Remote Sensing & GIS Based Spatio-Temporal Changes Analysis of Wetland in Different Tourist Spots in Bangladesh

By

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This Thesis Report Presented in Partial Fulfilment 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 “Remote Sensing & GIS Based Spatio-Temporal Changes Analysis of Wetland in Different Tourist Spots in Bangladesh”, submitted by Abdullah Al Jobair 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.

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DECLARATION

Hereby, I certify that I conducted this research project under the guidance of **Dr. A. B. M. Kamal Pasha, Ph.D., Head of the Environmental Science and Disaster Management (ESDM) Department at Daffodil International University (DIU)**. Furthermore, I affirm that neither this research study nor any portion of it has been submitted for consideration for a degree elsewhere.

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DEDICATION

To,

I dedicate this thesis to my beloved parents, Marium Akther and Rezaul Karim, whose unwavering love, sacrifices, and encouragement have been the driving forces behind my academic journey. Your endless support, guidance, and belief in my abilities have been my greatest source of strength and inspiration. This achievement is a reflection of your dedication and commitment to my education. I am forever grateful for your profound influence on my life.

And in remembrance of my beloved seniors, juniors, coordination officers, and staff members from ***Daffodil International University's (DIU) Department of Environmental Science and Disaster Management (ESDM)****, with whom I had the privilege of spending every moment of my final four years as an undergraduate.*

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ABSTRACT

This research study uses remote sensing and geographic information system (GIS) techniques to analyze the spatial and temporal variations in wetland areas in multiple regions of Bangladesh, with a specific focus on popular tourist sites. Wetland ecosystems are advantageous to humans and essential for conserving biodiversity. Human negligence is causing the steady loss of wetland areas. Comprehending this development can assist in taking measures to conserve these wetland areas. This study investigates wetland alterations in different regions of Bangladesh using the analysis of remote sensing data and geographic information system. The study primarily examined the effects of unmanaged wetland areas on tourism. This study aims to identify changes and propose an effective technique for preserving wetland habitats. This study will evaluate a strategic action required to save wetland regions. The study emphasizes the connection between wetland protection and tourism management, providing valuable information for individuals involved in land-use planning, infrastructure development, and conservation efforts. This study highlights the required alterations to wetland habitats and the significance of their conservation. Integrating wetland management with remote sensing and geographic information system (GIS) technology can save vital ecosystems in Bangladesh and improve their biodiversity and tourism potential in the future.

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CHAPTER 1: INTRODUCTION

A brief description of the research project is provided in this chapter. The presentation will consist of an easily understood summary of the objectives, significance, and history of the study. The outline of this analysis outcome is also shown and broadly discussed in this section. There are actually five chapters in this chapter. They are –

1.1 Background

Bangladesh once had a large area of wetlands, which helped decrease the occurrence of disasters and maintain ecological balance. The frequency and intensity of natural disasters have reached a major level, creating considerable threats. The deterioration of wetland habitats and the subsequent construction of human infrastructure in these places are significant factors to this phenomenon. The degradation of wetlands is an especially worrying issue in metropolitan settings, with a special focus on Dhaka and its neighboring regions (Khusrul Amin et al., 2013).

Various factors have contributed to the disappearance of these wetlands. This tool has the capacity to create different architectural designs. With the development of improved human mobility, there has been a clear rise in the demand for entertainment among people. Converting wetlands into commercial areas requires the destruction of a substantial number of natural ecosystems.

Upon reviewing extensive research, it was discovered that the pace of wetland depletion in Bangladesh has not been quantified using advanced technology, and there is a lack of study about potential future damages. To determine the damage's scope and predict possible problems, we must analyse it using advanced methods such as GIS.

1.2 Problem Statement

Bangladesh has a variety of habitats that thrive because of its rich natural beauty and wetland resources. Over time, people's needs are increasing, resulting in a growing preference for travel for enjoyment and relaxation. On the other hand, businesses are being formed in a disorganized manner, leading to harmful effects on the ecosystem and the wetlands in the region. Between 1990 and 2015, about half of the wetlands in Dhaka city were destroyed, primarily as a result of the city's swift urbanization and industrial expansion (Mukti et al., 2020). The wetland areas of Matasagar and Sukhsagar in Bangladesh require urgent conservation efforts due to commercial operations and lack of public awareness (Rahman & Rashid, 2016).

Nonetheless, it is conceivable to prevent it by means of strategic planning. In order to halt the degradation of wetland ecosystems and improve socioeconomic conditions, livelihoods, biodiversity, and livelihoods, Bangladesh must execute an all-encompassing strategy that incorporates technological, political, economic, and social developments (Byomkesh et al., 2009). Bangladesh needs a comprehensive strategy to address the impacts of climate change and ensure sustainable wetland protection. This strategy should involve institutional, technological, social, political, and economic support (Siddiquee et al., 2011).

We can enhance our understanding of wetlands by utilizing the Geographic Information System (GIS) technique. Utilizing remote sensing and GIS methods effectively to map and identify isolated wetlands (Reif et al., 2009); (Yi et al., 2010). An in-depth analysis of remote sensing and GIS applications in the context of mapping and monitoring wetlands, provided by (Wu, 2018). The importance of these instruments in the field of wetland management and conservation is shown by this study.

So, our objective is to quantify and examine the alterations in wetland regions in key tourist spots in Bangladesh during the past 12 years through the application of GIS and remote sensing technology. This goal involves analyzing multi-temporal satellite pictures to identify changes in land cover and land use patterns unique to wetland ecosystems, and measuring the pace of wetland depletion or growth. We will also investigate the impact of heightened tourism on wetland ecosystems in Bangladesh. It involves examining spatial data related to tourism and infrastructure development to see how these factors have impacted the wetlands. The goal is to determine how to enhance the sustainability of tourism while maintaining economic benefits.

1.3 Objectives of the Study

i. To measure and map the spatial and temporal changes in wetland areas. **Specific aim:** Utilize remote sensing data and GIS tools to accurately measure and depict the fluctuations in wetland coverage in well-visited tourist locations across different states in Bangladesh during a defined historical period.

ii. In this study, we aim to assess the current state of wetlands within the study area by employing satellite imagery analysis, field surveys, and GIS techniques. Our objective is to accurately map and delineate existing wetland areas while quantifying the extent of wetland loss over a specified period. **Specific aim:** Identifying Existing Wetlands and Wetland Loss.

iii. To evaluate the impact of tourism on wetland ecosystems. **Specific aim:** Investigate the impact of tourism development on wetland modifications by integrating tourist activity data with the spatio-temporal variations in the wetlands.

1.4 Significance of the research

This study explores the relationship between environmental conservation in Bangladesh and tourism. Bangladesh has a rich biodiversity, yet it is facing substantial losses over time. Continuation of this tendency will lead to the eventual loss of biodiversity. Human activity and negligence are causing an increase in natural disasters.

This work focuses on utilizing remote sensing and GIS methods to look into time frame variations in wetlands located in prominent tourist destinations throughout various regions of Bangladesh. It is essential to analyze these changes in order to protect the ecosystem. Studying the changes and developing an essential plan for managing and conserving these wetlands can greatly help in environmental preservation.

Studying tourism regions is essential since wetlands are key for maintaining both tourism and environmental health. Studying changes in tourism destinations and taking smart measures helps safeguard wetlands and maintain ecological balance.

The study's findings can offer valuable perspectives for influencing wetland conservation and tourism management policies, affecting decision-making at both local and national levels. Highlighting the dynamic nature of wetlands and the variables that drive their changes can assist policymakers in developing specific and effective measures to protect the long-term sustainability of these vital ecosystems.

This study has the potential to greatly influence wetland conservation, tourism experiences, and sustainable development in important tourism areas in Bangladesh.

1.5 Study Question

i. What are the spatial and temporal variations in wetland areas?

ii. How does tourism affect wetland ecosystems?

1.6 The Study Report's Structure

A total of five chapters in the research study report. The following are the chapters:

Chapter 01: Introduction

This chapter presents a synopsis of the research work. The components contain a quick summary of the context, problem description, and the research goals. This chapter additionally illustrates and briefly clarifies the structure of the research report for the study. This chapter has been divided into seven(7) sections.

Chapter 02: Literature Review

This chapter has an in-depth overview divided into four different sections. This chapter provides a full description of the inquiry, including several research sources and theses. The chapter has been divided into eight sections.

Chapter 03: Methodology

This chapter offers a full overview of the issue region and explores the methodical approaches utilized to conduct the research. This chapter has been divided into nine major parts.

Chapter 04: Result and Discussion

The following section thoroughly looks at the facts and conclusions of our research in a new way. We established two specific goals for ourselves at the start of our studies and worked hard to attain them. This chapter focused on building a systematic knowledge of the goals via the analysis of the acquired data and conclusions.

Chapter 05: Conclusion and Recommendation

In the study's last chapter, we aimed to summarize the key findings from the literature review, gathering data, analysis of data, outcomes, and comments. We also attempted to make clear the rationale for the study's objectives. Researchers are provided recommendations to assist them to better understand the upcoming studies.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to Wetland Importance

Wetlands are essential ecosystems because of their many functions and importance. Wetlands serve a crucial role in flood control and maintaining water quality, with around 3-7% of temperate-zone watersheds needing wetlands for sufficient protection (Mitsch & Gosselink, 2000). They are extremely productive, providing support for a diverse array of species and functioning as crucial habitats (Ow Us Epa, 2015). Wetlands play a crucial role in storing carbon, as 14% of the global carbon content is located in wetland soils (Adger, 1995). Their significance lies in their ability to regulate local ecosystems, support industry, and preserve freshwater purity, highlighting their ecological and economic relevance (Bhowmik, 2020).

A country's wetland environment is one of its most precious resources. Wetlands are crucial for the development of ecosystems. Wetlands offer essential functions for human survival and provide habitats for a diverse range of animal species (Jafari, 2009). Wetlands are essential for preserving water quality, controlling floods, minimizing storm damage, and protecting unique species (Patrick, 1994). It is susceptible to damage from people and other systems. Disruption of the natural equilibrium in a place can lead to many issues for the inhabitants. natural disasters, especially (Gajjar & Solanki, 2021). This part will focus on wetland habitats, remote sensing applications, GIS technology, and the connection between tourism and wetland ecosystems.

It is crucial for the survival of humans that wetland regions are conserved and effectively maintained (Gardner & Finlayson, 2018). Wetlands in Bangladesh play a crucial role in conserving biodiversity and enhancing rural socioeconomic conditions (S. N. Islam, 2010). Wetlands are valuable and delicate habitats that support a diverse range of plant and animal species, as well as human communities (Kotagama & Bambaradeniya, 2006).

2.2 Wetlands and Tourism

Wetlands have a substantial impact on tourism and offer opportunities for expanding the business (Bacon, 1987). They also positively influence local livelihoods by enhancing financial, natural, human, physical, and social capital (Aazami & Shanazi, 2020). Yet, the rising tourist influx in wetland regions can result in both conservation efforts and harm to animals (Angelos Kotios et al., 2009). Effective management of sustainable tourism is essential, as exemplified by the Boondall Wetlands Reserve in Australia, which effectively raises environmental consciousness and provides nature-oriented recreational activities and eco-tourist services (Lim & McAleer, 2002).

The relationship between wetlands and tourism is intricate, involving both favorable and unfavorable elements. Wetlands have the potential to attract tourists, but it is crucial to involve the local population and promote environmentally sustainable practices (Khoshkam et al., 2014; Khoshkkam & Marzuki, 2011). The effects of tourism on water consumption and the difficulties of preserving wetlands among increasing visitor arrivals (Angelos Kotios et al., 2009). A study highlights the adverse impacts of wildlife tourism on wetland animals, indicating a possible drawback to wetland tourism (R. Fulton, 2002).

Wetlands in Bangladesh, such as haors, baors, and beels, play a crucial role in supporting biodiversity and sustaining livelihoods (Yousuf Haroon & Kibria, 2017). The nation's varied natural features, such as wetlands, offer potential for the growth of tourism (Shamsuddoha, 2009). The forest-based tourism sector, including wetlands, encounters issues such stakeholder conflicts and forest degradation (Alam et al., 2009). Wildlife and modern tourism coexisting is a worry due to tourists indirectly causing a decline in wildlife species (Sultana et al., 2020).

The growth of tourism in Bangladesh, especially in wetland regions, is impeded by a shortage of proficient staff and specific training initiatives (Shamsuddoha, 2004). Construction activities, transportation systems, and visitor behavior are all factors that provide environmental hazards in these regions (M. Islam, 2015). Population expansion, agriculture, and pollution contribute to the deterioration of wetlands, worsening the existing difficulties (Byomkesh et al., 2009). A comprehensive strategy is required to tackle these difficulties and guarantee the sustainable growth of wetland tourism in Bangladesh.

2.3 Anthropogenic Impact on Wetlands

Human activities, such as population growth, urban development, and alterations in land use, have had a notable effect on wetlands in many locales, including Kerala, India's coastal

regions, and the Songnen and Sanjiang Plain in China (Zainulabdeen & Nagaraj, 2022) (Newton et al., 2020) (Chen et al., 2018). The repercussions encompass pollution, habitat loss, alterations in connection, and contamination. Restoration measures, including implementing artificial water input in China, can help reduce some of these problems (Wang et al., 2012).

The wetlands in Bangladesh, especially the Ganges-Brahmaputra-Meghna Delta, are experiencing notable human-induced pressures such as agricultural growth, shrimp farming, and urban development (S. N. Islam, 2016). The operations are causing the deterioration of wetland habitats, endangering biodiversity and the well-being of local residents (Byomkesh et al., 2009). It is important to implement thorough wetland management techniques that involve community-based approaches and integrate wetlands management into larger land and water use systems (Byomkesh et al., 2009). Emphasizing the significance of wetlands for preserving biodiversity and promoting rural socioeconomic growth, there is a need for transdisciplinary policies and strong political determination to safeguard these environmentally delicate habitats (S. N. Islam, 2010).

2.4 Role of Remote Sensing and GIS in Wetland Studies

Remote sensing and GIS are essential in wetland research, especially for mapping, monitoring, and evaluating changes in wetland ecosystems. (Kumar et al., 2020) Emphasizes the application of remote sensing in water erosion evaluation, whereas (Wu, 2018) and (Elias & Chand, 2019) both underscore the significance of these technologies in wetland cartography and surveillance (Wu, 2018). The text focuses on the utilization of high-resolution data and aerial pictures, whereas (Elias & Chand, 2019) showcases the usage of remote sensing and GIS in tracking changes in wetland regions. (Ghobadi et al., 2012) Emphasizes the importance of using multi-temporal remote sensing data and GIS to evaluate wetland change and degradation. These works emphasize the crucial importance of remote sensing and GIS in wetland research, offering valuable perspectives for conservation and management initiatives.

2.5 Wetland Studies in Bangladesh

Wetlands in Bangladesh are varied and environmentally important, offering a variety of benefits to nearby communities (Yousuf Haroon & Kibria, 2017). These wetlands are endangered by factors such as population increase, intensive agriculture, and pollution (Byomkesh et al., 2009). Emphasizing the necessity of a thorough approach to tackle these difficulties, with an emphasis on sustainable management and conservation (S. N. Islam, 2010). Studying the spatial and temporal changes in key tourism areas is important, and examining the evolution of wetland landscape patterns might offer vital insights in this context

(Haiying, 2010).

2.6 Current Situation of Bangladesh's Wetlands

Various research indicate that our wetlands are diminishing. In the Northwest region of Bangladesh, a study discovered that during the dry season in 1989, 2000, and 2010, the total wetland area was 1208.72 square kilometers, 903.54 square kilometers, and 867.18 square kilometers, respectively (Shopan, 2013). A research in Dhaka has revealed a significant drop in the area inhabited by rivers, khals, and wetlands over the last thirty years (Habiba et al., 2011). Urban infrastructure expansion has been occurring in an unplanned manner (M. S. Islam et al., 2014). Deterioration of the wetland ecosystem has a substantial adverse effect on the biological resources (Hossain St, 2013).

Prior research has offered background information for the consideration of this topic. The investigations illuminate the evolution of wetland habitats. They explain the role individuals play in the ecology and the damage being done to it. The significance of wetland resources in Bangladesh and their degradation due to human activities and habitat destruction (Hossain, 2019). The consequences, including as waterlogging, of the vanishing wetland lands in Dhaka metropolis due to uncontrolled urbanization (Habiba et al., 2011). It is crucial to use a comprehensive approach to manage wetland ecosystems in Bangladesh due to the various threats they face, such as pollution, exploitation, and lack of awareness (Byomkesh et al., 2009).

2.7 Discriminatory Impact of Tourism On Wetland Area

Multiple studies suggest that the tourism sector in Bangladesh negatively impacts wetland ecosystems by causing resource depletion, pollution, and climate change. Human activity, lack of understanding, and profit-driven behaviors worsen the susceptibility of wetlands and their biodiversity to heightened endangerment. Tourist development in Bangladesh has led to negative impacts on the environment such as marine resource depletion, overfishing, pollution, soil degradation, and air pollution (Kalam & Hossen, 2018). Tourist development in Bangladesh has led to negative environmental impacts such as marine resource depletion, overfishing, pollution, soil deterioration, and air pollution (Sun et al., 2017). This discussion explores the possible negative effects and deterioration of wetland ecosystems and their biodiversity due to climate change, which could influence the tourism industry in the area (Kibria & Yousuf Haroon, 2017).

2.8 Research Gap and Rationale

This literature review emphasizes the urgent need to participate in a critical discussion on the important interaction between human behavior, tourism, ecological well-being, and particularly wetland ecosystems. Prior research has investigated the human-induced alterations of wetlands or studied the changing features of wetlands. One can also gain a comprehensive understanding of the loss of biodiversity. Past studies have not focused much on tourism zones or highlighted the advantages of using remote sensing and GIS. Moreover, although many research projects have separately investigated environmental and socio-economic issues, the correlation between these two areas has not been explored. This study tries to establish a correlation between changes in wetland ecosystems caused by human activities and the consequent negative repercussions by analyzing and integrating findings from prior research.

CHAPTER 3: METHODOLOGY

The proposed research methodology aims to analyze spatio-temporal changes in wetlands within popular tourist destinations across 3 districts of Bangladesh, employing an integrated approach combining remote sensing, Geographic Information System (GIS) technologies, and field surveys for verification and fact-checking. This comprehensive strategy ensures a thorough investigation, capturing both the ecological dynamics of the wetlands and the impact of tourism.

3.1 Selection Criteria for Study Areas

1. Selection emphasized the diversity of wetland ecosystems proximate to tourist attractions, reflecting Bangladesh's ecological variety.
2. Areas with significant tourist activity were chosen to study human impact on wetlands.
3. Preference was given to Upazilas with accessible historical and current remote sensing data, facilitating detailed spatio-temporal analysis.
4. The geographical distribution of the study areas includes coastal, inland, and northeastern regions, offering a holistic view of the country's ecological settings.

3.2 Selection Process

1. Satellite imagery was initially reviewed to identify changes in land cover, focusing on wetland areas within tourist zones.

2. GIS overlay techniques pinpointed intersections between wetlands and tourism zones.

3. The selection favored regions with extensive remote sensing data history, enabling a comprehensive temporal analysis.

4. Input from environmental experts, local authorities, and tourism operators was incorporated, adding depth through ground-truthing and socio-economic insights.

3.3 Areas of Study

This visualization has the title a 'Study Area Map' and it shows the important areas and popular tourist attractions in certain parts of Bangladesh. It would be useful for studying the environmental impact and socio-economic aspects of the region. The study includes four different regions, and each region is represented by a different color. Gowainghat Upazila is located in Sylhet and is marked in pink on the map. It is home to popular tourist destinations

such as Bichanakandi and Ratargul Swamp Forest, which are famous for their stunning natural beauty and ecological importance. The green area on the map represents three Upazilas in the Moulvibazar District: Barlekha, Juri, and Kulaura. It also shows Hakaluki Haor, which is a large wetland that is important for aquatic biodiversity.

In Cox's Bazar Sadar Upazila, you will find beautiful beaches like Laboni, Sugandha, and Kolatoli. The area is shaded in purple on the map to make it stand out. These beaches are important tourist attractions and can serve as study areas for understanding their environmental pressures and the impacts of tourism. Lastly, Bandarban Sadar Upazila is a beautiful place with lots of greenery. It is home to several tourist attractions like Swarna Mondir, Meghla Lake, Nilachal, and Prantik Lake. These destinations are probably included in the study because they are popular, which could have an impact on the local ecosystems and the livelihoods of the community.

The small map in the top right corner shows the study areas in Bangladesh and their locations on the main map. This highlights the wide geographical range of the study, covering various terrains and environmental contexts.

This map is used as a tool to help define the boundaries and focal points of the study. This statement sets the foundation for studying how wetlands change over time and space, as well as identifying the reasons behind the loss of these areas, such as urbanization and tourism development. The sites chosen for the study indicate a focus on areas where people have a significant impact on the environment. This will allow for a detailed analysis of how humans and the environment interact with each other. The map serves as a basis for a study that seeks to comprehend the intricate relationship between conservation and development.

3.4 Data Collection

Utilizing a diverse range of methods, the research incorporates satellite imagery, tourism data, and field surveys to examine wetland transformations in well-visited tourist spots throughout Bangladesh. Utilizing high-resolution satellite images from different time periods is crucial for detecting changes in wetland areas over time. Examining the spatio-temporal aspects is essential to grasp the wetland ecosystems' dynamics amidst growing tourist activities. Utilizing satellite imagery is crucial for monitoring changes in land cover and land use, providing a broad perspective on environmental effects.

Analyzing tourism data, such as visitor statistics, is crucial for understanding the impact of human activity on wetland conditions. This data illuminates the trends and impact of tourism,

offering a foundation for evaluating the strain on natural resources and ecosystems. Through analyzing this data, experts can establish links between the expansion of tourism and its impact on the environment, especially in regions with remarkable natural beauty and ecological significance.

Field surveys are crucial for validating and improving the analysis done on satellite images. By conducting direct observations, measuring soil and water quality, and assessing vegetation, field surveys provide in-depth information about the current condition of wetlands. By taking a practical approach, we guarantee precise data analysis that connects remote observations with real conditions on the ground.

By combining various data sources such as satellite imagery, tourism statistics, and field survey results, a comprehensive understanding of the relationship between human activity and wetland ecosystems is achieved. It offers a strong empirical basis for the study, enabling a thorough analysis of the effects of tourism on wetland sustainability. Utilizing sophisticated remote sensing methods along with field assessments, the research seeks to provide valuable information on wetland conservation and management within the expanding tourism sector of Bangladesh.

3.5 Analytical Frame Work

Our study utilizes a structured analytical framework that combines change detection algorithms, spatial analysis in GIS, and time-series analysis to explore the wetland dynamics in connection with tourism activities. By using the Normalized Difference Water Index (NDWI) and supervised classification techniques, we analyze changes in wetland areas to understand environmental changes over time. Understanding this process is essential for precisely assessing the influence of human actions on these vital ecosystems.

Utilizing spatial analysis in GIS is crucial for mapping wetland areas over different time frames and linking these results to the growth and impact of tourist areas. By visually representing and analyzing the spatial relationships between tourism development and wetland conservation, we can identify areas of concern and opportunities for sustainable management.

Studying time-series analysis helps us gain a deeper understanding by pinpointing the rates and patterns of change in wetlands over time, connecting these trends to tourism activities. Through analyzing data gathered at various time points, we can track the changes in wetland areas and evaluate the lasting effects of human activity and construction projects.

Field surveys are carried out to address any discrepancies and confirm the findings.

Conducting these surveys is crucial for verifying the precision of remote sensing data and GIS analyses. Through combining firsthand observations with further data collection, including analyzing soil and water quality, we establish a thorough and dependable dataset. Our study utilizes advanced analytical techniques along with field verification to offer insightful and actionable results on the relationship between tourism and wetland sustainability.

3.6 Data Collection Methods

I have carefully crafted mine data collection methodology to include a combination of remote sensing data, aerial photography, ground verification, secondary data sources, and the integration of this information using Geographic Information System (GIS) technology, in addition to thorough field surveys. Beginning with remote sensing data, we use both historical and contemporary satellite imagery to track and evaluate the alterations in wetlands throughout time. By using this method, we can monitor the changes in these ecosystems, pinpointing areas that have been significantly impacted by natural forces or human actions, especially tourism.

Using high-resolution aerial photographs to enhance the satellite data. Examining these images reveals intricate wetland alterations, providing a detailed view of the precise locations impacted by tourism and human activities. Examining aerial photography in detail helps to pinpoint slight variations in land cover and usage that satellite images may miss, thus improving the accuracy of our spatial analysis.

Confirming data on the ground is crucial for maintaining the accuracy of our remote sensing information. By going out into the field, we make direct observations and gather on-site data such as soil samples, water quality measurements, and vegetation assessments. Validating interpretations made from remote sensing and aerial photography through the ground-truthing process is crucial to ensure that our findings accurately reflect on-the-ground realities.

Including secondary data is another vital component of our methodology. We collect demographic, socio-economic, and environmental data from various governmental and non-governmental sources. Examining this data offers a more comprehensive view of the shifts seen in the wetlands, aiding in grasping the socio-economic factors influencing these changes and their impact on local communities and ecosystems.

GIS technology plays a crucial role in our data analysis, allowing us to combine and analyze the different data layers we gather. Using GIS technology, we can observe the evolution of wetlands, connect these transformations with the growth of tourist areas, and assess the effects of tourism on these delicate ecosystems.

After conducting thorough field surveys, we gain crucial insights that remote sensing alone cannot offer, enhancing our dataset significantly. Conducting thorough surveys of particular locations, interacting with nearby residents, and evaluating the social and economic aspects that impact wetland preservation and tourism activities. Conducting field surveys not only helps verify data but also enhances our study with detailed insights into human-wetland interactions, ensuring a comprehensive approach to assessing the sustainability of wetland tourism. By blending cutting-edge technological tools with practical fieldwork, we have established a solid research approach to provide detailed perspectives on the conservation issues and possibilities in Bangladesh's wetlands.

Remote Sensing Techniques Employed:

1. NDWI monitored changes in water content and aquatic vegetation.

2. Land Use and Land Cover Classification categorized land into different use and cover types.

3. Change Detection Analysis quantified land cover changes over time.

4. Thermal Imaging analyzed temperature dynamics relevant to wetland health.

3.7 GIS Analysis Procedures

Our study utilizes thorough Geographic Information System (GIS) analysis procedures to carefully investigate the spatio-temporal changes in wetlands caused by tourism. At the start, data preparation includes merging different datasets in the GIS framework to create a solid foundation for analysis. Ensuring this step is completed is crucial as it brings together data from various sources, laying the foundation for precise and enlightening analysis.

After digitizing and vectorizing satellite imagery, we can pinpoint specific wetland and tourism features accurately. Converting raw satellite images into GIS formats allows for a thorough analysis of wetland areas and their relationship with tourism infrastructure. By conducting this analysis, we can precisely chart the distribution of wetlands and tourist areas, creating a solid foundation for future research.

Applying spatial analysis techniques such as buffer and overlay analyses to investigate the impact zones where tourism meets wetland areas. These analyses assist in pinpointing areas where wetlands are particularly at risk from tourist activities, making it easier to focus on conservation efforts. Examining data over various time periods helps us monitor shifts in wetland coverage and condition. Having a long-term view is crucial for grasping patterns and guiding conservation efforts.

Mapping habitat suitability is a critical step in pinpointing areas within wetlands that provide ideal conditions for species that may be impacted by tourism. This analysis helps in the preservation of biodiversity by identifying crucial habitats that require protection. Examining the impact of tourism infrastructure on wetland areas involves assessing the balance between visitor access and ecological preservation.

Using forecasting models to predict future changes in wetlands based on observed trends and current data. These models predict the possible consequences of ongoing tourism expansion and changes in the environment, guiding forward-thinking conservation strategies. After conducting a thorough GIS analysis, zoning and management plans are created by integrating field survey results to validate both ground truth and GIS data. These plans detail strategies for sustainable tourism and wetland conservation, with the goal of reducing negative effects and encouraging responsible visitor interaction.

During these processes, GIS technology acts as a potent instrument, allowing for the thorough and intricate examination of wetlands within the tourism framework. Through the integration of diverse datasets, utilization of advanced spatial and temporal analysis techniques, and validation of results via field surveys, our research establishes a strong basis for making informed decisions regarding the preservation and administration of Bangladesh's valuable wetland ecosystems.

This methodology, embracing remote sensing, GIS analysis, and field validation, forms a robust framework for examining the interplay between tourism development and wetland conservation in Bangladesh, underpinned by empirical data and enriched with socio-economic perspectives

CHAPTER 4: RESULT AND DISCUSSION

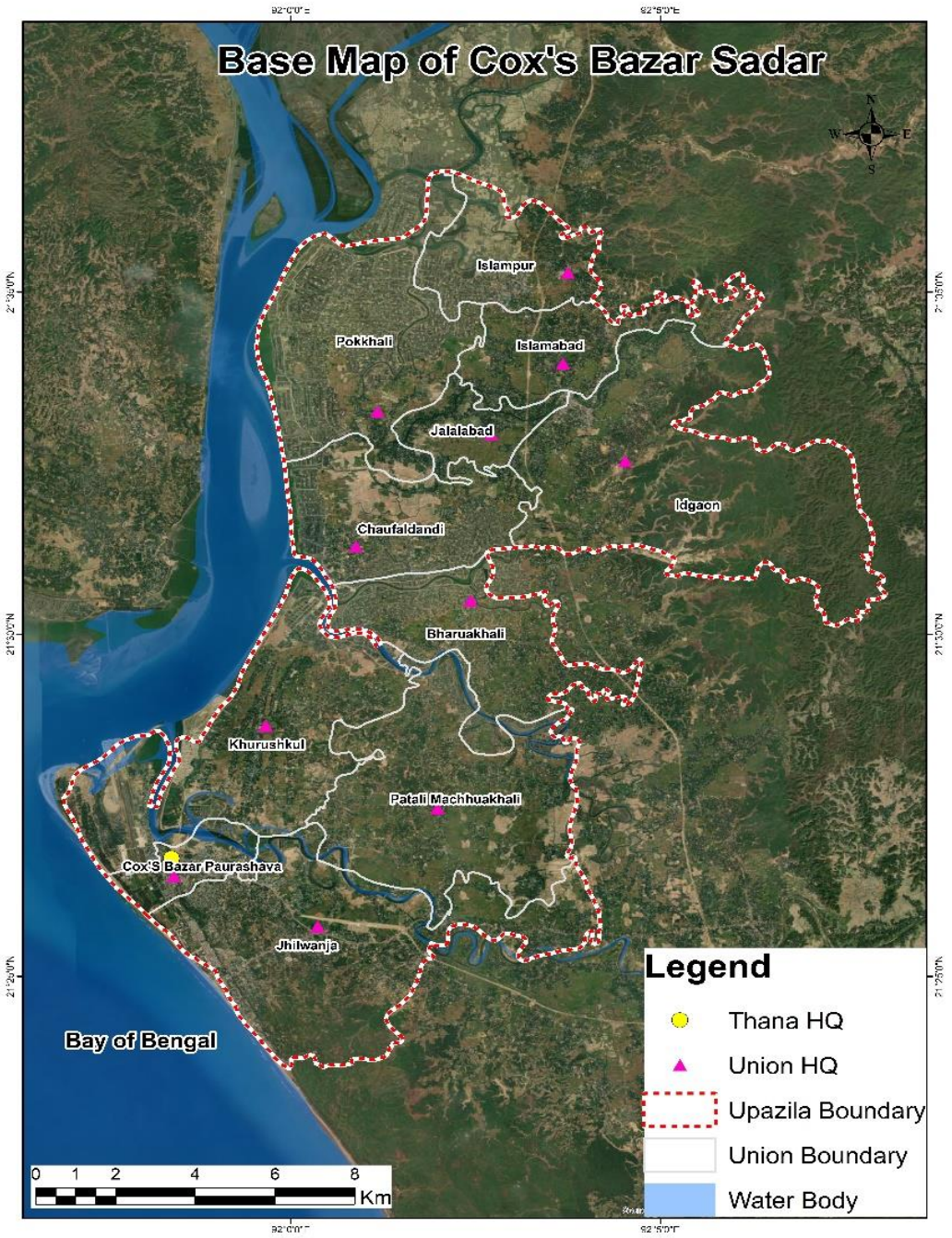


Figure 1: Study area map (cox's bazar Sadar)

This map shows the administrative boundaries and important features in Cox's Bazar Sadar, an area famous for its long sandy beach. The red dashed lines show the boundaries of Upazilas, which are larger administrative units, while the white solid lines show the boundaries of smaller administrative units called Unions. The Thana Headquarters (HQ) are represented by yellow dots, while Union HQs are represented by purple triangles, emphasizing the centers of local governance. The map also displays water bodies with blue shading to show the closeness

of the Bay of Bengal and different inland waterways. The scale at the bottom of the map shows the distance, indicating that the map covers an area of about 10 kilometers at its widest point.

4.1 Decadal Wetland Changes in Cox's Bazar Sadar: A GIS Analysis (2012-2022)

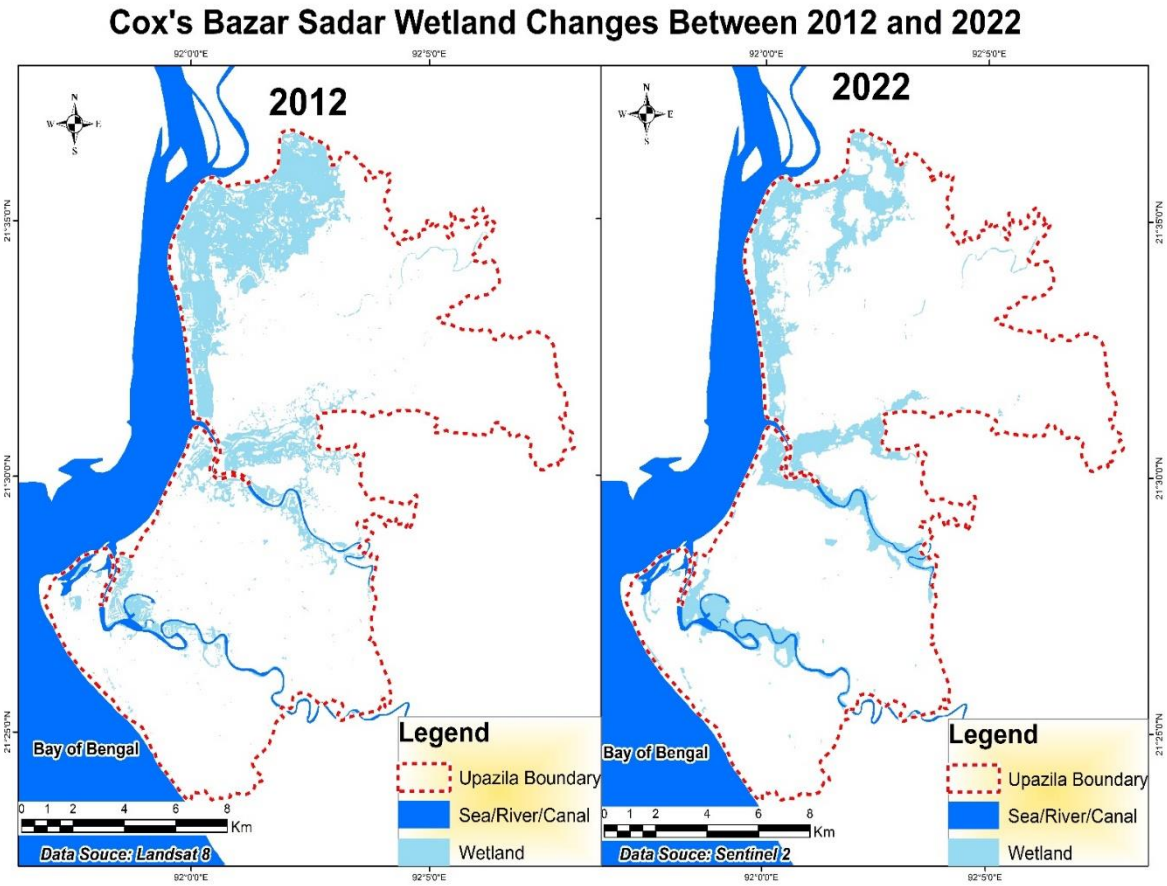


Figure 2: Cox's Bazar Sadar Wetland Change Between 2012 and 2022

The map shows a comparison of wetland changes in Cox's Bazar Sadar from 2012 to 2022. In the 2012 map, the wetlands, indicated in light blue, appear to be more widespread and connected, indicating a more robust ecosystem during that period. In 2022, there has been a noticeable decrease in the size and quantity of wetlands, suggesting a significant loss of this important habitat over the past decade. The decrease is especially noticeable along the edges of the Upazila boundaries, indicated by the dashed red lines, where encroachment due to development or changes in land use may be taking place. Based on the maps, it's clear that some wetland areas have completely vanished, particularly the smaller, isolated ones that are no longer present in the 2022 version.

This loss may be due to factors such as agricultural expansion, urban development, or changes in hydrological regimes. This comparison underscores how wetland ecosystems are impacted by human activities and the importance of conservation efforts. The blue shades on both maps

suggest that certain bodies of water, like the Bay of Bengal and rivers, have not changed, pointing to a level of resilience or steady management in those specific aquatic ecosystems. The spatial distribution of the remaining wetlands in 2022 indicates that conservation efforts might need to concentrate on linking fragmented habitats to maintain ecological continuity.

These maps clearly show the importance of implementing sustainable land management practices and enforcing environmental policies to protect and potentially restore the remaining wetland areas in Cox's Bazar Sadar.

4.2 Dynamic Comparative Analysis

The map displays the wetland losses in Cox's Bazar Sadar from 2012 to 2022. The yellow areas on the map show the wetlands that have been lost over the years, indicating a notable decrease in ecological habitats. The wetlands that are left, shown in light blue, are spread out and separated, suggesting habitat fragmentation. The map highlights the consistent presence of significant water bodies like the sea and rivers, which have not shown any significant decline, indicated by dark blue color. Clearly marking the Upazila boundaries with dashed red lines shows that the disappearance of wetlands is not limited to administrative borders, indicating a more intricate relationship between natural and human factors in these transformations.

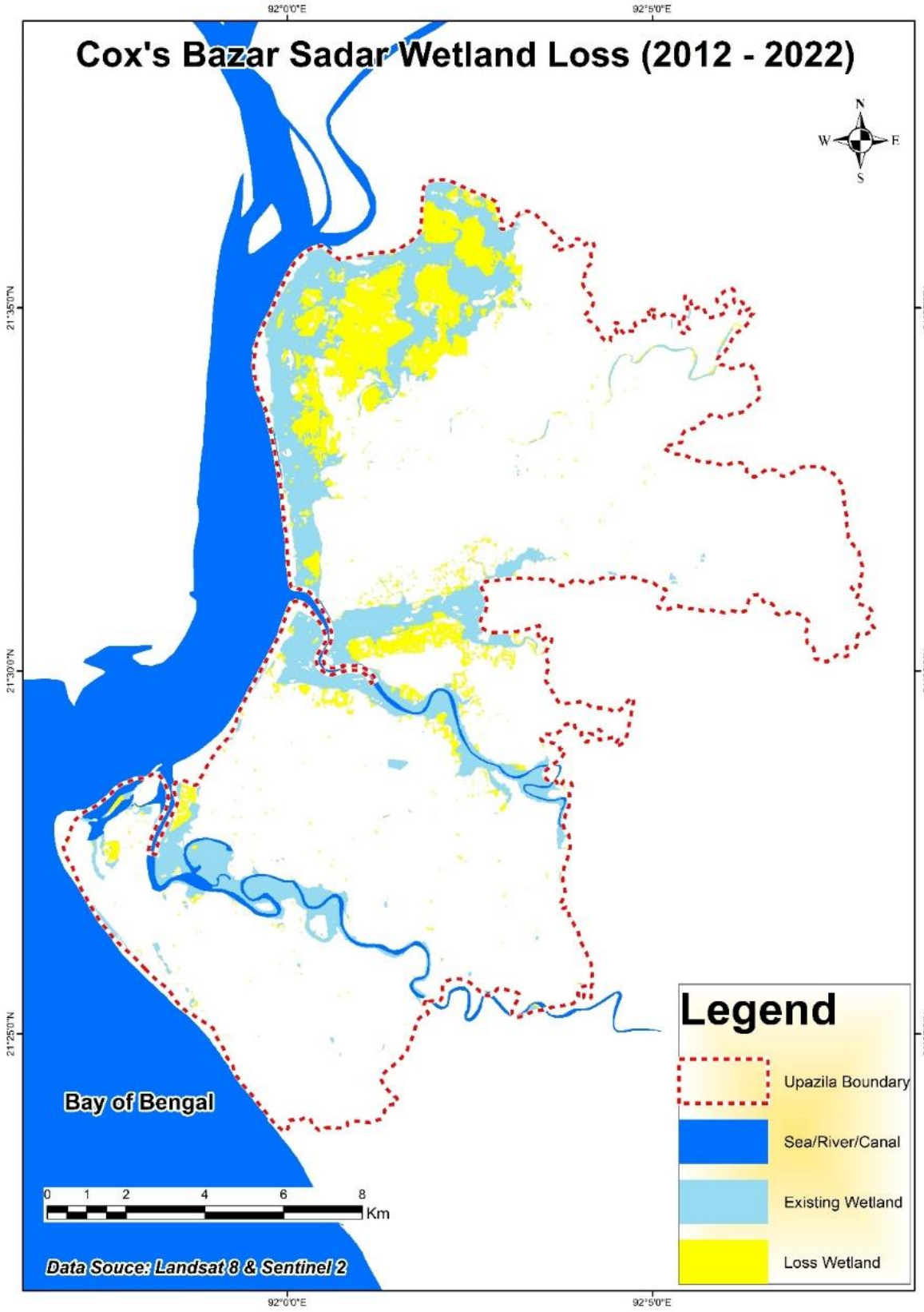


Figure 3: Cox's Bazar Sadar Wetland loss Between 2012 and 2022

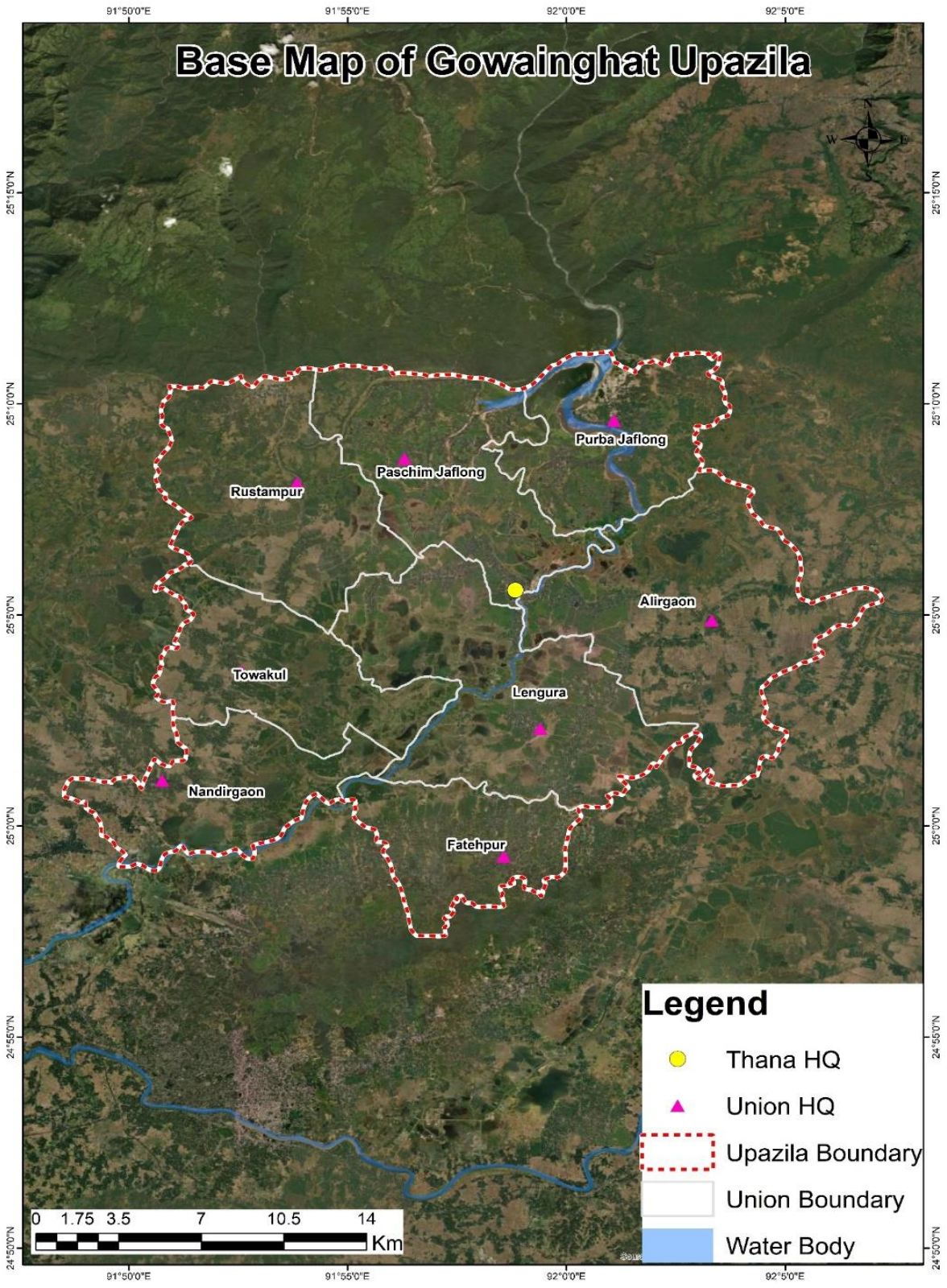


Figure 4: Study area map (Gowainghat Upazila)

The base map shows Gowainghat Upazila, emphasizing its geographical and administrative features with a satellite image in the background. The boundaries of the Upazila are marked by dashed red lines to separate it from the surrounding areas. Thana Headquarters (HQ) are

shown with yellow dots, serving as the main administrative center. The Union HQs, marked by purple triangles, indicate the presence of smaller administrative units within the Upazila. The map shows blue lines that represent water bodies like rivers and streams in the region. These waterways are important for the local ecosystem and the residents' livelihoods. The satellite images show us a close-up view of the land and how it's being used. The map showing areas with vegetation, which might be farmland, and other areas that look more barren, possibly indicating urban areas or land that can't be used for farming. The scale displayed at the bottom of the map helps you estimate the size of features within the Upazila by providing a reference for distance. This map is an essential tool for planning and managing resources in Gowainghat Upazila.

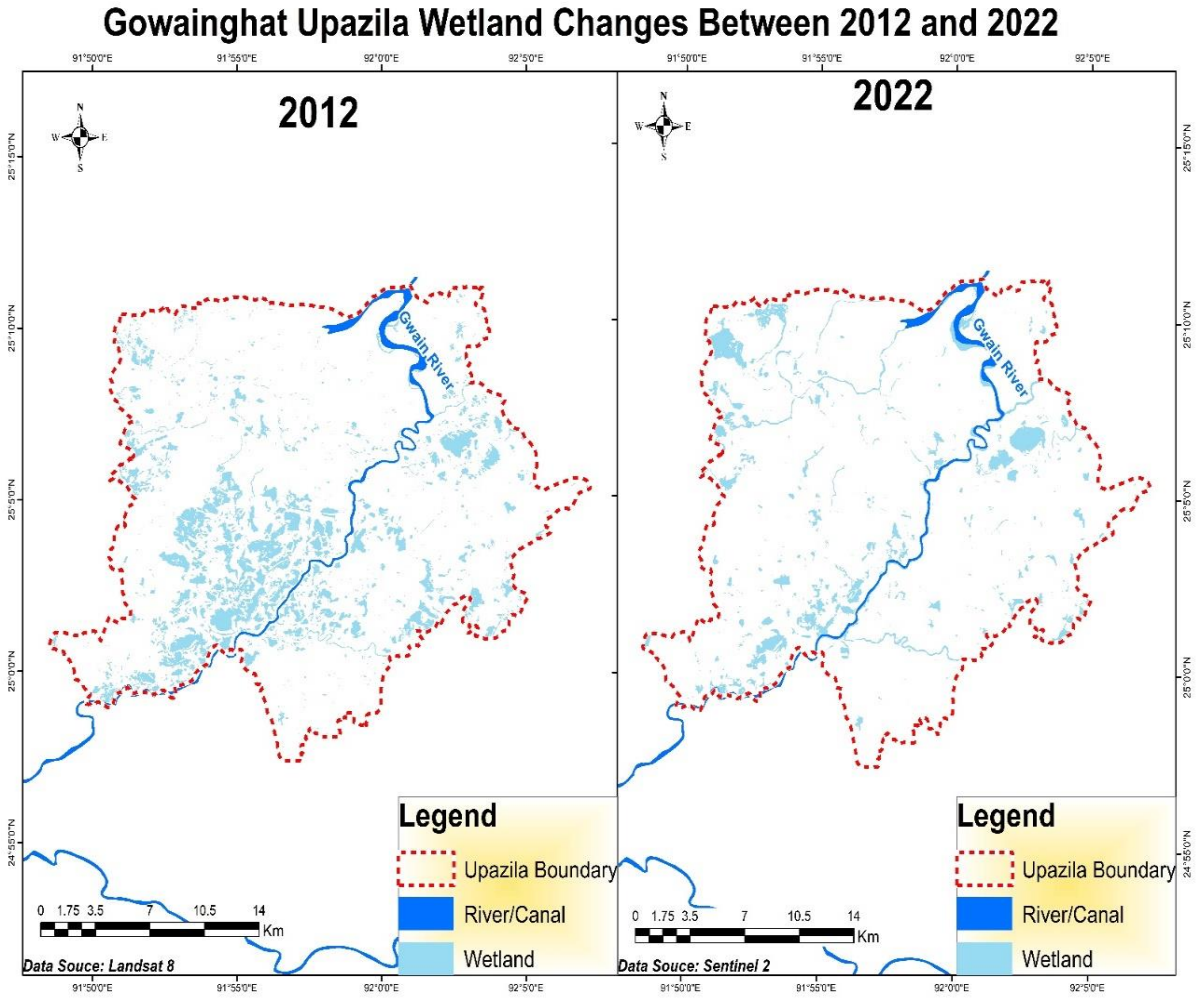


Figure 5: Gowainghat Upazila Wetland change between 2012 and 2022

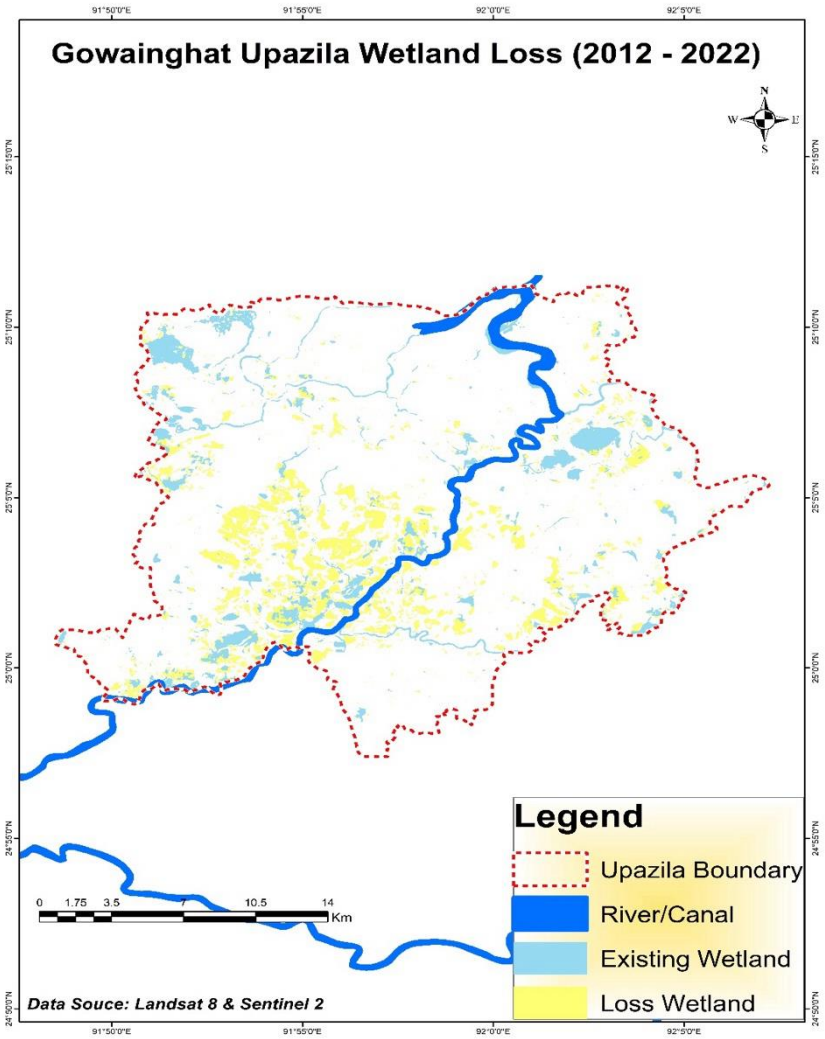
4.3 Assessing a Decade of Change: Gowalighat Upazila's Wetland Evolution from 2012 to 2022

These maps show how wetlands in Gowainghat Upazila changed from 2012 to 2022 by using satellite images to track the spatial and temporal differences. The 2012 map shows a significant amount of wetlands, marked in light blue, which are large and seem to be well-connected

across the Upazila. In 2022, the map showing that there has been a decrease in the wetland area. The wetlands are becoming more fragmented and are retreating, especially in areas that are not close to the main river channel. The consistent presence of the blue line representing the Goain River indicates that the main waterway has stayed fairly constant, but the wetlands around it have decreased. The red dashed lines marking the Upazila boundary remain the same, suggesting that the changes in wetland coverage are a result of environmental factors rather than administrative changes.

Two sources of data, Landsat 8 and Sentinel 2, offer high-resolution satellite images that allow us to identify environmental changes that have occurred over a ten-year period. These maps show a clear visual record of wetland loss, which could impact biodiversity, local climate, and water systems in the area. This change could be caused by a mix of factors such as climate change, urban development, and natural wetland patterns. It's important to compare these maps

Figure 6: Gowainghat Upazila wetland loss (2012-2022)



over time to highlight the importance of implementing strategies to preserve and safeguard

wetlands. Wetlands are crucial for their ecological benefits and as a home to a variety of wildlife. Understanding spatial analyses is important for environmental planning and carrying out conservation efforts.

This map shows how the wetlands in Gowainghat Upazila have decreased over the past ten years, from 2012 to 2022. The yellow areas on the map indicate where wetlands have been lost, while the light blue patches show the wetlands that still remain as of 2022. The blue lines show the rivers and canals that have stayed the same, which contrasts with the wetland areas that are getting smaller. The red dashed lines show the Upazila boundary, outlining the area being discussed. The Goain River flows northward and is a significant geographical feature that influences the distribution of wetlands in the area. The legend on the map clearly organizes these important elements, making it easy to identify and understand the environmental changes that have occurred. The information gathered from Landsat 8 and Sentinel 2 satellites has allowed us to closely monitor these changes, showing the decline of wetlands in this area and the significant impact it can have on the environment, water systems, and local economy.

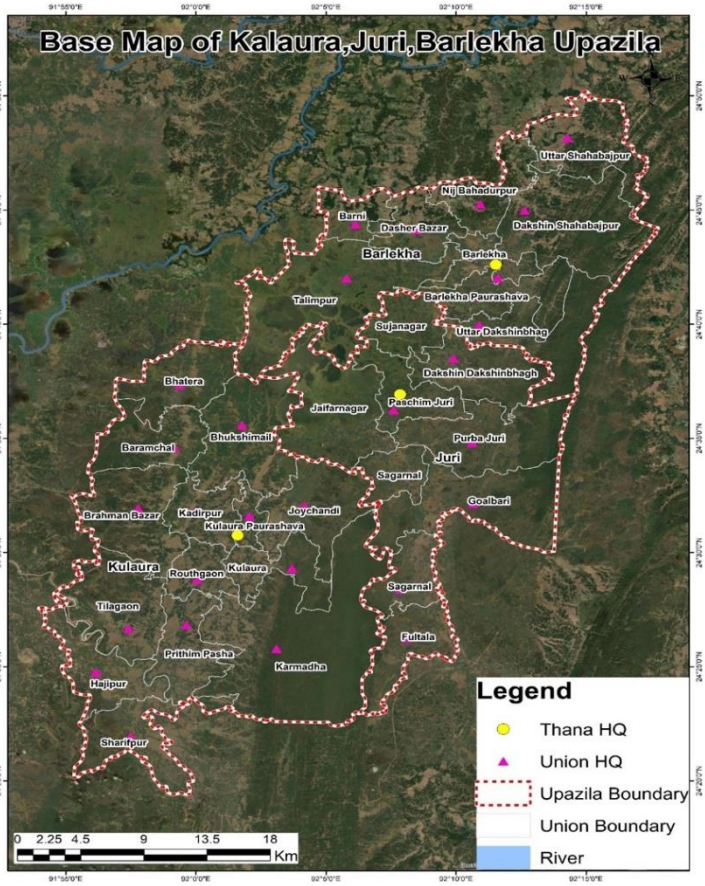


Figure 7: Study area map (Kalaura, juri, barlekha upazila)

The starting point displays the Kalaura, Juri, and Barlekha Upazilas, giving a detailed view of their geographic and administrative boundaries as well as significant features. The red dashed

lines show the boundaries of the Upazilas, which contain the areas marked by the solid white lines representing the Union boundaries. The Thana Headquarters (HQ) are shown with yellow dots, while Union HQs are marked with purple triangles, representing the administrative centers for local governance. Rivers are shown by the blue lines on the map. They are important geographical features that have a big impact on the environment and water systems in the area. The scale at the bottom of the map is useful for estimating distances and the size of geographic features. It shows a maximum stretch of about 18 kilometers from one edge to the other. The satellite images show detailed views of land use, vegetation, and buildings, which can be helpful for planning and management purposes. This base map is crucial for local development, resource management, and planning in these Upazilas.

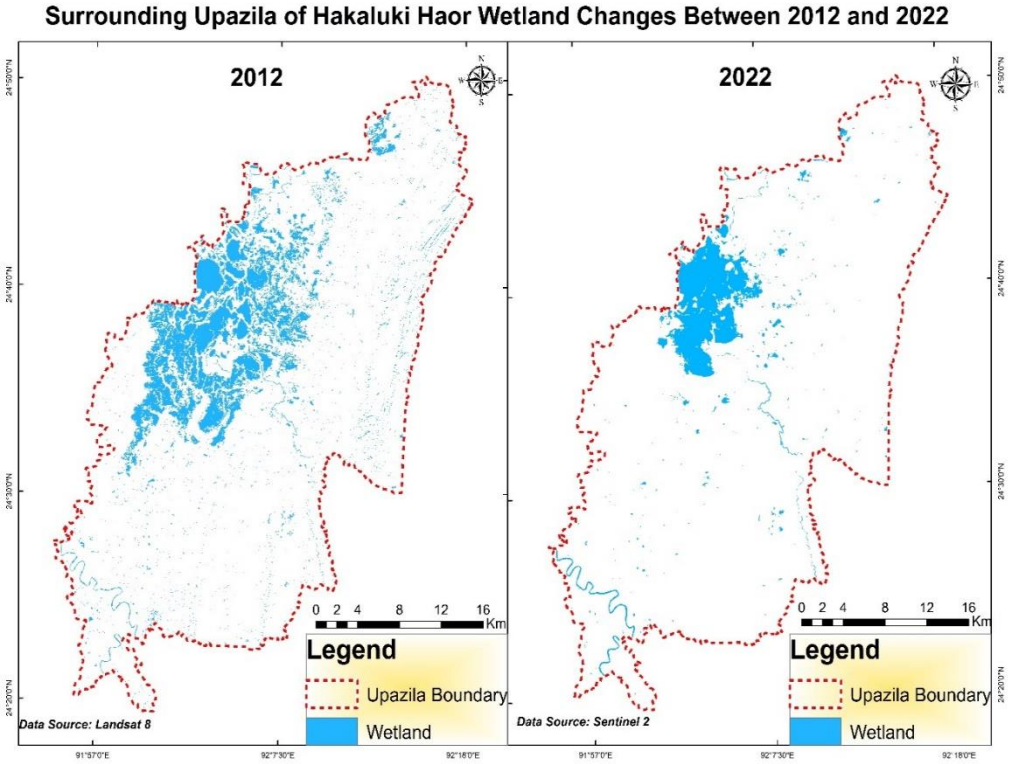


Figure 8: Surrounding upazila of Hakaluki Haor wetland change between 2012 and 2022

4.4 Decadal Changes in Wetlands: Geographic Information System Study of Hakaluki Haor from 2012 to 2022

The maps show how the wetland coverage in the surrounding Upazila of Hakaluki Haor has changed from 2012 to 2022. In 2012, the wetlands, highlighted in blue, are vast, spreading across a significant portion of the Upazila, indicating a healthy aquatic ecosystem. In 2022, it's clear that the wetland area has decreased, especially in the southern and central parts of the Upazila, indicating a loss of wetland habitat. The red dashed lines that mark the Upazila boundaries have not changed, indicating that the differences observed are related to the

environment rather than administrative reasons. From 2012 to 2022, the decrease in wetlands moving northward could be due to environmental factors like climate change, changes in land use, or other human-related influences.
Using Landsat 8 and Sentinel 2 data sources allows for detailed monitoring of changes due to their high-resolution imagery. The maps show how important wetlands are for biodiversity, cleaning water, controlling floods, and providing resources for local communities. We may need to focus on specific conservation efforts to prevent more loss and to make sure the remaining wetlands can be sustained, according to the spatial analysis. These changes in wetlands are important for policymakers, conservationists, and local stakeholders because they

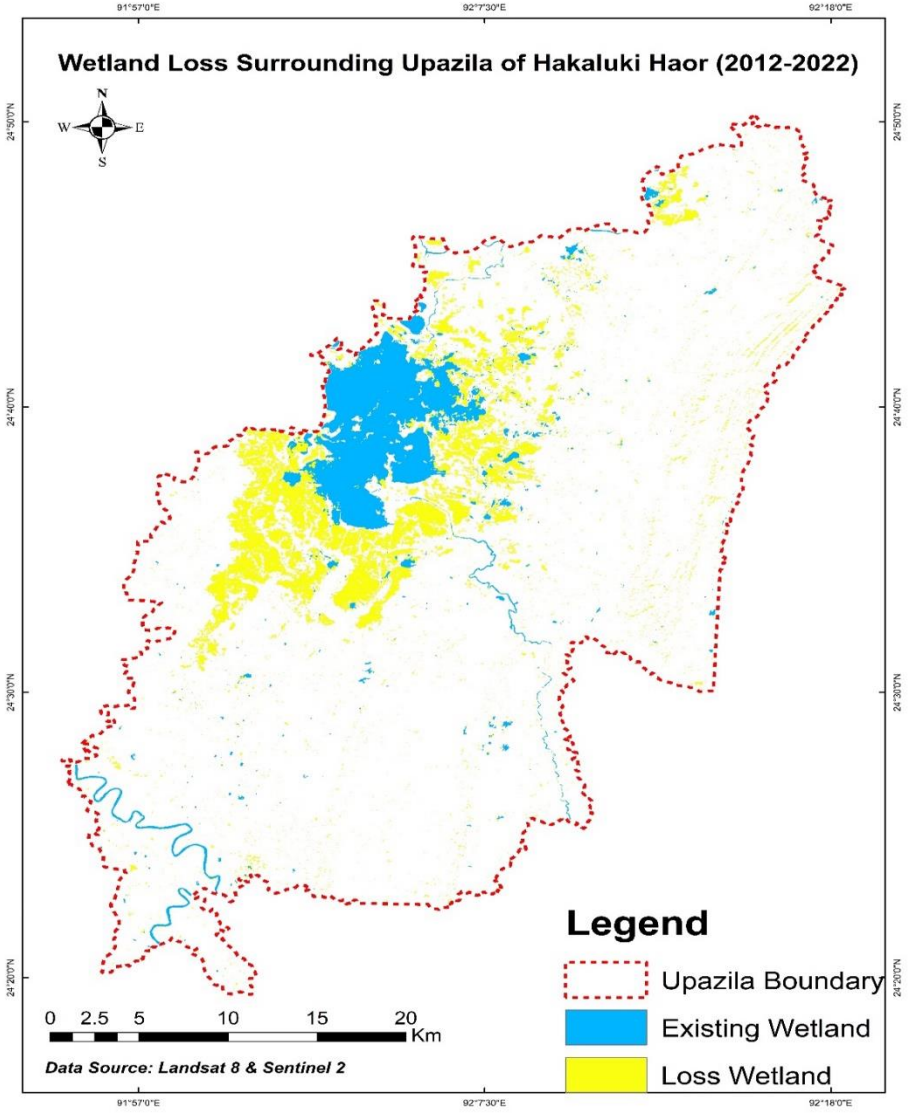


Figure 9: Surrounding upazila of Hakaluki Haor wetland loss between 2012 and 2022

use this data for environmental management and planning. Overall, the comparison of visualizations highlights how wetland ecosystems are constantly changing and the importance of continuing to take care of the environment.

This map shows the decrease in wetlands in the region around Upazila of Hakaluki Haor from 2012 to 2022. During this ten-year period, the yellow areas on the map indicate the wetlands that have been lost, while the blue areas show the wetlands that remain. There are large yellow areas, especially in the northern part of the Upazila, which show a significant decrease in wetlands. The boundaries of the Upazila are marked with a red dashed line, showing the changes within a specific administrative area. The map's scale indicates that it covers a large geographic area, with the most significant changes seen in the central and northern parts of the map.

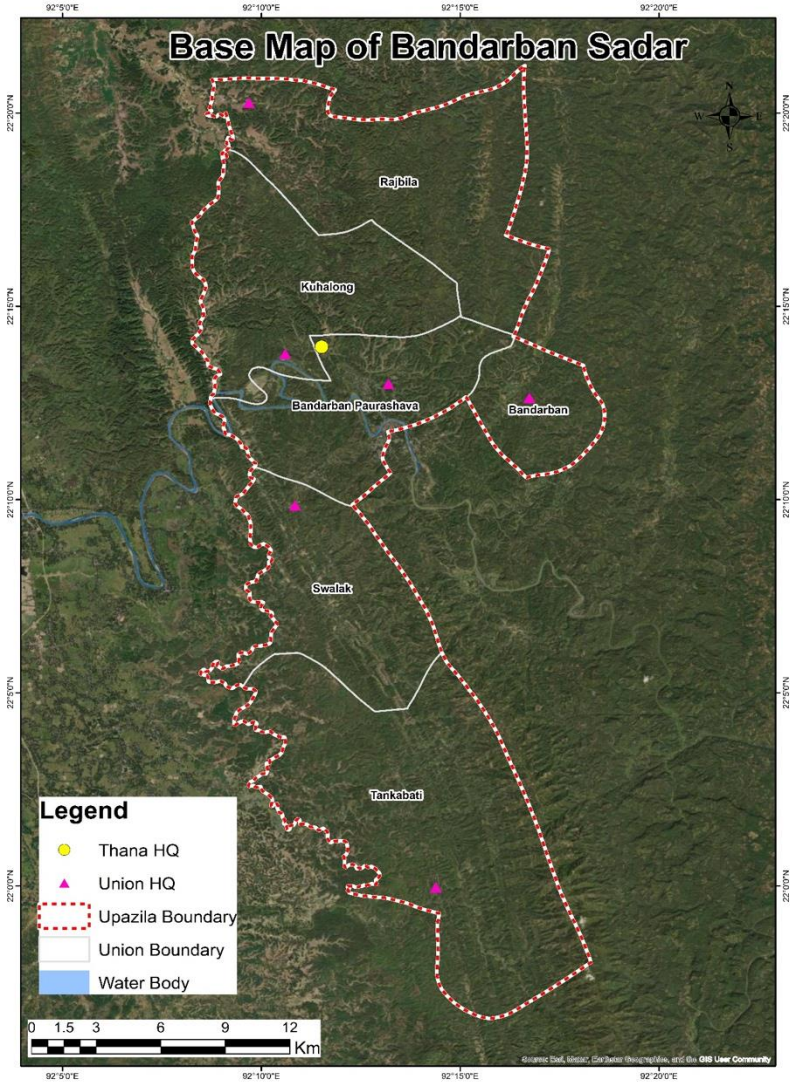


Figure 10: Study area map (Bandarban Sadar)

This map shows the layout of the Bandarban Sadar area from a top-down perspective, including the boundaries of Upazilas and Unions. The red dashed lines show the boundary of the Upazila, and the white lines inside mark the divisions of Union areas, showing the level of

government segmentation. Thana Headquarters (HQ) are marked with yellow circles and serve as central hubs for administration. Union HQs are marked with purple triangles and represent local governance sites within the Unions. The blue shapes on the map symbolize bodies of water like rivers or lakes, which offer important resources and add natural beauty to the area. The proportions displayed on the map in the lower left corner helps in estimating distances and the size of geographical features. It indicates that the Upazila covers an area that extends up to 12 kilometers from the north to the south.

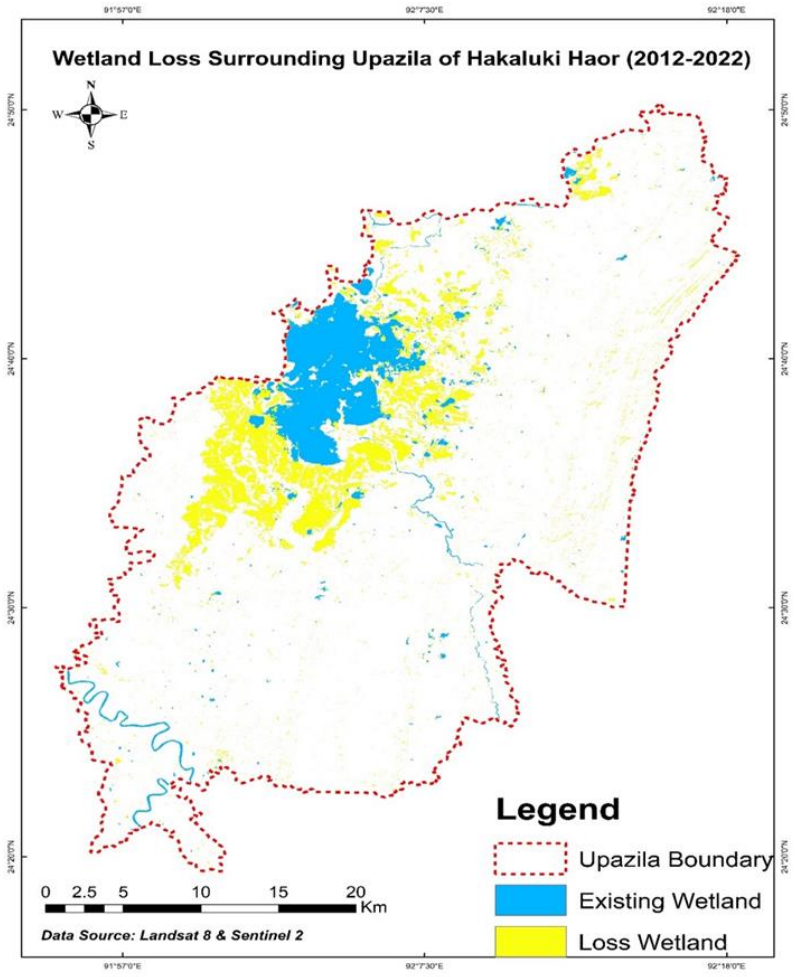


Figure 11: Bandarban Sadar Wetland change between 2012 and 2022

These two maps show how wetlands in Bandarban Sadar have changed from 2012 to 2022. In 2012, the light blue areas on the map show that there are many wetlands in the region, indicating a strong presence of wetland ecosystems. In 2022, there has been a significant decrease in wetland coverage, especially in the northern and central regions, suggesting a decline in wetland habitat over the past decade. The red dashed lines that have not been altered show the boundaries of the Upazila and help to outline the area where environmental changes have occurred within the administrative limits. It seems like the blue lines representing rivers

and canals have stayed the same over time, suggesting that the larger water bodies have remained stable.

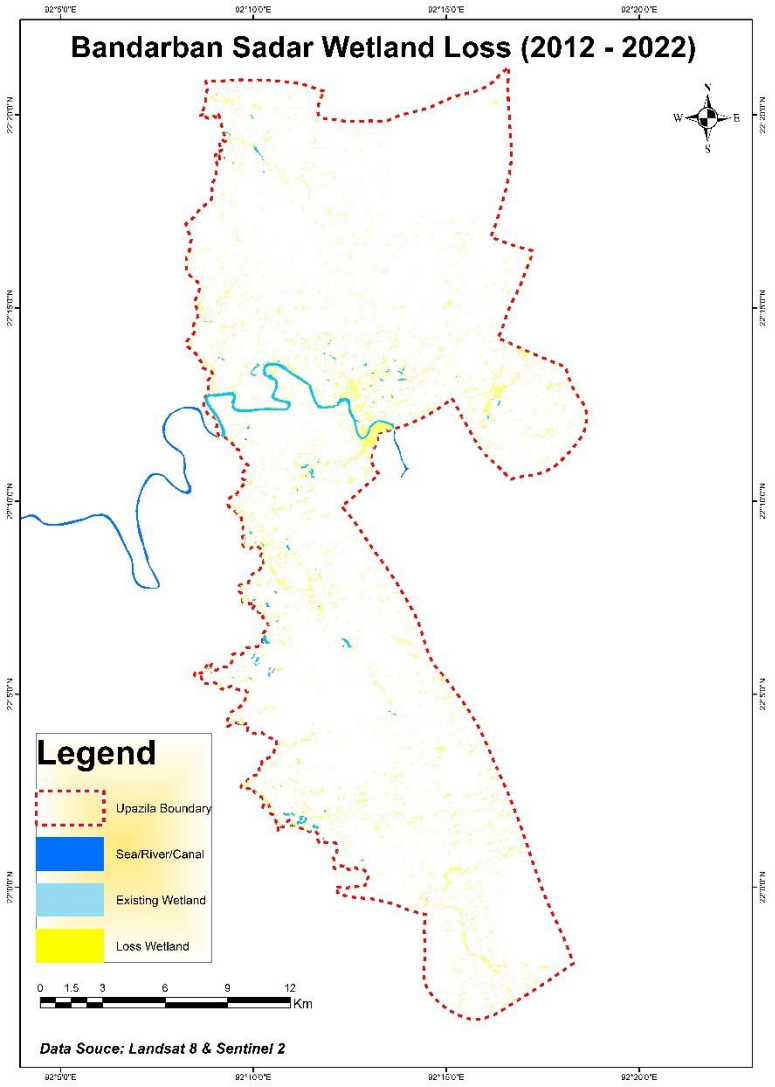


Figure 12: Bandarban Sadar Wetland change between 2012 and 2022

The maps use data from Landsat 8 and Sentinel 2 satellites to monitor environmental changes and track the health of ecological systems with high precision. Wetlands are disappearing for reasons like climate change, land development, and exploiting natural resources. The scale at the bottom helps show how big the changes are across different areas. Wetland conservation is crucial because it plays a critical role in supporting biodiversity, flood control, and local livelihoods. Studying the space and time aspects shows how wetland ecosystems are constantly changing and vulnerable, emphasizing the importance of sustainable environmental management.

4.5 Summarizing the Detection

From 2012 to 2022, the satellite images show that there has been a noticeable decrease in

wetland areas, especially in the central and southern parts of the region. It seems like a lot of wetland habitat has been affected, which could have negative effects on the region's biodiversity and water-related functions.

In Cox's Bazar Sadar, the wetlands have decreased significantly over the past ten years, especially in areas that are not close to the main water bodies. Even though there has been a decrease overall, the main rivers and coastline have not changed much, showing that the main waterways are still intact.In Gowainghat, there has been a noticeable decrease in wetland areas, particularly in areas far from the main river. In 2022, the images indicate that the wetlands are becoming more fragmented, which is worrying for the ecological balance and the ability of local habitats to withstand changes. In Bandarban Sadar, there has been a notable decrease in wetland areas from 2012 to 2022, especially in the northern part of the region. It seems like the wetland areas near the larger rivers have stayed about the same, but the smaller wetlands have shrunk or vanished.

The data from all four regions clearly indicate a trend of wetland reduction over time. The wetlands that are crucial for maintaining ecological balance, preventing floods, and providing a habitat for a variety of plants and animals, have decreased in size. It seems that the consistent loss of species in various locations may be due to a combination of human activities like agriculture and urban development, as well as natural factors such as climate changes. It's important to analyze these regions over time to highlight the need for sustainable management and conservation strategies. This will help protect the remaining wetlands and potentially restore those that are currently lost.

4.6 Analysis

The entire table shows that between 2012 and 2022, wetland areas in four different regions of Bangladesh significantly decreased. Hakaluki has suffered the greatest loss; 66 sqkm, or about half of its original extent, of wetlands have vanished. Even though the wetland area in Cox Bazar was initially smaller, it has shrunk by around 41%, indicating a significant

Feature	Year	Hakaluki (sqkm)	Cox Bazar (sqkm)	Gowainghat (sqkm)	Bandarban (sqkm)
Wetland (2012)	2012	138	34	58	22
Wetland (2022)	2022	72	20	22	5
Loss Wetland	2022	66	14	36	17
Agricultural Land	2022	54	5.75	24	3
Trees	2022	2	0.25	2	7
Flooded Vegetation	2022	3	0.5	1	0.5
Building Area	2022	6	7	7	6
Bare Land	2022	1	0.55	2	0.5
Total Loss	2022	66	14	36	17

Table 1: Study area wetland amount between 2012 and 2022

percentage loss. Wetland decreases of 36 sq km and 17 sq km, respectively, have been observed in Gowainghat and Bandarban, indicating significant ecological alterations.

In Hakaluki and Gowainghat, agricultural growth is the main factor causing the loss of wetland. This trend indicates an increasing amount of land being used for farming, which may be motivated by financial need. In contrast, Cox Bazar's construction area expansion is the most significant, as it is consistent with the city's growth as a tourism hub. According to Bandarban's estimates, there has been a noticeable increase in the area covered with trees, which may reflect attempts at afforestation or the natural regrowth of woods where swamps formerly existed.

The consistent decline in these areas underscores the pervasive difficulties in wetland conservation in the face of financial incentives for shifting land use. The expansion of building areas in every region is a sign of increasing urbanization, which, if not carefully controlled,

may conflict with environmental sustainability. The slight rise in flooded vegetation observed in all regions implies that the loss of original wetlands is not being made up for by newly created waterlogged areas, which may have an impact on the hydrology and biodiversity of the area.

This analysis emphasizes the necessity of policies, such as wetland restoration initiatives, sustainable farming methods, and regulated urban growth, that strike a balance between development and wetland conservation. In order to safeguard these vital ecosystems, the

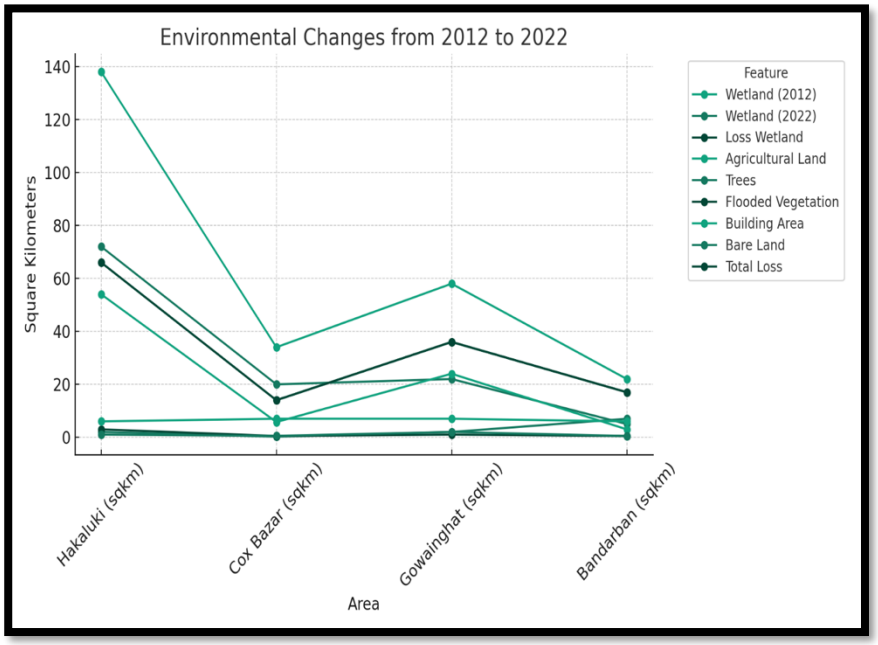


Figure 13: Environmental change from 2012 to 2022

statistics also point to the necessity of increased environmental monitoring and community involvement in land-use decisions. The trends that have been noticed demand quick intervention in order to protect these places for future generations, as wetlands are crucial for maintaining biodiversity, regulating the climate, and providing for local livelihoods.

Seeing the changes in environmental features across four regions — Hakaluki, Cox Bazar, Gowainghat, and Bandarban—from 2012 to 2022 is shown in this line graph. This illustration shows the contrast between wetland areas in 2012 and 2022, including the reduction of wetland, growth of agricultural land, alterations in tree coverage, flooded vegetation, urban development, and barren land during this period. It's worth mentioning that Hakaluki experienced a substantial decrease in wetland area, decreasing from 138 sqkm in 2012 to 72 sqkm in 2022, showing the biggest wetland loss compared to other regions. The wetland area in Cox Bazar has also decreased significantly, from 34 sqkm to 20 sqkm, showing significant environmental changes. Gowainghat and Bandarban saw notable decreases in wetland areas, underscoring a broad environmental issue.The graph indicates a rise in agricultural land in all

regions, with Hakaluki experiencing the most significant growth at 54 sqkm. This indicates a potential reason for the decrease in wetlands, due to the conversion of land for agricultural purposes. There is very little tree coverage in most regions, but Bandarban stands out with an increase, indicating that some areas are prioritizing reforestation. Over the past decade, the level of flooded vegetation has remained consistently low, suggesting minimal alterations or conservation initiatives in these regions.

There has been a noticeable expansion of building areas in all regions, with Cox Bazar and Gowainghat experiencing the most significant growth, pointing towards urban or infrastructural development. Changes in bare land are minimal, suggesting slight shifts in land use or erosion in certain areas. The total loss in wetland area aligns with the initial loss reported, underscoring the urgent concern of wetland reduction over the decade. This detailed overview emphasizes the intricate relationship between development, agricultural expansion, and conservation efforts, impacting the ecological balance in these areas.

The graph provides a visual overview of the environmental changes that have occurred over the past decade, highlighting the importance of sustainable planning and conservation actions to address these shifts. It highlights the significance of monitoring environmental characteristics for the efficient management and protection of natural resources.

Table 2: survey participant details

Perticipant Details		
Perticipant Type	Number	Percentage
Total perticipent	61	100.00
Male	57	93.44
Female	4	6.56
Busniessman	22	36.07
Job holder	19	31.15
Student	14	22.95
Unemployed	5	8.20

Housewife	1	1.64

Table 3: Survey questionary

Question	Yes		No	
	Number	**Percentage**	**Number**	**Percentage**
Q1. Do you think wetland decreased in last 10 years?	61	100.00	0	0.00
Q2. Do you think tourism caused wetland decrease?	58	95.08	3	4.92
Q3. Do you think urbanization caused wetland decrease?	61	100.00	0	0.00
Q4. Did tourism affect your livelihood?	59	96.72	2	3.28
Q5. Do you think decrease of wetland had an impact on your income?	43	70.49	18	29.51
Q6. Do you think because of wetland decrease, you are facing any water scarcity?	58	95.08	3	4.92
Q7. How strongly do you believe that tourism caused decrease in wetland?	54	88.52	7	11.48
Q8. Do your livelihood change with the decreasing of wetland and increasing urbanization?	61	100.00	0	0.00

All participants agree that wetlands have decreased in the last decade, with 100% (61 out of 61) confirming this change. Most people, 95.08% (58 out of 61), believe that tourism is contributing to the decline of wetlands, suggesting that tourism development could be harming these areas. Everyone agrees that urbanization has led to a decrease in wetlands, showing a general understanding of how expanding urban areas affect natural habitats.

Many people have noticed a significant personal impact from these environmental changes,

with 96.72% (59 out of 61) mentioning that tourism has influenced their way of life. The high percentage suggests that the respondents see a direct connection between tourism activities and how they make a living. Most people, 70.49% (43 out of 61), acknowledge that there is a financial impact when discussing income. This shows that the economic effects of wetland reduction are important to many individuals.

Furthermore, 95.08% (58 out of 61) of respondents recognize the problem of water scarcity due to the decline in wetlands, indicating a common awareness or worry about water-related problems associated with the disappearance of these regions. Many people strongly believe that there is a connection between tourism and wetland reduction, with 88.52% (54 out of 61) expressing a clear opinion on the issue, although this belief is not as unanimous as other questions. Everyone who answered the survey noticed a change in their way of life because of both the shrinking wetlands and the growing urban areas. This shows that people worldwide acknowledge the impact of environmental damage and development on socio-economic changes.

The data clearly shows that the respondents are aware of and agree on the decline of wetlands. They also identify tourism and urbanization as key drivers. Many of them also mention facing personal and economic consequences because of these changes in the environment. There is a strong agreement that highlights the importance of human-environment interactions and the need for sustainable development strategies that consider both economic development and the preservation of the environment.

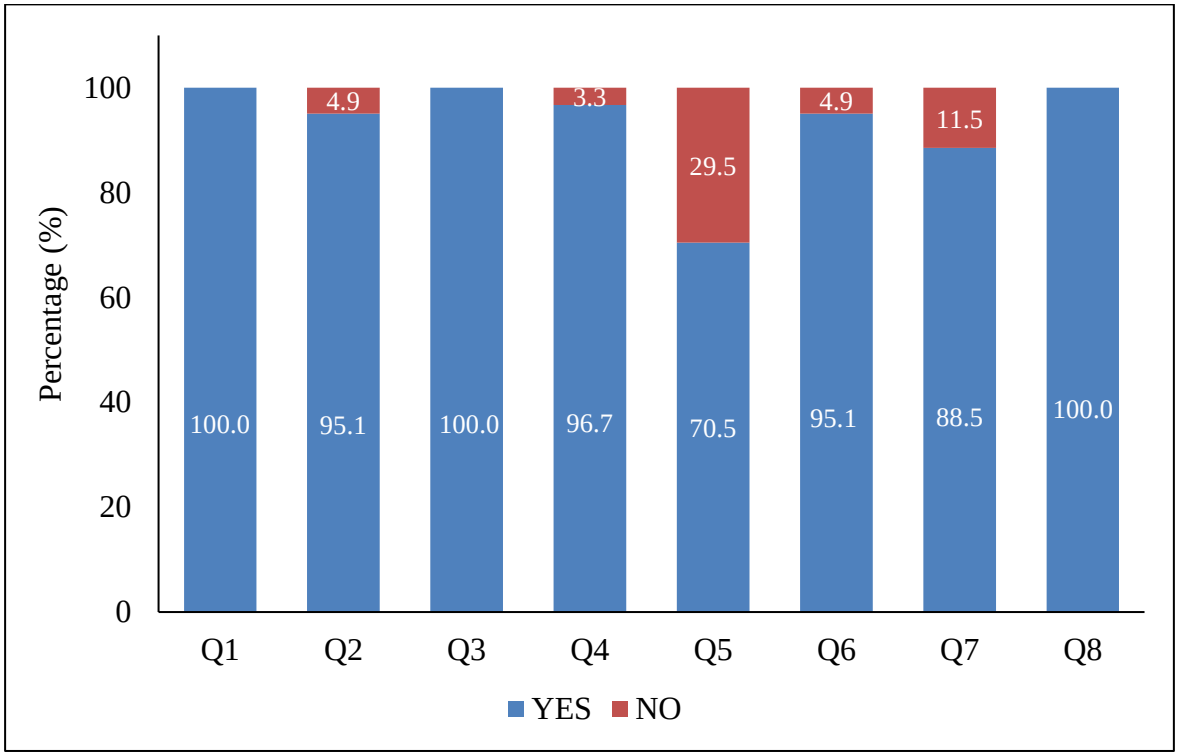


Figure 14: Survey questionary responses

The bar graph clearly shows what a group of people think about the decrease in wetlands over the last ten years and the possible reasons behind this environmental problem. Everyone agreed on the first question, showing that there is a widespread recognition of the decline of the environment. Every participant has noticed a decrease in wetland areas, showing that the community at large is aware of the changes in the natural landscape.

Almost everyone acknowledges that tourism plays a significant role in this decline, with an impressive 95.1% of respondents confirming its impact. Many people generally agree that the increase in tourists and development of infrastructure have harmed these important ecosystems. Perhaps the 4.9% who disagree may feel that tourism is not as important or that its effects are balanced out by conservation efforts or the economic advantages it provides.

All of the participants acknowledge that development is a factor causing wetland decrease. They believe that the growth of urban areas is encroaching on natural habitats. When there is 100% agreement, it shows that people understand the impact development has on the environment, which can be seen through changes in land use and the loss of wetlands that were once common.

96.7% of the participants admitted that tourism has affected their livelihoods when asked about

personal impacts in the survey. It shows that tourism doesn't just affect the environment, but also has an impact on the social and economic aspects of the community, potentially changing people's lifestyles and work patterns. When looking at the connection between wetland decline and personal income, there is a clear decrease in agreement to 70.5%. It seems that although many people are affected by the economic consequences of wetland degradation, there are some who may not have experienced it directly or there are factors that lessen or redirect these effects.

Lack of water is an urgent issue that is often connected to the health of wetlands. Recently, there has been an increase in consensus on this topic. 95.1% of the people surveyed believe there is a link between disappearing wetlands and the growing water scarcity, which is a concern for the sustainability and quality of life in their community.

88.5% of people still believe that tourism is a major factor in the decline of wetlands. Some people are less sure about the benefits of tourism, possibly due to conflicting information or not having experienced its negative effects firsthand.

The unanimous agreement in the last question indicates that the survey participants have a shared experience. They all recognize that adapting their livelihoods in response to environmental and urbanization pressures is a common reality for them. This sentiment could be because changes in the environment have a direct impact on the goods and services that people rely on, which in turn affects their daily lives.

Overall, the graph not only shows numerical data about how people perceive environmental change but also gives insight into an area on the verge of important ecological as well as economic changes. The survey responses clearly show that people believe wetland health, economic stability, and community sustainability are all connected. They are calling for an approach that considers both development and preservation.

4.7 Result & Discussion

The study of the way wetlands has changed over time and looking at survey data gives us a detailed view of how the environment has evolved in the past ten years. The data show a clear trend of wetland loss in different areas, and respondents' perceptions support the observed changes.

By using satellite imagery and geographical mapping, I found that there has been a significant decrease in wetland areas over time. In areas such as Hakaluki and Bandarban Sadar, where ecological monitoring has shown a decrease in wetlands, the survey results align with these

findings. People are very aware of these changes because they see them in their daily lives. They all agree that wetlands have decreased over the years. This response's consistent tone highlights the clear evidence of environmental damage happening locally.

Additionally, the survey's findings about why wetlands are disappearing match up with the spatial data trends. Most participants strongly believe that urbanization is a major factor in these changes. This belief is backed by satellite images that clearly show urban development expanding into natural wetland areas. Urban areas are expanding, causing wetlands to recede. The correlation is direct and compelling.

Moreover, people who took the survey believe that tourism also plays a major role in affecting wetlands, especially in places with high numbers of tourists like Cox's Bazar Sadar. These observations suggest that wetland loss is more common in regions with heavy tourism, indicating that tourism development may harm these ecosystems.

In addition, the survey gives a detailed understanding of how these environmental changes affect different levels of society. It's clear that most people agree on the negative impact of wetland loss on their lives, recognizing problems like water scarcity. This shows that the changes in the area have significant social and economic consequences.Overall, when I combine spatial-temporal analyses with survey data, it tells a convincing story of wetland reduction.

Table 4: Detected Wetland Accuracy Assessment of Cox's Bazar Sadar 2022

	Water Body	Settlement	Vegetation	Barren Land	Agricultural Land	Total (USER)
Water Body	27	1	1	0	1	30
Settlement	0	0	0	0	0	0
Vegetation	0	0	0	0	0	0
Barren Land	0	0	0	0	0	0
Agricultural Land	0	0	0	0	0	0
Total (Producer)	27	1	1	0	1	30

It's clear that many different people recognize the problem of wetland loss as a significant environmental challenge. The data emphasize the importance of immediate and collaborative

conservation efforts, along with sustainable development policies that focus on protecting these crucial ecosystems for the benefit of both nature and the communities that rely on them.

The accuracy assessment for the identified wetland areas in Cox's Bazar Sadar for the year 2022 has been completed. The assessment focused on different types of land cover, such as water bodies, settlements, vegetation, barren land, and agricultural land. The classification results indicate that out of the 30 reference pixels for water bodies, 27 were accurately identified as water bodies. This suggests a high level of accuracy for this specific class.

The accuracy of classifying water bodies is 90%. This means that out of 30 reference pixels, 27 were correctly classified. This high number of correct classifications shows that the wetland detection method used is reliable. I must say, the high overall accuracy percentage is quite impressive. It's especially commendable considering the challenges involved in distinguishing between different types of land cover using remote sensing techniques. The study suggests that the method used to detect wetlands in the study area is reliable for identifying water bodies. However, there is room for improvement to further reduce classification errors and increase precision. Overall, the accuracy assessment shows that the classification of water bodies in Cox's Bazar Sadar was successful. This means that the current methodology used to detect wetlands is mostly accurate and can be relied upon for similar ecological studies or environmental monitoring.

Table 5: Detected Wetland Accuracy Assessment of Bandarban Sadar 2022

	Water Body	Settlement	Vegetation	Barren Land	Agricultural Land	Total (USER)
Water Body	26	0	3	0	1	30
Settlement	0	0	0	0	0	0
Vegetation	0	0	0	0	0	0
Barren Land	0	0	0	0	0	0
Agricultural Land	0	0	0	0	0	0
Total (Producer)	26	0	3	0	1	30

The accuracy assessment table for detected wetlands in Bandarban Sadar for the year 2022 is specifically looking at the classification of water bodies. This classification is commonly used as a way to identify wetland areas using remote sensing technology. We have analyzed a total

of 30 pixels that were classified by the users during the assessment process.

Among these, 26 pixels were correctly identified as water bodies, demonstrating a high level of accuracy in recognizing real wetland areas. But there were a couple of mistakes: three pixels were wrongly labeled as vegetation, and one as agricultural land. It seems like these errors occurred because some parts of the landscape or certain spectral signatures were mistaken for water bodies. This could be because they were close to water or had wetland vegetation.

The wetland detection in Bandarban Sadar has an overall accuracy of 86.67%. This was calculated by dividing the number of correctly classified pixels (26) by the total number of reference pixels (30) and multiplying the result by 100.

I'm satisfied with the level of accuracy for remote sensing applications, but there is still some room for improvement. Overall, the wetland detection for Bandarban Sadar is quite reliable, with only a small margin of classification error.

Table 6: Detected Wetland Accuracy Assesment of Gwainghat 2022

	Water Body	Settlement	Vegetation	Barren Land	Agricultural Land	Total (USER)
Water Body	28	0	1	0	1	30
Settlement	0	0	0	0	0	0
Vegetation	0	0	0	0	0	0
Barren Land	0	0	0	0	0	0
Agricultural Land	0	0	0	0	0	0
Total (Producer)	28	0	1	0	1	30

In the accuracy assessment conducted for wetland detection in Gowainghat in 2022, we analyzed the data and found that out of the 30 pixels that were categorized as 'Water Body', which usually indicates the presence of wetland, 28 of them were accurately classified. This indicates a very high level of accuracy in our wetland detection process.

The overall accuracy for wetland identification in Gowainghat is quite impressive at 93.33%. This accuracy is calculated by taking the proportion of correctly classified water body pixels (28 out of 30) and multiplying it by 100.

The fact that the method used for identifying wetlands in the area has a high accuracy rate is

really impressive. It shows how effective the method is, which is really important for environmental issues management and monitoring. Stake holders in Gowainghat can use the reliable detection rate to make well-informed decisions about wetland conservation and land use planning.

Table 7: Detected Wetland Accuracy Assessment of Hakaluki 2022

	Water Body	Settlement	Vegetation	Barren Land	Agricultural Land	Total (USER)
Water Body	26	0	1	1	2	30
Settlement	0	0	0	0	0	0
Vegetation	0	0	0	0	0	0
Barren Land	0	0	0	0	0	0
Agricultural Land	0	0	0	0	0	0
Total (Producer)	26	0	1	1	2	30

In the Hakaluki wetland assessment for 2022, it was found that 26 out of the 30 pixels identified as 'Water Body' were correctly classified. This reflects an accuracy rate of 86.67%. The percentage is determined by dividing the number of accurately identified water body pixels by the total number of reference pixels used in the assessment, and then multiplying by 100.

The overall accuracy rate indicates that the methodology employed for detecting wetlands in Hakaluki is generally effective. However, there is still room for growth, particularly in differentiating between wetlands and agricultural areas. The accurate classification of most reference pixels indicates that the assessment method is dependable for comprehending and tracking wetland changes in the region.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study on Remote Sensing & GIS Based Spatio-Temporal Changes analysis of Wetland in Major Tourist Zones from Different States in Bangladesh has provided useful insights into the changing nature of wetlands and their significance in major tourist areas. Remote sensing and GIS techniques are essential for studying spatio-temporal changes and gaining a comprehensive understanding of the factors that affect these changes. A study on flood monitoring in Bangladesh using RADARSAT remote sensing and GIS data demonstrated the ability to precisely assess and define inundation zones, crucial for efficient flood monitoring, mapping, and disaster management (Papastergiadou et al., 2008). Remote sensing and GIS were used to monitor environmental changes in a Mediterranean wetland in Northern Greece, showcasing their efficacy in assessing alterations in land cover/use and devising management strategies. The findings emphasize the need of effective wetland management and conservation efforts (Hoque et al., 2011).

Stakeholders can utilize the identification and monitoring of wetland changes to make educated decisions on land-use planning, tourism infrastructure development, and conservation activities. Studies show that changes in land cover, such as the growth of reed beds and the decrease of open-water areas and peatlands, significantly impact the management of freshwater wetland resources. Proactively maintaining ecosystem services is essential for preserving biodiversity and enhancing tourist experiences. Remote sensing and GIS have proven to be useful in conserving and sustainably managing wetland ecosystems in response to human activities and natural changes.

5.2 Recommendations

After looking at the changes in space and time and the results of the survey, we have come up with some recommendations to help address the issue of wetland loss:

1. Develop a wetland management plan: That balances ecological preservation with the socio-economic needs of the local population. We need to make sure there are strict rules in place to protect the current wetlands from any more development and come up with ways to restore wetlands that have been damaged.
2. Sustainable Tourism Practices: Let's create guidelines for sustainable tourism development to reduce the impact of tourism on the environment. Let's support eco-tourism that focuses

on environmental education and helps protect natural habitats.

3. Urban Planning with Green Spaces: It's important to plan urban development with a focus on creating green spaces and incorporating natural wetlands into city planning. These are critical components of urban ecosystems that can help maintain biodiversity and provide flood mitigation.
4. Community Engagement and Education: Encourage the community to participate in wetland conservation by providing education and raising awareness through campaigns. Local communities have the potential to be strong protectors of the environment when they are well-informed and involved in the decision-making process.
5. Economic Incentives for Conservation: Encourage local businesses and communities to participate in wetland conservation by offering economic incentives. We could offer tax breaks, subsidies for sustainable practices, and support for eco-friendly businesses.
6. Water Conservation Strategies: Create thorough water management plans that acknowledge the important role of wetlands in purifying and storing water. I think that such approaches should focus on reducing shortages of water and enhancing water quality using natural methods.
7. Enhance monitoring and research efforts: To track wetland health and understand the impacts of human activity. It's important to use data-driven approaches to evaluate how well conservation measures are working and to help make informed decisions about managing resources.
8. Legal Protection for Wetlands: We should improve legal frameworks to provide better protection for wetlands. We should make sure that current environmental regulations are followed and think about officially designating wetlands as protected areas according to national and international laws.
9. Climate Change Adaptation Measures: Understand how wetlands help with climate change adaptation by preserving them as carbon sinks and protection against severe weather events. It's important for policies to recognize the significance of wetlands in the larger context of climate resilience.
10. Cross-Sector Collaboration: Encourage collaboration between government agencies, non-governmental organizations (NGOs), the private sector, and local communities. Working together is more likely to lead to successful and long-lasting results for protecting wetlands.

By combining regulatory, educational, and economic strategies, we can work together to restore and preserve these important natural resources.

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Appendix

1. **Do you think wetland decreased in last 10 years?**

☐ Yes

☐ No

2. **Do you think tourism caused wetland decrease?**

☐ Yes

☐ No

3. **Do you think urbanization caused wetland decrease?**

☐ Yes

☐ No

4. Did tourism affect your livelihood?

☐ Yes

☐ No

5. **Do you think decrease of wetland had an impact on your income?**

☐ Yes

☐ No

6. **Do you think because of wetland decrease, you are facing any water scarcity?**

☐ Yes

☐ No

7. **How strongly do you believe that tourism caused decrease in wetland?**

☐ Strongly Agree

☐ Moderately Agree

☐ Slightly Agree

☐ None of them above

8. **Do your livelihood change with the decreasing of wetland and increasing urbanization?**

☐ Yes

☐ No