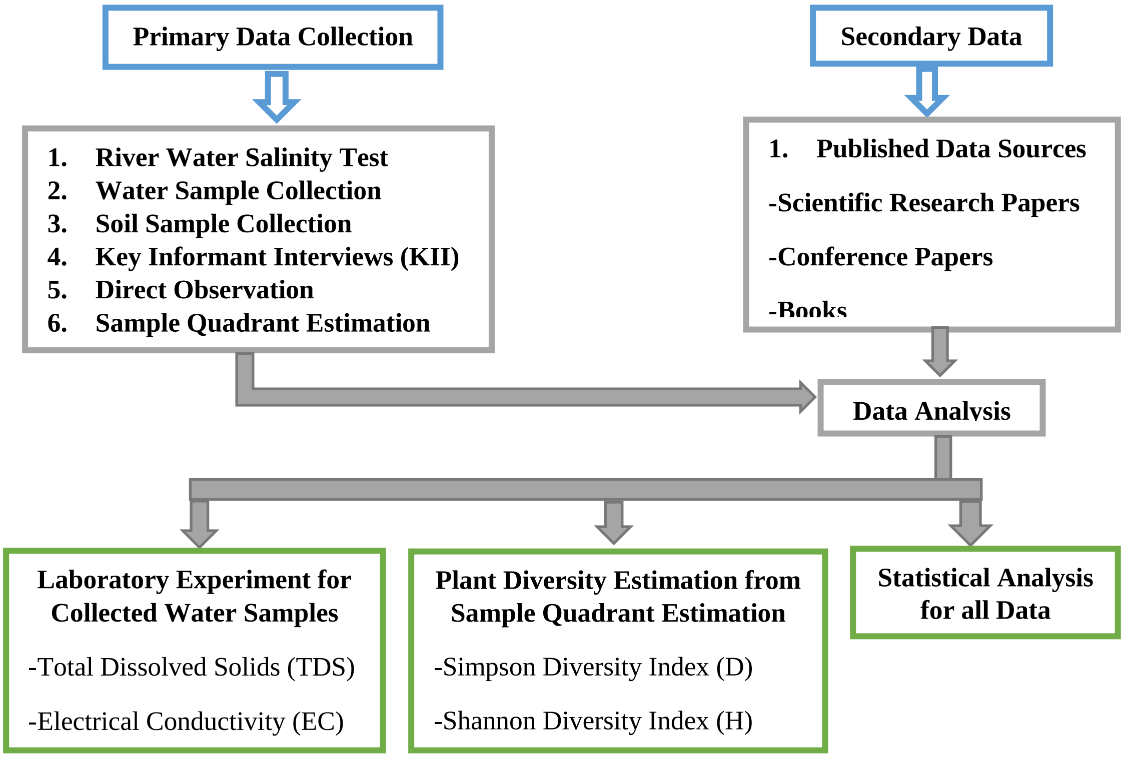


Figure 3.2: Structured Framework for Data Analysis.

Analysis and interpretation of qualitative data have been done through the following steps constructed by (Taylor & Renner, 2003), that are:

i. Explore the knowledge of the data

ii. Give focus on the analysis of the data
iii. Compile and categorization of the information

3.3.1. Laboratory Experiment

This study conducted to explore the status of water salinity level of the Sangu. Collected water samples from all the 11 locations where we conducted the test to measure the water salinity of the Sangu river.

Both Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were analyzed separately from the water samples collected from the 11 sampling locations. This experiment was taking place in the Environmental Science and Disaster Management (ESDM) Laboratory of Daffodil International University (DIU), Ashulia, Savar.

HANNA Ph/EC/TDS/Temperature Meter (HI9814) used to measure the TDS value of the 11- water sample separately. HANNA EC Tester (HI98304) used to measure the EC value of the 11- water sample separately. The water samples that were consisting of above 60 ppt salinity, they were diluted 8 times before the lab test to get the value within the existing range of the equipment.

3.3.2. Plant Diversity Estimation

Diversity indexing is a mathematical measurement that estimates the species diversity of a given area or a community. The more species an area or a community have, the more diverse the area or the community. Normally, there are two types of diversity indexing (Odum, 1969). These are –

3.3.2.1. Simpson Diversity Index (D)

Simpson diversity index is a kind of dominance index as it gives more and more weight to common and dominance species. The main feature of this index system is that a few rare species with a few individuals will not affect the overall diversity of an area (Simpson, 1949). So, the equation is –

$$\boldsymbol{D = 1/\sum_{i=1}^{s} P_i^2}$$

Where, D = Simpson Diversity; Pi = Proportion of (n/N); n = Individuals of one species; N = Total number of all species individuals; Σ = Sum of the calculations.

3.3.2.2. Shannon Diversity Index (H)

Shannon diversity index is a widely used information statistic index by which all species are represented in a sample and samples are collected randomly (Shannon & Weaver, 1963). So, the equation is –

$$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$$

Where, H = Shannon Diversity; Pi = Proportion of (n/N); n = Individuals of one species; N = Total number of all species individuals; ln = Natural log; Σ = Sum of the calculations.

3.3.2.3. Estimation Procedure

In every place, we selected a plot in the riverside within the range of 50 m of river water salinity test spots. The selected plots were a quadrat of $4m^2$ area. So, each of the 11 plots was a quadrat of $4m^2$ area. Then we identified the existing plant species and find out the number of individuals for one plant species in every single plot of a quadrat. Later we calculated the diversity for a specific quadrat plot using the equation or formula of both Simpson Diversity Index (D) and Shannon Diversity Index (H) by the following estimation procedure –

Table 5: Diversity Estimation Procedure by Using both Simpson (D) and Shannon (H) Diversity Index.

Sampling Location (01): Kodom Rosul					
Plant Species	n	**n/N=Pi**	**Pi²**	**Ln Pi**	**Pi x lnPi**
Tamarix Dioica	14	0.368	0.1357	-0.999	-0.368
Cocos Nucifera	8	0.211	0.044	-1.558	-0.328
Acacia Auriculiformis	8	0.211	0.044	-1.558	-0.328
Alstonia scholaris	4	0.105	0.011	-2.251	-0.237
Vachellia Nilotica	2	0.053	0.003	-2.944	-0.155
Ficus Benghalensis	2	0.053	0.003	-2.944	-0.155
N = 38		**Pi^2 = 0.241**		**Pi x LnPi = -1.571**	
$D = 1/\sum_{i=1}^{s} P_i^2$		**D = 1/0.241**		**D = 4.149**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		**H = -(-1.571)**		**H = 1.571**	

We repeated this procedure for the other 10 sampling locations separately. By following this procedure, we were able to estimate the plant diversity of every sampling locations throughout the study area of the Sangu river.

3.3.3. Statistical Analysis

First, we compile and organize the data in Microsoft Excel. Then we checked it out to avoid any kind of data missing or errors in the excel sheet that we input. Now, using Microsoft Excel, data has been investigated to find out the correlation coefficient and regression between the variables. T-test also is done to prove the hypothesis of the study that was assumed.

3.4. Instrumental Techniques

To the successful completion of this study, we used various materials. We used three separate instruments to measure the river water salinity, total dissolved solids, and electrical conductivity. We used one google product for mapping. We used a tool to identify the geographical position of the places. We used one modeling software that helps us to make the various maps. We used statistical software to analyze the collected data.

Table 6: Used Instruments, Tool, and Software to Conduct the Study.

Category	Parameters	Name or Model
Instruments	Water Salinity	Portable Salinity Refractometer
	TDS	*HANNA* Ph/EC/TDS/Temperature Meter (HI9814)
	EC	*HANNA* EC Tester (HI98304)
Tool	Navigation	Garmin eTrex® 10 (GPS Navigation Device)
Software's	Mapping	ArcGIS 10.2.1
		Google Earth Pro
	Statistics	Microsoft Excel 2016

So, these are the materials that we used during our study to collect, measure and analysis of the collected data.

Table 7: Major Characteristics of the Instruments.

Instruments	Characteristics Category	
	Range	**Resolution**
HANNA pH/EC/TDS/Temperature Meter (HI9814)	0 to 3999 ppm	10 ppm
HANNA EC Tester (HI98304)	0.00 to 20.00 mS/cm	0.01 mS/cm
Portable Salinity Refractometer	0 to 100 %	20 %

CHAPTER 04: RESULT AND DISCUSSION

This chapter broadly discusses the findings and results of our study in a different form. At the beginning of this research project, we have assumed three different objectives and we worked on it. Here, in this chapter, we tried to get a well-organized understanding of the objectives by analyzing the collected data and findings in different ways. So, this chapter of results and discussion is divided into five (05) different sections. The sections are –

4.1. Study Findings

In this section, we tried to show all our findings and results that we observed from the beginning to the end of this research study. Here we tried to demonstrate the status of salinity, measured TDS and EC from the water samples that were collected from the sampling locations of the study area. The status of plant diversity also shown here throughout the study area of the Sangu River, Chattogram

We've shown the measured river water salinity, TDS, EC, and estimated plant diversity according to the distance from the Rasulabad to the Kodom Rosul of the Bay of Bengal. We directly measured river water salinity in places. We measured the TDS and EC of water samples by laboratory experiment and we estimated the plant diversity using both Simpson (D) and Shannon (H) diversity index.

4.1.1. Salinity

In the Sungu river water salinity increases with the increase of distance from Majhir-ghat to the Kodom Rosul of the Bay of Bengal (Rahman, 2019; Gain et al., 2014; Petersen & Shireen, 2001). In the other zone, measured river water salinity was zero (0) in every sampling location. Though we measured the river water salinity in seven (7) sampling locations, we were not finding any salinity in the water of the Sangu river.

Table 8: Measured Salinity at the Sampling Locations (SL) of the Study Area.

Sampling Location	Latitude	Longitude	Salinity (ppt)
Kodom Rosul	N22°05'51.7"	E91°51'47.0"	10
Pharmacia-ghat	N22°07'22.6"	E91°51'35.0"	8
Moloipara	N22°07'48.3"	E91°51'23.6"	5

Majhir Ghat	N22°07'44.2"	E91°52'04.3"	1
Lachara	N22°07'24.5"	E91°53'16.0"	0
Issorbabur Hat	N22°07'09.9"	E91°53'57.6"	0
Toilardip Bridge	N22°10'26.8"	E91°54'34.6"	0
Sarwar Bazar	N22°08'31.1"	E92°00'30.9"	0
Naluwa	N22°08'11.3"	E92°02'21.8"	0
Morfola Bazar	N22°08'12.4"	E92°02'56.3"	0
Rasulabad	N22°09'13.2"	E92°03'29.6"	0

10 ppt salinity measured at Kodom Rosul, Bay of Bengal. 8 ppt, 5 ppt, 1 ppt, salinity measured at Pharmacia-ghat, Moloipara and Majhir Ghat from the Rasulabad to the BoB respectively. Highest 10 ppt salinity measured at the Kodom Rosul of the Bay of Bengal. Kodom Rosul is the transition point between the BoB and the Sangu river.

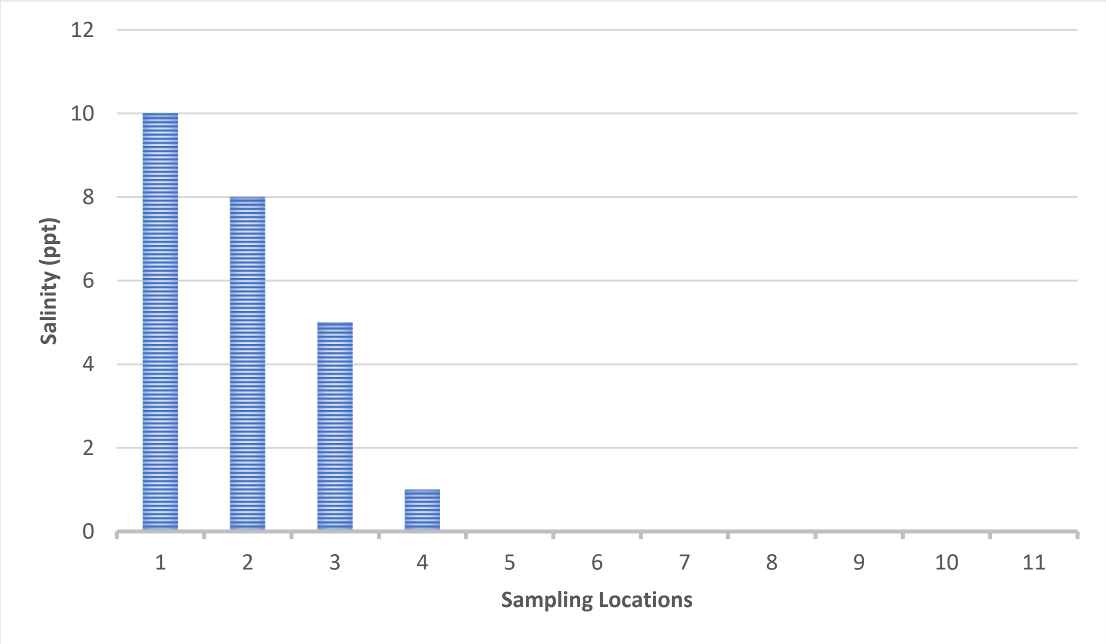


Figure 4.1: Status of Salinity in the Water of the Sangu River

So, the status of water salinity in the Sangu river is –

a) In the Sangu river, 10 ppt is the highest and 1 ppt is the lowest value of water salinity. Salinity increases from 1 ppt to 10 ppt with the increase of the distance of sampling locations from the Majhir-ghat to the Kodom Rosul.

b) In other sampling locations of the Sangu River, salinity is not existing at all. Measured salinity is zero (0) in all sampling points or locations.

4.1.2. Total Dissolved Solids (TDS)

During the laboratory experiment, we used the TDS Meter (HANNA Ph/EC/TDS/Temperature Meter - HI9814) (Corwin & Yemoto, 2017). The sampling locations are Rasulabad, Morfola Bazar, Naluwa, Sarwar Bazar, Toilardip Bridge, Issorbabur hat, Lachara, Majhir ghat, Moloipara, Pharmachiar ghat, Kodom Rosul of the Bay of Bengal.

Table 9: Measured TDS at the Sampling Locations (SL) of the Study Area.

#	*Sl.*	*Location Name*	*TDS (ppm)*
Sampling Locations	*01*	Kodom Rosul	3010
	02	Pharmachiar ghat	1470
	03	Moloipara	2260
	04	Majhir ghat	580
	05	Lachara	850
	06	Issorbabur hat	750
	07	Toilardip Bridge	230
	08	Sarwar Bazar	120
	09	Naluwa	130
	10	Morfola Bazar	130
	11	Rasulabad	140

In the study area, the TDS increases with the increase of the distance from the Rasulabad to the Kodom Rosul or increase of water salinity towards the Bay of Bengal from the Majhir-ghat. Here, the highest TDS value is 3010 ppm at the Kodom Rosul of the Bay of Bengal. The lowest TDS value is 120 in Sarwar Bazar.

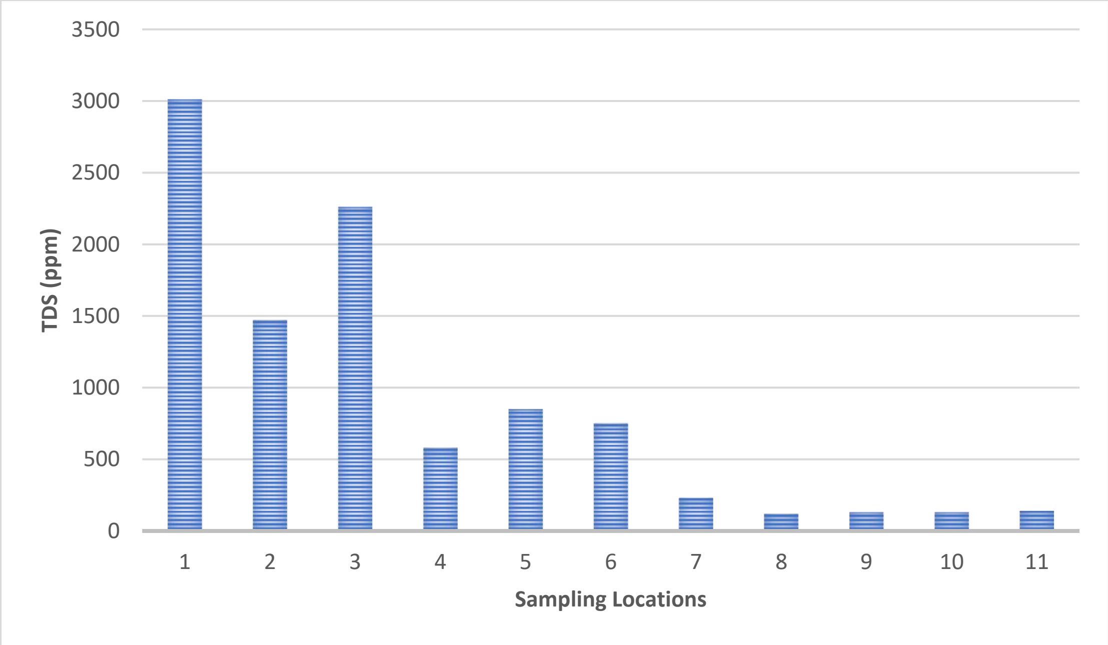


Figure 4.2: Status of TDS in the Sangu River

In the study area, river water salinity was zero (0) from Rasulabad to Lacara sampling location. Though, we measured the TDS of the collected water samples from the sampling locations. So, in the measured TDS values, all the values are almost the same or close to one another. But the fact is, TDS decreases with the increase of distance from the Rasulabad to the Kodom Rosul. Here, the highest TDS value is 3010 Kodom Rosul. The lowest TDS value is 120 at Sarwar Bazar.

We did not dilute the water samples of the TDS value within the range of the instruments. Due to the zero (0) salinity of the river water, the TDS value of the sampling locations remains lower and relatively close to each other. So, the TDS values tend to be lower due to the zero (0) salinity in all sampling locations.

4.1.3. Electrical Conductivity (EC)

During the laboratory experiment, we used EC Tester (HANNA EC Tester– HI98304) (Corwin & Yemoto, 2017). The sampling locations are Rasulabad, Morfola Bazar, Naluwa, Sarwar Bazar, Toilardip Bridge, Issorbabur hat, Lachara, Majhir ghat, Moloipara, Pharmachiar ghat, Kodom Rosul of the Bay of Bengal.

Table 10: Measured EC at the Sampling Locations (SL) of the Study Area.

#	*Sl.*	*Location Name*	*EC (µS/cm)*
Sampling Locations	*01*	Kodom Rosul	3.54
	02	Pharmachiar ghat	1.68
	03	Moloipara	2.60
	04	Majhir ghat	0.67
	05	Lachara	0.96
	06	Issorbabur hat	0.84
	07	Toilardip Bridge	0.24
	08	Sarwar Bazar	0.12
	09	Naluwa	0.14
	10	Morfola Bazar	0.13
	11	Rasulabad	0.14

In the study area, the EC increases with the increase of the distance from the Rasulabad to the Kodom Rosul or increase of water salinity towards the Bay of Bengal from the Majhir-ghat. Here, the highest EC value is 3.54 µS/cm at the Kodom Rosul of the Bay of Bengal. The lowest EC value is 0.12 µS/cm in Sarwar Bazar.

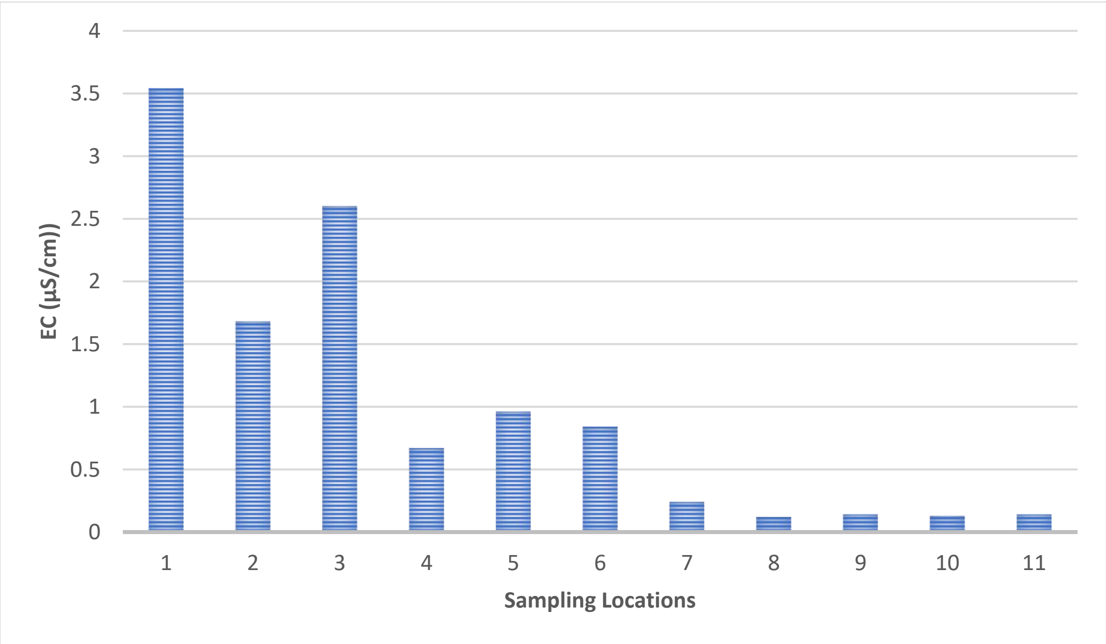


Figure 4.3: Status of EC in the Sangu River.

Like TDS, we did not dilute the water samples of the study area to measure the EC value within the range of the instruments. Due to the zero (0) salinity of the river water, the EC value of the sampling locations remains lower and relatively close to each other.

4.1.4. Plant Diversity

We also estimated the plant diversity and show the estimated plant diversity according to the all sampling locations of the study area. We estimated the plant diversity according to the distance of sampling locations from Rasulabad to the Kodom Rosul of the Bay of Bengal. We calculate the plant diversity for every sampling location using both the Simpson Diversity Index (D) and Shannon Diversity Index (H) formula or equation respectively.

4.1.4.1. Simpson Diversity Index (D)

In the study area, we estimated plant diversity according to the downward distance of the sampling locations from the Rasulabad to the Kodom Rosul of the Bay of Bengal. The diversity decreases with the increase of the distance of sampling locations from the Rasulabad to the Kodom Rosul of the Bay of Bengal.

Table 11: Estimated Plant Diversity using the Simpson Diversity Index (D) at the Sampling Locations (SL) of the Study Area.

#	*Sl.*	*Location Name*	*Diversity (D)*
Sampling Locations	*01*	Kodom Rosul	4.149
	02	Pharmachiar ghat	3.906
	03	Moloipara	5.917
	04	Majhir ghat	5.348
	05	Lachara	6.993
	06	Issorbabur hat	8.475
	07	Toilardip Bridge	8.850
	08	Sarwar Bazar	8.264
	09	Naluwa	8.403
	10	Morfola Bazar	7.042
	11	Rasulabad	9.434

In the study area, 9.434 (highest) plant diversity estimated at Rasulabad and 3.906 (lowest) plant diversity estimated at Pharmachiar-ghat, which is the next sampling location of Kodom Rosul. In the study area, all the value of Simpson diversity (D) is close to each other and all values are almost similar. Here, all estimated diversity values are placed within the range of 3.906 – 9.434.

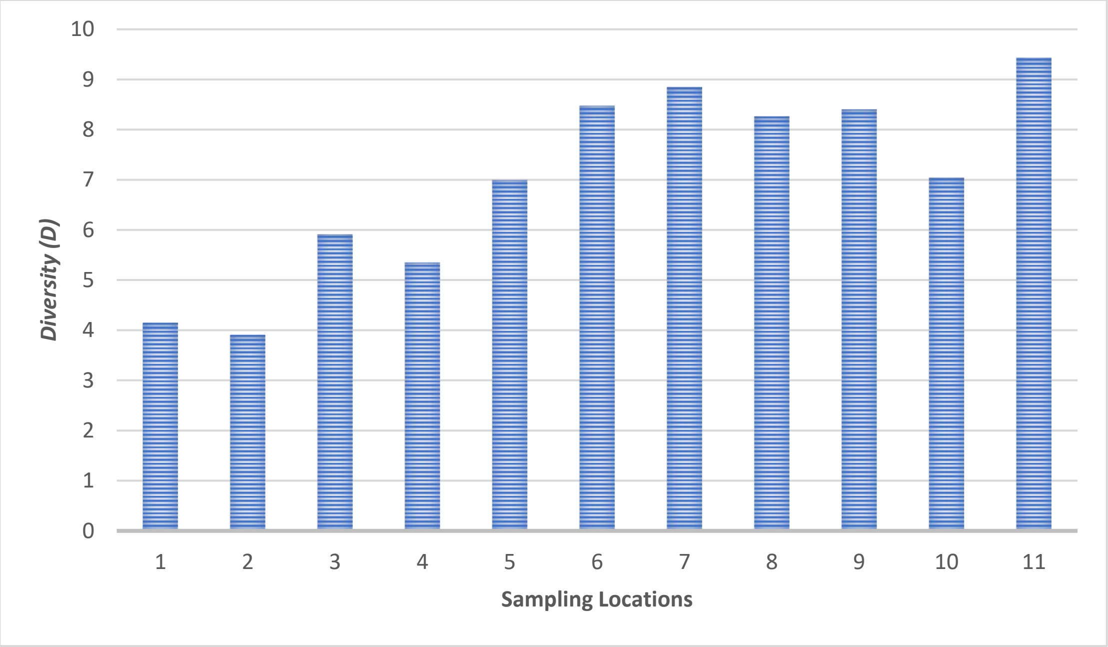


Figure 4.4: Status of Plant Diversity using the Simpson Diversity Index (D)

According to the Simpson diversity index (D), the status of plant diversity around the Sangu river is –

In the study area of the Sangu river, 9.434 is the highest and 3.906 is the lowest value of plant diversity. Plant diversity decreases gradually with the increase of the distance of sampling locations from the Rasulabad to the Bay of Bengal (BoB).

4.1.4.1. Shannon Diversity Index (H)

In the study area, we estimated plant diversity according to the distance of the sampling locations from the Rasulabad to the Kodom Rosul of the Bay of Bengal (BoB). The diversity decreases with the increase of the distance of sampling locations from the Rasulabad to the Kodom Rosul. The highest plant diversity exists in Rasulabad, eleven number or last sampling location of our study area. This plant diversity consequently decreases with the increase of the distance of sampling locations from Rasulabad to the Kodom Rosul of the Bay of Bengal (BoB).

Table 12: Estimated Plant Diversity using the Shannon Diversity Index (H) at the Sampling Locations (SL) of the Study Area.

#	*Sl.*	*Location Name*	*Diversity (H)*
Sampling Locations	*01*	Kodom Rosul	1.571
	02	Pharmachiar ghat	1.467
	03	Moloipara	1.967
	04	Majhir ghat	1.73
	05	Lachara	2.007
	06	Issorbabur hat	2.166
	07	Toilardip Bridge	2.276
	08	Sarwar Bazar	2.155
	09	Naluwa	2.208
	10	Morfola Bazar	2.064
	11	Rasulabad	2.309

In the study area, 2.309 (highest) plant diversity estimated at Rasulabad and 1.467 (lowest) plant diversity estimated at Pharmachiar-ghat, which is the next sampling location of Kodom Rosul. All the value of Shannon diversity (H) is close to each other and all values are almost similar. Here, all estimated diversity values are placed within the range of 1.467 – 2.309 of the Sangu river.

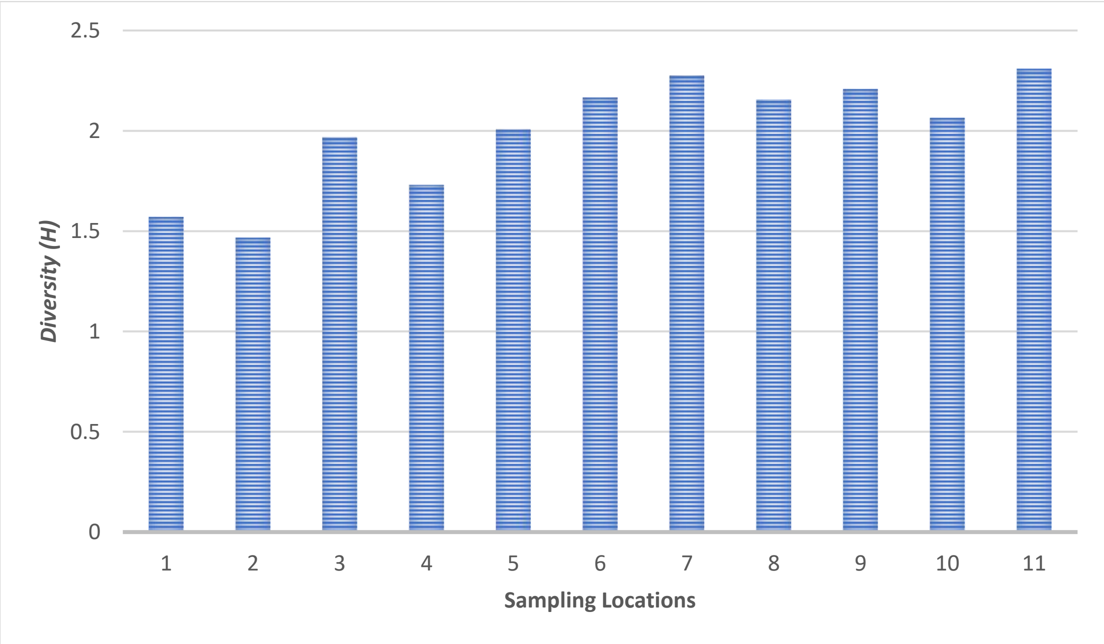


Figure 4.5: Status of Diversity using the Shannon Diversity Index (H) in the Sangu River

According to the Shannon diversity index (H), the status of plant diversity around the Sangu river is –

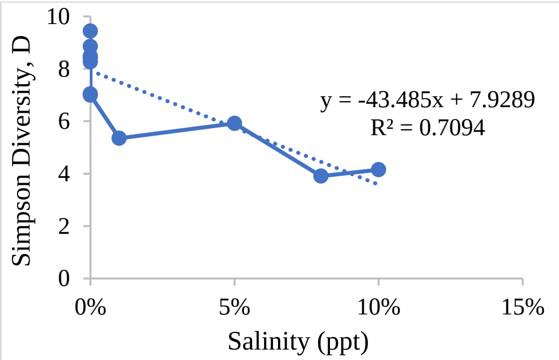
a) In the study area, 2.309 is the highest and 1.467 is the lowest value of plant diversity. Plant diversity decreases gradually with the increase of the distance of sampling locations from the Rasulabad to the Bay of Bengal.

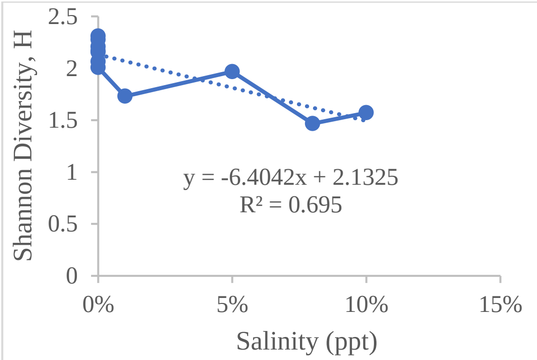
b) In the Sangu river plant diversity values of sampling locations are close to each other and relatively similar.

4.2. Impact of Water Salinity on Plant Diversity

Here we tried to investigate the impact of water salinity on plant diversity in th study area of the Sangu river. We used both the Simpson (D) and Shannon diversity index (H). We investigated the impact using correlation regression formula in Microsoft Excel (Gain et al., 2014; Briggs & Taws, 2003).

If we observe the figure 4.9 (a) and (b) we can easily understand the relationship between salinity and plant diversity in both Simpson (D) and Shannon (H) diversity index. Plant diversity decreases as the salinity increases in the downstream zone.





(a) **(b)**

Figure 4.9: Impact of Salinity in Plant Diversity of the Sangu River (a) Simpson Diversity Index (D), (b) Shannon Diversity Index (H).

Both figures show the negative relation between salinity and plant diversity in the study area. Both linear trendlines are similar and represented a negative correlation between salinity and plant diversity. So, the value of correlation coefficient (r) is -0.84224 for Simpson (D) and -0.83368 for Shannon (H) diversity index.

That means, in the study area, both trendlines show the negative (fairly) relationship where diversity decreases as the salinity increases towards the Bay of Bengal (BoB) from the Rasulabad.

Although, we identified the reasons behind the very slight changes in plant diversity pattern in the study area. So, the reasons are –

a. Immense riverbank erosion
b. Restrained population settlement
c. Excessive agricultural activity near the riverbank
d. A huge amount of agricultural field (acres to acres) in both sides of the river

These are the major reasons for the very slight changes in the plant diversity pattern in the study area of the Sangu river.

CHAPTER 5: CONCLUSION & RECOMMENDATIONS

In this final chapter of the study, I tried to assemble all study points from the literature review, data collection, data analysis, result, and discussions. Here, we also tried to justify the objectives of the study. Recommendations are also given for the researchers in order to better understanding of the future study. This chapter divided into two part.

5.1 Recommendations

Here, I tried to give certain recommendations that are informative and valuable based on a few facts or criteria. Such as –

a. Study limitations
    - The local language of Chattogram is very tough to understand in any way. You always must be patient on this issue.
    - You will not get adequate water transport facilities wherever you need. So, you must have to be aware of that.
    - Sometimes, a significant difference can be existing between the water of the riversides. So, you must have to conscious and aware of the proper parameter measurement or collection of the water from both sides of a river.

b. Study outcomes or understandings
    - The Kodom Rosul and the transition point between the Sangu river and Bay of Bengal (BoB) could be the most valuable estuarine zone of our country. For that, the government should have to think about that.
    - The government easily can extend the range of mangrove forest in our country by the cropping of salt-tolerant mangrove plants in the very study area of the Sangu river.
    - Due to the immense increase of salinity in the study area of the Sangu river, local faunal species are migrating or dying. Simply, they become extinct day by day.

So, these are the major points of recommendations of this study from the beginning to till the end of the study.

5.2. Conclusion

In the Sangu river, the study area salinity gradually increases with the increase of the distance of the sampling locations from the Majhir ghat to the Kodom Rosul of the Bay of Bengal (BoB). So, here we can see a huge difference in water salinity of the Sangu river.

In the study area of the Sangu river, plant diversity gradually decreases with the increase in water salinity. Because of that, the pattern of plant diversity is not well distributed throughout the study area.

In the study area of the Sangu river, plant diversity decreases with the increase of salinity towards the Kodom Rosul of the Bay of Bengal (BoB) from the Rasulabad. In the study area, there is no impact of salinity observed on the local plant diversity.

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Appendix – I

Sampling Location-1: **Kodom Rosul**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi × lnPi**
Tamarix Dioica	14	0.369	0.136	-0.999	-0.368
Cocos Nucifera	8	0.211	0.044	-1.559	-0.328
Acacia Auriculiformis	8	0.211	0.044	-1.559	-0.328
Alstonia scholaris	4	0.105	0.011	-2.251	-0.237
Vachellia Nilotica	2	0.053	0.003	-2.944	-0.155
Ficus Benghalensis	2	0.053	0.003	-2.944	-0.155
N=38		**Pi^2=0.241**		**Pi × LnPi = −1.571**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D=1/0.241**			**D=4.149**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H= − (−1.571)**			**H = 1.571**	

Sampling Location 2: **Pharmacia-ghat**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi × lnPi**
Cocos Nucifera	12	0.3	0.09	-1.204	-0.361
Acacia Auriculiformis	14	0.35	0.123	-1.050	-0.367
Samanea Saman	6	0.15	0.023	-1.897	-0.285
Alstonia Scholaris	3	0.075	0.006	-2.590	-0.194
Bambusoideae	5	0.125	0.016	-2.079	-0.260
N=40		**Pi^2 = 0.256**		**Pi × LnPi = -1.467**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D= 1/0.256**			**D = 3.906**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H = − (−1.467)**			**H = 1.467**	

Sampling Location 3: **Moloipara**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi × lnPi**
Acacia Auriculiformis	10	0.185	0.034	-1.686	-0.312
Samanea Saman	7	0.130	0.017	-2.043	-0.265
Ziziphus Mauritiana	3	0.056	0.003	-2.890	-0.161
Cocos nucifera	6	0.111	0.012	-2.197	-0.244
Tectona Grandis	2	0.037	0.001	-3.296	-0.122
Mangifera Indica	5	0.093	0.009	-2.380	-0.220
Bombax Ceiba	3	0.056	0.003	-2.890	-0.160
Calotropis Procera	2	0.037	0.001	-3.296	-0.122
Avicennia Officinalis	16	0.296	0.088	-1.216	-0.360
N= 45		**Pi^2 = 0.169**		**Pi × LnPi=-1.967**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D = 1/0.169**			**D=5.917**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H = − (−1.967)**			**H=1.967**	

Sampling Location-4: **Majhir Ghat**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi × lnPi**
Cocos Nucifera	4	0.174	0.030	-1.750	-0.304
Syzygium Cumini	3	0.130	0.017	-2.037	-0.266
Areca Catechu	6	0.261	0.068	-1.344	-0.351
Bombax Ceiba	3	0.130	0.017	-2.037	-0.266
Acacia Auriculiformis	5	0.217	0.047	-1.526	-0.332
Calotropis Procera	2	0.087	0.008	-2.442	-0.212
N= 32		**Pi^2= 0.187**		**Pi × LnPi=-1.730**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D= 1/0.187**			**D= 5.348**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H= − (−1.730)**			**H= 1.730**	

Sampling Location-5: **Lachara**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi×lnPi**
Acacia Auriculiformis	8	0.211	0.044	-1.558	-0.328
Plumeria Alba L.	3	0.079	0.006	-2.539	-0.200
Cocos Nucifera	6	0.158	0.025	-1.846	-0.291
Mangifera Indica	4	0.105	0.011	-2.251	-0.237
Artocarpus Heterophyllus	6	0.158	0.025	-1.846	-0.291
Bombax Ceiba	2	0.053	0.003	-2.944	-0.155
Samanea Saman	4	0.105	0.011	-2.251	-0.237
Swietenia	5	0.132	0.017	-2.028	-0.267
N= 38		**Pi^2=0.143**		**Pi × LnPi=-2.007**	
$D = 1/\sum_{i=1}^{s} P_i^2$		**D=1/0.143**		**D=6.993**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		**H= − (−2.007)**		**H=2.007**	

Sampling Location-6: **Issorbabur Hat**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi × lnPi**
Neolamarckia Cadamba	3	0.071	0.005	-2.639	-0.189
Acacia Auriculiformis	6	0.143	0.020	-1.946	-0.278
Cocos Nucifera	6	0.143	0.020	-1.946	-0.278
Areca Catechu	5	0.119	0.014	-2.128	-0.253
Mangifera Indica	6	0.143	0.020	-1.946	-0.278
Acacia Acuminata	3	0.071	0.005	-2.639	-0.189
Albizia Lebbeck	4	0.095	0.009	-2.351	-0.224
Samanea Saman	4	0.095	0.009	-2.351	-0.224
Swietenia	5	0.119	0.014	-2.128	-0.253
N= 42		**Pi^2= 0.118**		**Pi×LnPi=-2.166**	
$D = 1/\sum_{i=1}^{s} P_i^2$		**D= 1/0.118**		**D= 8.475**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		**H= − (−2.166)**		**H=2.166**	

Sampling Location-7: **Toilardip Bridge**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi×lnPi**
Tectona Grandis	6	0.109	0.012	-2.216	-0.242
Cocos Nucifera	3	0.055	0.003	-2.909	-0.159
Mangifera Indica	6	0.109	0.012	-2.216	-0.242
Calotropis Procera	2	0.036	0.001	-3.314	-0.121
Areca Catechu	8	0.145	0.02	-1.928	-0.280
Artocarpus Heterophyllus	4	0.073	0.005	-2.621	-0.191
Acacia Auriculiformis	10	0.182	0.033	-1.705	-0.310
Albizia Lebbeck	4	0.073	0.005	-2.621	-0.191
Bombax Ceiba	2	0.0364	0.001	-3.314	-0.121
Samanea Saman	3	0.055	0.003	-2.909	-0.159
Swietenia	7	0.127	0.016	-2.061	-0.262
N= 55		**Pi^2= 0.113**		**Pi×LnPi=-2.276**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D= 1/0.113**			**D= 8.850**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H= − (−2.276)**			**H= 2.276**	

Sampling Location-8: **Sarwar Bazar**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi×lnPi**
Acacia Auriculiformis	11	0.180	0.033	-1.713	-0.309
Samanea Saman	7	0.115	0.013	-2.165	-0.248
Populus Balsamifera	8	0.131	0.017	-2.031	-0.266
Calotropis Procera	4	0.066	0.004	-2.725	-0.179
Tectona Grandis	7	0.115	0.013	-2.165	-0.248
Cocos Nucifera	5	0.082	0.007	-2.501	-0.205
Trewia Nudiflora	6	0.098	0.010	-2.319	-0.228
Azadirachta Indica	8	0.131	0.017	-2.031	-0.266
Swietenia	5	0.082	0.007	-2.501	-0.205
N= 61		**Pi^2=0.121**		**Pi × LnPi=-2.155**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D= 1/0.121**			**D=8.264**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H= −(−2.155)**			**H=2.155**	

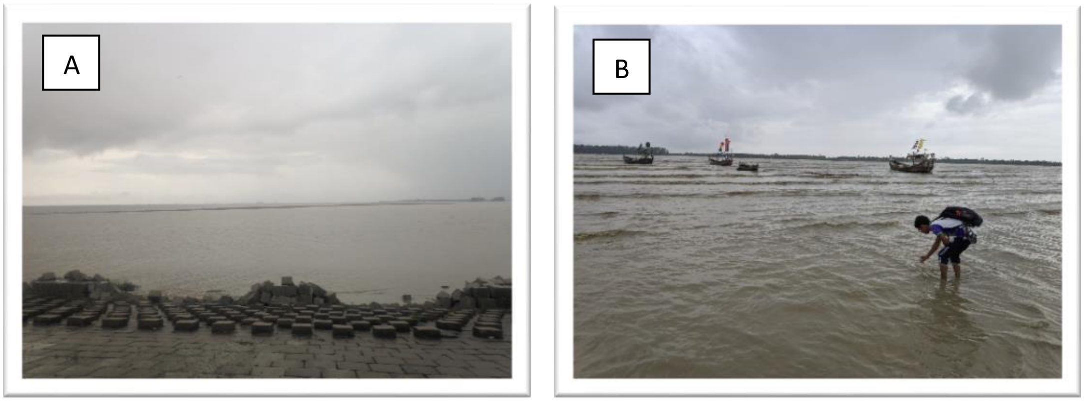
Sampling Location-9: **Naluwa**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi×lnPi**
Terminalia arjuna	7	0.132	0.017	-2.024	-0.267
Artocarpus Heterophyllus	10	0.189	0.036	-1.668	-0.315
Samanea Saman	6	0.113	0.013	-2.179	-0.247
Ficus Benghalensis	3	0.057	0.003	-2.872	-0.163
Tectona Grandis	8	0.151	0.023	-1.891	-0.285
Saraca Asoca	5	0.094	0.009	-2.361	-0.223
Dipterocarpus Turbinatus	4	0.075	0.006	-2.584	-0.195
Bombax Ceiba	4	0.075	0.006	-2.584	-0.195
Cocos Nucifera	2	0.038	0.001	-3.277	-0.124
Swietenia	4	0.075	0.006	-2.584	-0.195
N= 53		**Pi^2=0.119**		**Pi×LnPi = −2.208**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D=1/0.119**			**D=8.403**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H= −(−2.208)**			**H=2.208**	

Sampling Location-10: **Morfola Bazar**					
Plant Species	**n**	**n/N=Pi**	**Pi^2**	**ln Pi**	**Pi×lnPi**
Ficus Benghalensis	2	0.038	0.001	-3.277	-0.124
Terminalia arjuna	7	0.132	0.017	-2.024	-0.267
Acacia Auriculiformis	12	0.226	0.051	-1.485	-0.336
Mangifera Indica	4	0.075	0.006	-2.584	-0.195
Areca Catechu	6	0.113	0.013	-2.179	-0.247
Artocarpus Heterophyllus	4	0.075	0.006	-2.584	-0.195
Calotropis Procera	3	0.057	0.003	-2.872	-0.163
Samanea Saman	5	0.094	0.009	-2.361	-0.223
Swietenia	10	0.189	0.036	-1.668	-0.315
N= 53		**Pi^2=0.142**		**Pi×LnPi= −2.064**	
$D = 1/\sum_{i=1}^{s} P_i^2$	**D=1/0.142**			**D=7.042**	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$	**H= −(−2.064)**			**H=2.064**	

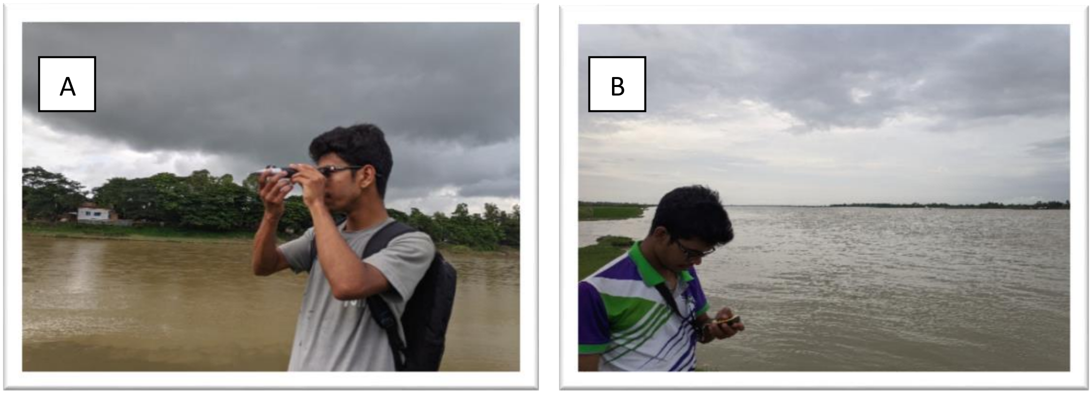
Sampling Location-11: **Rasulabad**		**Latitude:** N22°09'13.2"		**Longitude:** E92°03'29.6"	
Plant Species	**n**	**n/N=Pi**	**Pi²**	**ln Pi**	**Pi×lnPi**
Swietenia	8	0.107	0.011	-2.238	-0.239
Acacia Auriculiformis	8	0.107	0.011	-2.238	-0.239
Tectona Grandis	12	0.16	0.026	-1.833	-0.293
Samanea Saman	7	0.093	0.009	-2.372	-0.221
Ziziphus Mauritiana	3	0.04	0.002	-3.219	-0.129
Artocarpus Heterophyllus	6	0.08	0.006	-2.525728644	-0.2020582915
Ficus Benghalensis	2	0.027	0.001	-3.624	-0.097
Areca Catechu	8	0.107	0.011	-2.238	-0.239
Cocos Nucifera	6	0.08	0.006	-2.526	-0.202
Mangifera Indica	10	0.133	0.018	-2.015	-0.269
Populus Balsamifera	5	0.067	0.004	-2.708	-0.181
N= 57		**Pi²= 0.106**		**Pi×LnPi= −2.309**	
$\boldsymbol{D = 1/\sum_{i=1}^{s} P_i^2}$	**D=1/0.106**			**D=9.434**	
$\boldsymbol{H = \sum_{i=1}^{s} -(P_i \times \ln P_i)}$	**H= −(−2.309)**			**H=2.309**	

Appendix – II

Photographs

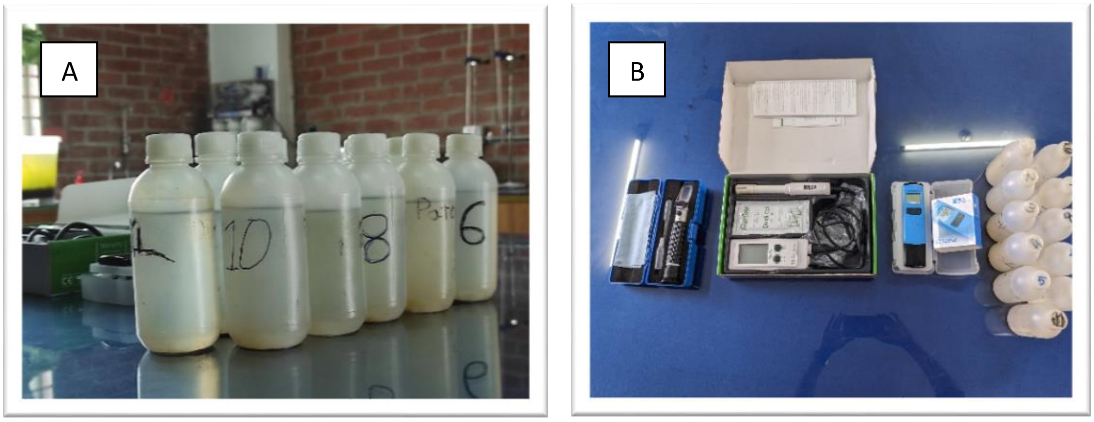


Photographs: (A) Transition point between Sangu river and Bay of Bengal, (B) Collecting water sample of the Kodom Rosul.



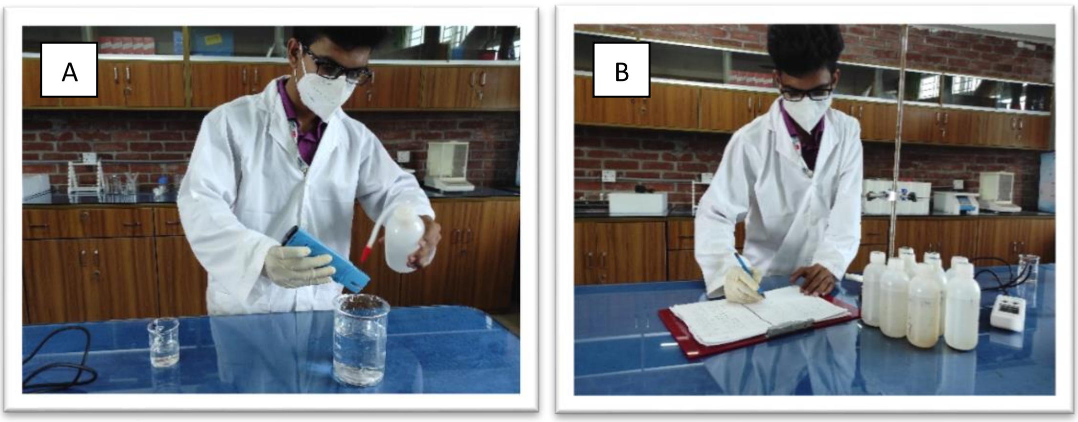
Photographs: (A) Identifying the water salinity in refractometer (Rasulabad), (B) Check GPS data (Moloipara)

Photographs: (A) Numbering Water Sample (Sarwar Bazar), (B) Sampling Location (Moloipara).



Photographs: (A) Collected 11 water samples, (B) Collected water samples and the tools and equipment's of the study. (in Environmental Science and Disaster Management Laboratory of Daffodil International University)

Photographs: (A) Measuring EC, (B) Measuring TDS in Environmental Science and Disaster Management Laboratory of Daffodil International University.



Photographs: (A) Calibration of EC, (B) Writing Data in Spreadsheet (in Environmental Science and Disaster Management Laboratory of Daffodil International University)