UNIVERSITY OF CAPE COAST

ASSESSMENT OF THE ECOLOGICAL AND SOCIO-ECONOMIC IMPLICATIONS OF LAND-USE CHANGES IN THE BUTUAH WETLAND OF THE SEKONDI-TAKORADI METROPOLIS OF GHANA

ESTHER NYAMEKYE ACHEAMPONG

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BY

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Thesis submitted to the Department of Fisheries and Aquatic Sciences of the School of Biological Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy Degree in Integrated Coastal Zone Management

OCTOBER, 2021

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:.. Date:..........................

Name: Esther Nyamekye Acheampong

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:.................................... Date:........................

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ABSTRACT

Coastal ecosystems in urban areas provide critical services that support biodiversity and improve the livelihoods of coastal communities. However, pressures of increasing urbanization and industrialization in urban areas reduce their economic value by limiting their ability to provide needed ecosystem services. The need to underscore the impacts land-use changes in urban coastal wetlands could have on societal and ecological conditions necessitated this study. The Butuah wetland in the Sekondi Takoradi Metropolitan Area (STMA) was selected as the study site following the recent surge in urbanization and industrial activities in the region upon the discovery of oil in commercial quantities in 2007. The study involved the mapping of wetland types using high-resolution satellite images, analysis of changes in landscape pattern using the FragStats software, the estimation of Total Economic Value (TEV) of the resources, stakeholder analysis and a risk assessment of the ecosystems in the wetland using the InVEST HRA model. The study revealed that three-quarters of the Butuah lagoon has been lost over a period of 14 years i.e. between 2007 and 2021. High fragmentation in the various habitats of the wetland had led to a decrease in landscape diversity. Furthermore, the TEV of the wetland was estimated to be $974.54/individual/ha/year although anthropogenic stressors such as refuse dumping, overgrazing and deforestation continue to threaten the resources. The study calls for rapid implementation of conservation plans for the area and an inclusion of stakeholders in management plans to promote sustainable development.

KEYWORDS

Coastal Ecosystems

Ecosystem Services

Land Use

Remote Sensing

Urban

Valuation

Wetland

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DEDICATION

To my family.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

BCR	Benefit Cost Ratio
BV	Bequest Values
CDA	Coastal Development Authority
DUV	Direct Use Values
EPA	Environmental Protection Agency
ES	Ecosystem Services
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GSA	Ghana Standards Authority
GTA	Ghana Tourism Agency
HRA	Habitat Risk Assessment
ICM	Integrated Coastal Management
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
IUV	Indirect Use Values
MEA	Millennium Ecosystem Assessment
NPV	Net Present Value
OUV	Option Use Values
SVM	Support Vector Machine
TEV	Total Economic Value
UAV	Unmanned Aerial Vehicles
UNEP	United Nations Environment Program

CHAPTER ONE

INTRODUCTION

For decades, coastal areas have been a hub of human activity and are home to the world's most important ports of commerce. However, the ecological, economic, and social values drawn from coastal resources have reduced over time partly due to unavailability of data supporting the importance of coastal resources and the negligence of certain governmental institutions to realize the need for coastal sustainability especially in urban coastal communities (Lin & Yu, 2018). The coastal regions of Ghana are home to around 20% of the country's 25 million people (Ghana Statistical Service, 2013), whose livelihoods are heavily dependent on fish and fishery resources making the sector liable to collapse in the absence of drastic management interventions (Lazar et al., 2018). This argues for a re-examination of coastal wetlands for their capacity to replenish fish stock by acting as spawning, feeding and nursery grounds for different species of fishes, crustaceans and birds as part of a larger group of services that they provide, because as these ecosystems degrade over time, the services they provide deteriorate as well. Consequentially, the dip in coastal resources development simultaneously affects socio-economic gain in the country. To salvage the situation, this study presents data on land-use changes in coastal urban wetlands and how they affect the socio-environmental and economic well-being of resource dependents as well as management interventions for remediating the identified problems.

Background to the Study

Over the years, humans have sought to understand ecosystem services mainly for their increasing economic value. In the Millennium Ecosystem Assessment of 2005, a qualitative analysis was carried out to identify the trends in the state of ecosystem services (Millennium Ecosystem Assessment, 2005). The results indicated that 60% of ecosystems suffered degradation worldwide. Among these ecosystems are coastal forests, wetlands, and seas. Coastal ecosystems generate a variety of goods and services that are important in human well-being (Burke et al. 2001)

From 1961 to 2017, global food fish consumption rose at an annual rate of 3.1 percent, that is, over twice the rate of annual world population growth (1.6 percent) and greater than all other animal protein meals, which grew at a pace of 2.1 percent each year (Bruinsma, 2017). The global dependence on fish products has increased, increasing demand for the already depleted coastal/marine resources. A key aspect of marine fisheries production rests on the management of coastal systems. Consequently, coastal degradation affects global fisheries production and increases poverty in coastal states.

Today, over 40% of the world's population lives in coastal areas (UN ocean facts report, 2017). While coastal cities cover only 0.1% of earth's total land surface, the increasing populations in these areas can be attributed to the ample benefits humans derive from coastal ecosystems. Coastal communities in Western Africa alone host one-third of the sub- region's population. Understandably, over 42% of the sub-region's GDP is generated from coastal resources. Major cities, ports, agricultural and fisheries industries, as well as offshore petroleum exploration and production companies, are hosted in the coast (WACA, 2019). These ecosystems provide critical services to support the livelihoods of coastal communities. However, coastal zones face growing challenges with pollution of vital coastal resources, erosion, and declining livelihood support, limiting economic growth. Over-utilization of coastal ecosystems as a result of rapid population increase and urbanization over the years have affected their sustainability. Coastal resources have therefore become depleted and several species of fauna and flora are close to extinction. Options for coastal ecosystem management and biodiversity conservation have also become very limited, being restricted by increasing poverty. The need to assess coastal ecosystem types, understand the ecosystem services they provide and the nexus between the biodiversity they hold is stronger now than ever. Furthermore, assessing the health of these ecosystems, to evaluate their pollution sources and their impacts on the physical and physiological conditions of health to biodiversity is a necessity which could allow managers to explore management options for degraded coastal and marine ecosystems and to explore opportunities for sustainable exploitation of coastal and marine resources. To incorporate the coastal zone into national financial plans, researchers need to effectively communicate the economic value of resources and the potential GDP losses from their mismanagement. Unfortunately, quantifying coastal resources is an arduous task (Duffield et al., 2019). Aside from the dynamic nature of the coastal zone and its resources, valuation requires time and information and the ability to put certain monetary values on benefits that emotions and/or beliefs can only describe. Consequently, the inadequacy of information in terms that policy makers apprehend results in the diversion from coastal problems in the allocation of national funds. This challenge in coastal development can only be addressed by bridging the gap between research and policy making.

Statement of the Problem

The search for a society that is ecologically, socially and economically sustainable, and where economic development is achieved within the context of attaining global goals such as poverty alleviation and social equity is a universal concern. Unfortunately, the need for economic well-being often tramples on the need for environmental sustainability. Likewise, the human ability to accomplish economic gain has dramatically outstripped the human capability to comprehend the interdependence of all three aspects of development; i.e.: Environmental, Social, and Economical. As a result, economic development is often catered for at the expense of environmental development and humanity is repeatedly confronted with a storm of environmentally related issues driven by overpopulation, overexploitation and urbanization. The biophysical issues that arise from the disregard for environmental, and most importantly, coastal issues are inextricably linked to human governance structures, organizations, and social systems.

Indeed, coastal ecosystems supply a variety of services at the municipal, state, and global levels. Most of the gains are contingent on ecological systems remaining undisturbed or exploited with minimal intervention, while the rest, may only be realized when the resources they contain are harvested for the benefit of mankind. Apart from providing raw materials for industrial and household needs, medicinal products, recreational and tourism areas for coastal dwellers and visitors, coastal wetlands could reduce the level of erosion and chemicals that reach waterways (Burke et al., 2001). Coastal wetlands serve as habitats to a diverse array of organisms and more importantly, offer coastal protection to surrounding communities by serving as a buffer in natural disasters such as floods and storms. The rivers and lagoons in coastal areas also provide a habitat for finfishes and shellfishes, which humans consume as food (Rosen, 2000). That notwithstanding, vast areas of urban coastal marshes, mangrove swamps and lagoons are under constant threats of degradation fueled by the surge of rapid urbanization in these areas. In a finite world, where resources are scarce, coastal degradation is detrimental with intergenerational consequences. Moreover, with the realization that over three billion people rely on coastal and marine resources for their subsistence, and the global market value of marine and coastal resources and industries is approximated at $3 trillion each year (about 5 per cent of global GDP) (UN ocean facts report`, 2020) it is imperative that coastal wetlands and surrounding ecosystems that support their functionalities are understood and protected. Accomplishing such a task is, however, not elementary, since in as much as there is the need for environmental tranquility, societies cannot exist without reliance on the environment for economic development. The image created resembles two opposite forces in a tug of war for the environment. The resolution lies in understanding the benefits derived from coastal urban wetlands and exploring options for sustainable utilization that can be acceptable to all parties. Again, there is the hurdle of assessing large coastal ecosystems usually in distant areas to fully understand their social, economic and environmental importance. However, the introduction of Geographic information systems and Remote Sensing techniques has positively tackled the issue. When supplemented with assessments of the social, geographical, and economic dimensions of coastal resource use and degradation; environmental and geographic analysis will be better suited to address the heterogeneity of coastal problems as well as serve the need of policymakers for sustainable economic growth.

Objectives of the study

This study seeks to assess the socio-ecological implications of land-use and land-cover changes in the Butuah wetland in the Sekondi-Takoradi Metropolitan Assembly (STMA) in the Western Region of Ghana and to further develop a framework for a multi-stakeholder-led approach towards effective management of the wetland. This study forms an informed scientific basis for assessing comparable urban ecological systems in West Africa.

The specific objectives of the study are to:

i. map the wetland types in the study area over a 14-year period (2007 to 2021)

ii. assess the changes in area of the wetland types over the period of the study

iii. analyze landscape pattern changes in the Butuah wetland over the period of the study

iv. estimate the economic benefits for local use and total economic value of the wetland's resources

v. assess anthropogenic threats posed to the habitats in the Butuah wetland; and

vi. develop an effective management framework for the sustainable use and conservation of the wetland.

Significance of the study

In order to realize the goal of a sustainable future, there is the need for comprehension of the interconnectedness of economic, social, and environmental components of coastal resource management and their incorporation into one system for governmental and private sector decision-making. While socio-economic factors consider persons and respective resource allocation ratios, integration of environmental components involve examining how natural resources may be exploited with no harm to ecosystems. The interplay among the economic, social and environment sectors are boosted and its cohesion becomes effective should their respective objectives be translated into quantifiable forms in a specified timeframe.

Coastal communities, national governments and international organizations such as the UN-FAO recognize the significance of ecological services in coastal wetlands, among other social and economic services. Evidently, the prospect of economic opportunities in urban coastal cities is a powerful draw that attracts people from economically disadvantaged rural areas (Dhiman et al. 2019). As a result, substantially larger, youthful populations can be predicted to emerge in coastal cities of developing countries such as Ghana in the near future. Hence, demand for ecosystem services, are projected to rise owing to the growing populations and their advancing demand for improved living standards (FAO, 2010; Miura et al., 2015). These incoming coastal populations will require jobs, shelter, water, nutrition, and waste management, among other issues, posing a significant development challenge and a need for sustainable planning of coastal resources. While Coastal ecosystems in urban cities have the capacity to supply all these needs, degradation, mostly caused by anthropogenic activities presents a menace to their structure and function. To address this, it is important to understand the services that are offered by coastal ecosystems and how those benefits can benefit humans environmentally and socioeconomically without affecting the function of the former. This will refocus the attention of governmental and civil institutions on the need to properly manage and conserve such coastal ecosystems. Thus, research that informs policy makers on the need to acknowledge the severe limitations that such degradation poses on a nation's GDP through the measure of socio-economic growth restrictions as well as appropriate options for remediation towards environmental sustainability is principal. Obviously, understanding on the causes and implications of deterioration of urban coastal wetlands in Ghana need be expanded, and remedial options must be developed and evaluated based on temporal data that recognizes industrial and economic changes in those areas.

This could shed more light on the loss of several coastal urban wetlands in the country over the years and provide remediation options for those at the brink of destruction. In effect, this study provides data on how land-use changes in a coastal urban wetland could result in the depletion of value of coastal resources. This is to arouse the interest of governmental and non-governmental agencies to the protection of coastal resources such as, lagoons, marshes and mangroves as well as present a case for the need to sustainably weigh alternative investment initiatives in urban coastal management and resource development. For this purpose, the parameters chosen seek to address the economic interests of policy makers in wetland restoration and livelihood support assessment as well as the interest of the environment and environmental activists; by incorporating all the services provided by the ecosystems with their relevance to communities. Distinctively, in recognition that the process of determining the wide range of services that are vital to human well-being results in their consideration as ecosystems worth conserving**;** modern geographic tools available are employed in research as the coastal environment – the key to the well-being of individuals within and outside the boundaries of coastal nations, is at stake.

Delimitations of the Study

There are a number of coastal wetlands in Ghana. However, the Butuah wetland was chosen for two reasons; first, it is an urban coastal wetland, sandwiched between an eroding shoreline and area of high economic activity, which clearly depicts the pressures imposed on such wetlands in numerous coastal countries. Secondly, the study area contains a lagoon, mangrove swamp and a coastal marsh- and presently, the lagoon stands as the only lagoon in Ghana that has been closed for fishing activities following the discovery of high doses of lethal herbicides in the water in 2011. Thus, it presented an opportunity to localize the concern of understanding the fore-issues that lead to the phenomenon of "dead" lagoons as well as offered a possibility for restoration through management approaches (from the research) that could be upscaled to similar cases recorded in other geographical areas.

The selection of temporal timelines for the study was based on the availability of high-resolution satellite images of the area and the delineation of the wetland area for image processing was based on previous studies recorded in literature and observed wetland characteristics. Sampling for social survey was restricted to resource users in the adjacent communities because a large number of community members do not directly depend on the resource. Again, the selection of stakeholders was limited to individuals that could be affected by management decisions of the study area.

Limitations of the study

The satellite images acquired were subjected to classification algorithms. Thus, the accuracy of the images was limited by the efficacy of the algorithms used. However, an analysis of the accuracy of the classified images of the study area was carried out and the algorithm with the highest accuracy (Closest to the in-situ data points collected) was used for all further analysis.

Definition of terms

Spatial resolution: a measure of the smallest object that can be resolved by the sensor

Image segmentation: involves dividing a digital image into several segments (pixel sets, also known as image objects) with the goal of making its representation more understandable and easier to analyze.

Algorithm: A technique for addressing a well-defined computational issue.

Radiometric correction: A process of calibrating the pixel values and/or compensate for inaccuracies in the values.

Organisation of the study

The thesis is divided into six chapters. Chapter 1 presents the study's overall idea, providing background information and defining the study's problem, purpose, objectives, and relevance.

The second chapter delves into the literature related to the topic in context. An in-depth examination of a review of the research on land use changes in coastal areas and their global consequences are given. In Chapter 3, the research techniques are explained in detail, with illustrations when appropriate. The study topics are well-described, as are the statistical techniques and software that were utilized to analyze the data obtained. The results and discussion are presented in Chapters 4 and 5, respectively. In Chapter 4, the study findings are presented in graphs, maps, charts, and tables with brief explanations. In Chapter 5, detailed analysis of data and implications are presented in the form of a commentary organized around the study's key topics. Chapter 6 ends with conclusions and recommendations based on the results generated from the study.

Chapter Summary

In this chapter, the study's main rationale is provided, along with the purpose of the study and advantages those coastal communities and governing institutions may expect from assessments of coastal wetland services and land use changes. To assist readers, the objectives have been stated and terminologies used in the study have also been clarified.

CHAPTER TWO

LITERATURE REVIEW

Coastal Wetlands

Coastal ecosystems cover about four percent of the total earth surface (UNEP 2006). Incongruous to the size in the area, coastal resources support nearly 2.4 million people who live within 100 km of the coast (U.N., 2017). With over 600 million (which is around 10 percent of the world's population) people living within distances less than 10 meters above sea level (U.N., 2017), it is imperative that the relatively small stretch's scarce resources are properly managed and sustainably utilized. Rapid urbanization in coastal cities is largely due to the availability of resources and the opportunities immigrants anticipate. The dynamic natural systems of the coastal area interact to form distinct interconnected systems, including estuaries, salt marshes, mangrove swamps, coral reefs, seagrass beds and lagoons (Murugan et al., 2019). These ecosystems are unique biodiversity and ecological processes that are impacted by conditions in the oceans and lands and vice versa. Humans have been a natural component of coastal ecosystems for thousands of years. However, the natural equilibrium of these systems has shifted in recent years. While humanity's reliance on them cannot be dismissed, in the last few centuries, the human impact on the ecology of these areas has been so severe that their productivity and services have been severely harmed.

Recent findings have shown that inland areas have less dense populations relative to coastal areas over the last two decades. Kay and Alder (2017) through quantitative analysis of population figures, saw that the population density of coastal areas is around three times that of inland locations. Many ecological services critical to the well-being of coastal economies and coastal dwellers are degraded by human pressures on coastal resources. Coastal communities tend to congregate near the kind of coastal systems that support their economic growth. Estuaries, marshes, and lagoons serve a crucial role in the maintenance of hydrological balance, water filtration, habitat provision for birds, fish, mollusks, crustaceans, and other ecologically and commercially significant species, regardless of spatial location. Estuaries and marshes supply the broadest range of environmental services among coastal subtypes. Mangroves, on the other hand are spatially restricted to tropical and sub-tropical regions of the globe, although their environmental and socio-economic benefits surpass the continents by which they are bound (Adame et al., 2021).

Their deep roots aid in the binding and formation of soils while their above-ground roots decrease coastal erosion by slowing water flows and encouraging sediment deposition. The intricate root systems of mangrove trees filter nitrates, phosphates, and other contaminants from the water, thus, enhancing the water quality that flows from rivers and streams into coastal wetlands and ocean environments (Wang et al., 2019).

Mangrove forests sequester large amounts of CO_2 and other greenhouse gases from the atmosphere, trapping and storing them for millennia in their carbon-rich waterlogged soils, making them an asset in tackling climate change. Furthermore, most birds, fishes, and invertebrates inhabit mangrove forests and seek refuge (from predation). Juvenile marine animals such as shrimps, crabs, and a variety of recreational and commercial fish species use coastal wetland ecosystems with strands of mangrove trees as spawning and nursery grounds (Aheto et al., 2011; Engle, 2011; Okyere et al., 2012). Coastal wading birds such as egrets, herons, cormorants, and roseate spoonbills also use the branches of mangroves as rookeries and breeding places (Yang et al.,2017). Oysters cling to red mangrove roots that hang in the water as part of their biological development process. Salt marshes and mudflats also support various life development stages in the life cycles of fish, shellfish, and migrating birds. Coastal lagoons and their surrounding flora serve as habitats for aquatic organisms and provide recreational services, flood control, salt extraction, and are also used for religious purposes (Ajonina et al., 2017; Baffour-Awuah et al., 2014).

Salt marshes, mangrove swamps, and shrubby depressions are also forms of wetlands found in coastal watersheds. Salt marshes are wetlands along the coast that are filled and drained by tide-driven saltwater. These intertidal environments are critical for fisheries, coasts, and communities and serve as an important component of economies and cultures. Over 75 percent of fishery species, comprising shrimp, blue crabs, and numerous finfishes, acquire food from marshes, while some use them as nursery grounds or for refuge (Hutchinson et al.,2014). The total area covered by salt marshes in the world is unknown, however, it is approximated to be between 40 and 80 million hectares (Nellemann et al., 2009).

By buffering wave action and retaining sediments, salt marshes can protect shorelines from erosion. They also maintain water quality by filtering runoff and metabolizing excess nutrients, and they minimize flooding by delaying and absorbing rains. Mudflats support marine fisheries by serving as nurseries, breeding grounds or refuge to finfishes and shellfishes. Burrowing species such as crabs live in mudflats while certain finfishes such as the *periopthalmus* sp. take refuge in them. These ecosystems contribute to fish production in developing countries, where fish consumption significantly increased from 5.2 kg per capita in 1961 to 19.4 kg in 2017 (FAO, 2020).

Economic and social benefits derived from coastal wetlands

As much as coastal communities depend on coastal wetlands to provide food and marketable resources for economic gain, the spiritual connection and cultural identification they attach to the resources is significant (Ferguson & Tamburello, 2015). The Galápagos Islands in Ecuador, Sundarbans in Bangladesh, as well as the Coiba National Park and its Special Zone of Marine Protection in Panama are among mangrove areas recognized as UNESCO heritage sites and natives affix cultural values to such sites. The sacred Kaya forests stretch throughout Kenya's coastal plains and highlands and are culturally significant in Africa. As Kenya's old Coastal Province, the Kaya forests are thought to have been the home of nine coastal Mijikenda ethnic tribes. They have a diverse plant community, and certain sacred locations in the area are still maintained through a system of ritual acts in honor of the original occupants' ancestors, monitored by community organizations and elders (Mwaipopo & Shalli, 2014).

Wetland resources support livelihoods. The term “livelihoods” extends beyond activities meant to generate income and/or supply food for resource-dependent families. The understanding of natural resource dependence as dynamic (subject to shocks, changes and seasonal effects) permits a more holistic approach in resource valuation aimed at sustainable management and intergenerational equity.

> “*A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain its capabilities and assets both now and in the future, while not undermining the natural resource base”.* (Carney, 1998)

Food provision from fish catches in coastal wetlands such as coastal lagoons serve as the primary. and in certain cases, the only source of animal protein for coastal communities. Fisheries and fish production also provide direct and indirect employment to individuals within the sector (FAO, 2010).

UNEP (2014) reports that “over 100 million people live within 10 km of large mangrove ecosystems in 123 countries covering approximately 15.2 million hectares”. Mangroves are responsible for an estimated 80% of global fish catches, both directly and indirectly (Sandilyan & Kathiresan, 2012). These forests contribute considerably to local livelihoods and provide work for coastal inhabitants, ensuring food security for local people. Developing countries with mangroves are estimated to benefit from the ecosystem services the forests provide to the tune of US$ 33,000, per hectare per year (Goodwin & Rivera,2019; UNEP, 2019). Accordingly, as they cover an area of 14 million hectares, mangroves in the world provide service worth US$ 800 billion per year (Salem & Mercer, 2012). They are also instrumental in global warming and climate regulation strategies since mangrove carbon storage capacities are about 3-5 times higher than those of tropical upland trees (Donato et al., 2012). There are over 2000 mangrove-related tourist attraction sites globally, contributing revenue to national economies (Spalding et al., 2016).

Most communities in Africa and Asia roof their houses through thatching, while others use them in making mats. Thus, indigenes of local coastal communities gather sedges and rushes from surrounding salt marshes as roofing materials and/or sell them for profit. For roofing, the practice involves using dry vegetation such as straw, water reed, sedge (*Cladium mariscus*), rushes, heather, or palm branches, to build roofs by layering and densely packing the dry vegetation. It is a low-cost construction option derived mainly from local vegetation in coastal wetlands. It is an old practice in some developing countries, although, even in developed countries, affluent people roof these gazebos and houses with thatch as an aesthetic and ecologically friendly option. Many fringing communities in Africa also depend on mangrove resources for fuelwood for sustenance as well as for economic gain. In West Africa, certain mangrove swamps or portions of mangrove ecosystems are reserved for local deities (Mangora & Shalli, 2014). Hence resources from those portions, if exploited at all, are done sustainably. Such traditional management approaches could be instrumental in wetland management towards the attainment of sustainable development goals under the U.N. Decade of Ocean Science (Hampton & Jeyacheya, 2020)

The aesthetic and historical values of certain coastal wetlands register them as preferred tourist destinations. Coastal tourism is an important aspect of the international tourism sector, especially for island nations, where tourism accounts for more than 40% of their GDP (Bardolet & Sheldon, 2008). Brett (2021) examined the economic impact of tourism on the economies of African island states with statistics from the World Travel and Tourism Council's annual reports and found tourism (which is an important source of revenue for island governments) to be centered along the coast.

Remote sensing and coastal wetland management

The advent of remote sensing technology has advanced coastal resource studies and management. The flexibility of assessing and monitoring resource use in coastal wetlands has allowed researchers and coastal managers to address issues in large areas within a short span of time. Coastal zones are complex and varying systems which contain a variety of species depending on their distances from the shoreline, each of which serves a particular ecological purpose in habitat adaptation (Hopkins et al., 2011). However, current onsets of increasing degradation and anthropogenic intrusion of coastal wetland structures accentuate the urgency for landscape structure studies to ascertain basic wetland characteristics to implement time-bound conservation and restoration efforts. Unfortunately, conventional methods of coastal zone studies may not be ideal for this purpose due to belligerent drawbacks (Klemas, 2015). As coastal zone development faces environmental changes and disasters, there is a need to improve the means and intensity of coastal zone monitoring. Remote sensing is one of the most important current methods for monitoring earth's ecosystems because of its capacity to deliver synoptic information across large areas with high acquisition frequencies (Guo et al., 2017). Geographic information systems have been leveraged upon over the years and, satellite imagery and Unmanned Aerial Vehicles (UAVs) such as drones have been applied in resource development, coastal zone planning and management, shoreline monitoring, and research into coastal zone forces and processes (Turner et al., 2016; Green et al., 2019; Yang et al., 2019). Remote sensing technology collects and captures data without contact with an entity and it is applicable at global, regional, and local levels (Jiang et al., 2016). In support of their relevance, Adade et al. (2021) also noted the importance of UAV in Coastal management and advocated for their inclusion in sustainable coastal management.

Today, high-resolution remote sensing imaging has become possible as satellite sensor resolution has improved, thus making the prospects of their application even greater (Yang et al., 2019).

In applicable research areas, remote sensing has played a very prominent role. Port construction, roads, ecosystem attributes, and species diversity could all be collected in detail using high-resolution remote sensing images within a short time span since remote sensing of high-resolution spectral information, shape, and texture are all present in images. High-resolution satellite imagery is an excellent tool for mapping and monitoring the coastal environment. The increased prevalence of high-resolution and multispectral satellite data allows numerous images derived from multiple sensors with varied resolutions to be used to measure the same coastal location (McCarthy et al., 2017). This allows for the study of trends and changes in land-use over periods of time (Liu et al., 2020). Klemas (2011) noted how such technologies (equipped with sensors with fine spatial (1–4 m) and spectral (200 narrow bands) resolutions) are allowing scientists to detect changes in coastal ecosystem health and habitat quality more precisely and Randazzo et al. (2020) confirmed the efficacy of such satellite images in coastal management by using Geo-eye 1 images to map a coastal shoreline. The corresponding results in both cases were used in devising management strategies for the coastal resource use. Even in developing countries like Ghana, the use of remote sensing for data collection in coastal management is gradually becoming more rampant (Adade et al., 2017; Asomani-Boateng, 2019; Ekumah et al., 2020) and studies to this effect are welcomed.

The challenge in remote sensing, nonetheless, is accuracy. This is because the quality of these images in terms of temporal, spatial, and spectral resolution determines the accuracy of remote sensing intelligence. To address this, Conchedda et al. (2008) suggested using intricate classification approaches as opposed to simpler ones in conjunction with in-situ ground truthing to eliminate errors in using remote sensing technology.

Threats to coastal Wetlands

Coastal areas are beyond doubt among the most widely altered ecosystems globally as human pressures continue to increase (Newton et al.,2020). Although they are among the most productive systems worldwide, their productivity is threatened as Coastal systems experience growing exploitation pressures, which can be attributed to the rapid population increase in coastal areas (Berwick, 2013). Demographic trends suggest that coastal populations are increasing expeditiously, mostly through migration, increased fertility among natives, as well as coastal industrialization -which tend to be very high (Barbier, 2014). These factors have attributed to the Population densities of coastal areas being nearly three times that of inland areas (Neumann et al.,2015). Communities and industries located within the rather narrow stretch of global landscape increasingly exploit fisheries, timber, fuelwood, construction materials, oil, natural gas, sand, strategic minerals, and genetic resources. Auxiliary to the above is the demand on coastal areas for shipping, waste disposal, military and security uses, recreation, aquaculture, as well as habitation. Agardy et al. (2005) acknowledged the risks that human dependence laid on coastal systems and raised concern on the reported 71% of coastal populations living within 50 kilometers of estuaries, mangroves, and coral reefs especially in tropical regions of the world at the time. Today, the figure is higher, and environmental ‘squatters’ are clearing coastal ecosystems they cohabitate to make room for their growing populations, thereby increasing the ecosystem’s vulnerability. Several studies have attempted to address the issue on an international scale over the years. Malchykova et al. (2019) proposed intensive restrictive rules for coastal dwellers and visitors as a method of protecting the rapidly decreasing acreage of natural coastal ecosystems. On the contrary, Khan (2015) had a different view and postulated that the practice of afforestation and enforcement of the polluter pays principle could drive us towards the path of intergenerational equity and sustainability in coastal ecosystems.

Perhaps the disregard for environmental wellbeing as humanity strives for internal and external development may be backed by social foundations. The Abraham Maslow theorem of needs (Maslow, 1954) affirmed the inherent desire of humans to attain their basic needs prior to their self-actualization needs. In practice, one would prefer to use all available resources to reach a certain level of affluence and avert through mitigation, the damage that may have been caused in the process of "building up". By that logic, institutions and individuals would seek pardon for coastal degradation and pollution in the name of development, resolving to invest and support coastal restorative measures despite ownership of coastal ecosystems not belonging solely to institutions or individuals. Nonetheless, the unsustainability of the idea is undeniable as the cost of restoration is high and often fails to provide optimum results (Suman, 2019; Akpalu & Stage, 2021).

Centralizing on the issue at hand, anthropogenic activities have drastically affected coastal and marine habitats through time and the human-induced deterioration and loss of habitats have had enormous economic and societal effects. The pattern of consequences from the disturbances is observed in the habitat degradation and loss, which has diminished the density of fish populations, reducing commercial and recreational fishing options (Zhou et al,2017; Calizza et al.,2017). Human convergence in coastal areas puts further strain on the coastal and marine environment. The U.S reports an annual coastal watershed loss of about 80,000 acres in 48 states (Dahl, 2009). In Africa, coastal wetland losses are rapidly increasing and efforts to keep track of wetland land use and land cover reclamation are impeded by technological inadequacies and challenges in the enforcement of punitive measures. Annual global economic losses of 0.7–1.2 percent culminated in about 63 percent of all coastal wetland losses due to rapid expansion over the twentieth century (Zedler & Kercher, 2005). At the time, between 25–50 percent of the earth's reclaimed coastal marshes were converted to agricultural areas, whereas many of them were discovered to be eutrophic and/or hypoxic, with damaged habitats (Zedler & Kercher, 2005). Presently, the level of losses has doubled (Hu et al., 2017).

Under development demands, urban coastal wetlands face two types of stress: land conversion loss and ecological degradation. In the few urban coastal wetlands where encroachment is not obtrusive, there remains the menace of alteration of ecological diversity due to unsustainable management practices or the lack thereof. In fact, numerous studies point to eutrophication as a primary cause of salt marsh functional decline and eventual loss (Turner et al.,2009; Gedan et al.,2011; Deegan et al.,2012) and river flows of land-derived sediment as well as contaminants to coastal wetlands which are increasing as watersheds become more urbanized are also a major contributing factor (Chmura, 2009; Day et al.,2011). Again, rearing grazing animals near urban coastal wetlands, dumping of sewage and plastic waste from homes as well as wastewater and runoffs from industries and surrounding agricultural farms, affect wetland biology and ecology (Lin & Yu, 2018). Animal grazing threatens coastal wetlands by destroying coastal biodiversity resulting from stomping, infestations from faecal matter, and when herds feed on wetland flora. Morris and Reich (2013) detail their detrimental grazing effects discussing how animal trampling can compact soils and prevent surface water from reaching roots.

According to Ampomah (2017), water pollution in Ghana is mostly caused by industrial waste, illegal mining, agricultural and residential waste disposal. The nation's rising urban coastal lagoon pollution due to growing urbanization is a major concern. Essel et al. (2019) disclosed that the drastic shrinkage in coastal lagoons that led to ecological fragmentation increased as a result of increasing plastic waste pollution in lagoon habitats in Ghana. In such cases, biodiversity is lost, leading to a diminished supply of ecosystem services and as a result, immediate vicinities that are dependent on the lagoons suffer the earliest effects. Likewise, coastal mud flats, which are primary habitats for crabs are filled with sand for construction in many urban cities across the country. This leads to displacement of inhabiting species and possible extinction of endemic species. Surely. land use change occurs when natural land resources are changed to agricultural areas, residing areas, commercial establishments in a manner that could negatively affect biological diversity. The argument is no different for coastal marshes since dredging and filling operations in salt marshes result in structural alteration, sedimentation, increased nutrient concentrations, and the introduction/interchange of genetic materials.

Economic valuation and its impacts on land use management

The economic valuation of environmental elements entails assigning a monetary value to them (Burkhard & Maes, 2017). Practically, it serves as the foundation for weighing socio-economic trade-offs between the costs and benefits of environmental actions, as well as determining the appropriate level of an environmental tax or subsidy (Cheung & Sumaila, 2008). It is vital for the incorporation of resource value into national and global economic planning. The incapacity of markets to recognize the economic value of non-market services supplied by coastal habitats is among the underlying factors (root causes) for the extensive depletion of coastal habitats (Galos et al., 2015). Since it is human behavior to protect items and facilities deemed valuable and waste of expendable resources, the slip in valuation leads to a loss in the value of unique coastal products and services. As a result, the importance of coastal habitats' ecological services in maintaining coastal economy is poorly understood, and for that, coastal wetland conservation receives insufficient attention as critical coastal ecosystems are occasionally thought of as low- or no-use lands. Generally, valuation of coastal habitats economically serves as a direct persuasive tool for environmentalists to convince government officials of the profits of coastal ecosystems hence the need for their inclusion in developmental decision making. However, some environmentalists do not support the idea of valuing environmental resources. According to Pearce (2001), determining the economic value of biodiversity is a critical step towards protecting the resource. Although generally accepted, natural resource valuation techniques have been met with some skepticism over the years. One of the most significant drawbacks of economic valuation is that the approximations it generates are frequently highly context-dependent, relying on both the methodologies and hypotheses used (Lienhoop et al., 2015). Some strategies, for instance, focus primarily on marketed services while ignoring non-market values (Obst et al., 2016). To counter this, selected strategies for estimations of total economic value in coastal ecosystems need to be extensive because not only is determining economic value an important aspect of sound decision-making in the field of coastal management, but it is also a necessary component of sound decision-making in the field of economics.

Thus, economic valuation could be determinative for the development and utilization of coastal ecosystems. It also permits the recognition of underutilized commodities and services that could serve as the foundation for alternative livelihood development in coastal communities (Azanza et al. 2017). Hanley and Shogren, (2002), argued that techniques for valuing the environment can provide useful evidence to promote habitat protection and that by assessing the economic value connected with the protection of natural resources, conservation policies may be developed. The concept of total economic value (TEV) is a broad assessment of the economic worth of any environmental asset. It can be broken down into use and non-use (or passive use) values, with further sub-categories available where necessary (OECD, 2006). In support, Jantzen (2006) added that by assigning monetary values to ecosystems, the economic value of alternative use options could be directly compared. Consequently, it could and should be used in cost-benefit analyses of (greater) government and private enterprises. In valuation, use and non-use values combine to form the overall economic benefits of environmental resources and of the two, use values are frequently easier to assess. Use values are placed on services that people benefit from directly. They include food production, flood control, recreational opportunities, and the provision of potable water. On the other hand, non-use values are less tangible. Examples are a desire for endangered tigers to survive even among people who will never see them in the wild; concern for leaving a planet with healthy fish populations to future generations; a sense that people have an ethical responsibility to be good stewards of the earth (Constanza et al., 1997). Skeptics continually raise the challenge of ‘pricing’ non-priced goods in resource valuation attempts as a criticism of the approach. However, economic theory addresses the issue of non-priced goods and services, as well as the optimal supply and demand for them, to help coastal degradation become visible and well comprehended.

The efficacy of coastal resource assessment and economic valuation is its use in policy. Jati & Pribadi (2018) assessed the economic value of mangroves in the Baros Mangrove Forest , Indonesia and succeeded in establishing a management strategy for the area following the argument by Hanley et al., (2015) that the challenge with valuation methods is with applicability in management. To put economic value in perspective, Asrofani et al. (2020) made an argument combining environmental, and social aspects with economic valuation approaches to create a comprehensive development planning unit towards a systematic policy formulation and implementation goal.

Coastal resource valuation research from Africa has largely been on the continental scale and advances in technological capacities of researchers have enabled that. For instance, Sannigrahi et al. (2019) evaluated landscape capacity to provide significant ecosystem services in the region while Huxham et al. (2015) focused solely on mangrove forests and their value in climate compatibility.

In Ghana, publications on coastal resource valuation of coastal wetlands that borders on land use changes are scarce. Aheto et al. (2016) valued direct use benefits of mangroves as part of a study on community-based mangrove forest management although the focus was restricted to livelihood impacts and not land use impacts of conservation or degradation of the mangroves. Akpalu & Wong (2020) also used cost-benefit analysis to address the need for fisheries management and from that, proposed management interventions for the country's depleting fisheries resources. In essence, economic valuation of coastal resources could be crucial for decision-making so far as the approach adapted (direct use, indirect use, intrinsic values or total economic value) is exhaustive and embodies the totality of all resource use.

Land Use and Land Cover (LULC) impacts on coastal wetlands and livelihoods

Land use change involves the process through which anthropogenic activities alter the natural landscape. It refers to how land is used, with an emphasis on its functional role in economic activity (Paul & Rashid, 2017). Sustainable coastal development is critical in today's society. Hence, monitoring is essential in achieving long-term viability and environmental preservation of wetlands in urban areas. Changes in LULC have been an important parameter in recent initiatives to achieve integrated coastal zone management as part of natural resource development which has relevant economic impacts. At both the global and regional levels, changes in land use and land cover (LULC) are one of the key drivers of biodiversity loss and ecosystem degradation. These effects are substantial in Sub-Saharan Africa, according to Temesgen and Wei (2018) and a slew of anthropogenic disruptions has exacerbated the problem by disturbing ecological activities and services (Cork and Shelton 2000; FAO 2011; Temesgen et al. 2018). Evidently, changes in landscape nature, have impacts on ecosystem function and provision of ecosystem services. Thus, the value of coastal wetlands and their ability to continually provide services is impacted by LULC changes. Näschen et al. (2019) theorized that a decrease in land cover resulted in a decrease in water resources in tropical catchments. Simply put, when a function is disrupted, a resulting service or group of services will also become reduced. The fragility of coastal wetlands makes them more susceptible to this theory. The consequence of clearing one hectare of mangroves or salt marsh may be more severe than repeating the same action on inland vegetation. In coastal wetlands a variation in land cover could have massive effects on biodiversity, soil composition, environmental sustainability, and the general livelihood of coastal populations, among other issues (Camacho-Valdez et al.,2014).

Furthermore, persistent changes in land use pose significant threats to livelihoods by altering the wetland's ecological conditions through which it can provide goods and services. Expanding urbanization and industrialization, and their resulting land-use changes together with increasing climate change variability, are limiting resource availability and livelihood sustainability, specifically in sensitive urban coastal wetlands and crucial watersheds (Tijani et al., 2020). The severity of the deterioration of these habitats has been accelerated by population pressure and socio-economic activity and there is a risk that these ecosystems will be further harmed in the absence of adequate management inputs (Camacho-Valdez &Berlanga-Robes,2016). Conversion of coastal wetlands in urban areas emanates from social and economic statuses of resource dependents.

Ondiek et al. (2020) found that between 1966 and 2018, certain wetlands in Kenya, East Africa, decreased by 55%, owing primarily to agricultural growth, and deduced that a wetland's potential to deliver a larger monetary value was usually the purpose for its conversion. Li et al. (2020) also noticed that transformations in LULC were fueled by Economic development and land policies. Ligate et al. (2018) recommended regulating population and socio-economic activity to prevent further detrimental effects of coastal LULC change.

In addressing the impacts of urbanization on wetlands in Ghana, Ekumah et al. (2020) suggested an improvement in research communication to foster effective policy implementation strategies.

To accurately understand LULC impacts on urban coastal wetlands and livelihoods, collective efforts and integrated solutions from research, governance and investment sectors are required. What this provides is a combination of resources to address LULC in a multifaceted ecosystem through a multidisciplinary approach.

Coastal Habitat Risk Assessment

Coastal habitat Risk Assessment is a systematic process of detecting hazards and analyzing any related risks in coastal zone habitats, followed by the implementation of appropriate control measures to eliminate or decrease them.

To find crucial relationships underlying stressors and wetland adaptations and devise the most appropriate risk management methods, the risk assessment process must be placed in an ecosystem context. Recognizing the main factors that influence the structural and functional properties of wetlands (ecology, hydrology, geomorphology, and soils) and using that tool to evaluate where, when, how, and to what extent stressors could be the tool to identifying causes of adverse effects, and thus adequately assimilate wetland science into risk assessment.

There is frequently a deficiency of science and risk assessment. In wetland and risk assessment research, there is a disconnection of communication and understanding. Risk assessors are frequently unfamiliar with wetland science and ecology, while wetland scientists are sometimes unfamiliar with risk assessment principles (Hope, 2006). Environmentally, sustainable conception and execution of wetland risk assessments requires finding a balance between wetland research and risk assessments.

Anthropogenic disruptions have increased the vulnerability of coastal ecosystems and compromised their ability to deliver diverse ecosystem services. Risks are a product of stressor exposure, impact sensitivity, and resilience; it can serve as a proxy for assessment of the propensity of a coastal habitat to provide ecosystem services (Caro et al., 2020). Over the years divergent measures of ecosystem risk emerged; a few believe that as coastal habitats offer greater ecosystem services, vulnerability is reduced because the ecological resilience is increased, whereas others believe the contrary, because numerous activities (exploiting multiple services) introduce multiple stressors (Mackintosh et al., 2016). The state of a habitat influences the ecological services it can supply; for example, damaged coastal mangroves are less capable of attenuating waves and reducing coastal exposure. Thus, species risk could suggest a decrease in long-term viability, and the ability to detect and predict a risk using appropriate models could address management questions on where, when and how to implement a directive.

The model comparison approach by Caro et al. (2020) is commendable. Emphasis was placed on the assessment of two versions of the Habitat Risk Assessment model from InVEST and the applicability of the result in management scenario generation. However, the management scenarios generated from the study were not exhaustive, possibly due to the large coverage of the study area and data unavailability. That notwithstanding, an addition of stakeholder participation and analysis is crucial in the assessment of habitat risks irrespective of project scale or scope. The importance of stakeholder involvement was highlighted by Arkema et al. (2014); where future scenarios for coastal development and conservation were created for Belize based on habitat risk assessment estimated with the InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) model developed by the Natural Capital Project. The study demonstrated the efficacy of the model in coastal habitat risk assessment. By default, the model requires data regarding habitat-specific sensitivity to specific projects as well as life history characteristics of different species in order to evaluate the consequences of exposure to anthropogenic activities, yet the methodology is uncomplicated, adaptable and flexible to a variety of habitat risk categories, depending on the local scenario (Arkema et al.,2014).

The InVEST model assumes that ecosystems around the world respond in similar ways to any given stressor. It also assumes that cumulative risk is additive. The model is not without limitations as even the most recently modified versions of the model report the quality of the results(output) based on the quality of the data(input) as with most systems. Thus, accuracy is constrained by the availability and quality of the input data. Utilizing data of maximum quality from current local evaluations reproduced at many locations in the region of interest for the organisms in the study will produce more accurate outcomes than poor quality data retrieved at a distant location with a reduced spatial or temporal resolution, specifically in the context of criterial scores. Since most research on the effects of particular pressures has only been acquired in a limited number of areas globally, there is a need to access data from other geographical areas for some stressor-habitats. As a counter measure, data quality score is added in the analysis to alleviate these data restrictions. This score enables researchers to de-weight criteria with poor data quality.

Positively, due to the nature of the scoring process, results can be used to compare the risk of several human activities among several habitats or species within the study region (which can range in size from small local scales to a global scale. Moreover, the HRA approach does not bluntly account for the impacts of historical human activities on existing risks although exposure to past anthropogenic actions may have an impact on the outcomes of current and future human activities. Fortunately, historical land-use data could be included as well as information on how they affect current consequential scores in the assessment to get more accurate results (Sharp et al., 2014) . Empirical testing of the InVEST HRA model has shown strong relationships between modeled risks and habitat fragmentation and health (Pastorok et al., 2016), hence its efficiency in assisting policy making (Arkema et al., 2014). As empirical data become available locally, a great avenue of future work would be to validate and relate regional risk scores to conditions of habitat quality (e.g., density, fragmentation, etc.).

The model also assumes that cumulative risk is additive as opposed to synergistic or antagonistic. However, the interplay of multiple stressors on marine fauna and flora is largely unexplored (Crain et al. 2008; Teichert et al. 2016); and the interactions being additive, synergistic, or antagonistic is possible; making their predictability laborious. That notwithstanding, the assessment of habitat risk with the InVEST model for wetland conservation, policy conservation and economic development is very effective and highly recommended (Zhai et al., 2021).

Image Classification techniques

Founded on the notion that varieties of features on the surface of the planet have distinct spectral reflectance, the classification technique is used to recognize the qualities of remittances. Improved classification accuracy of advanced classification approaches is vital in socioenvironmental and economic research. Ultimately, the processes of image classification involve designing a classification scheme (typically information classes) such as marshes, built-up area or forest etc., gathering ground data and other auxiliary data of the research area, image preprocessing, which includes radiometric, atmospheric, geometric, and topographic corrections, as well as image augmentation and clustering. These are followed by choosing representative sections of the image and assessing the clustering findings or creating training signatures as well as algorithms for image classification and post-processing (which consists of thorough geometric correction, filtering, and classification decoration).

Finally, the image is checked for accuracy by comparing categorization results to field investigations. Classifying multispectral images is fundamental in remote sensing. The technique involves categorizing pixels into a fixed number of classes depending on their data values. If a pixel conforms to a set of standards matching a specific class (pattern), it is allocated to that class. Pattern recognition is a mathematical technique for a computer system, where pixels are categorized and sorted based on computational items (Sisodia et al., 2014). Generally, image classification is sub-divided into two: supervised classification and unsupervised classification. Unsupervised image classification involves separating random pixels into groups based on their spectral reflectance with no manipulation by the analyst. The process is centered on spectral pixel-based statistics, with no previous understanding of the effects of the themes under consideration. Unsupervised classification is simple to apply, since it requires no analyst-supplied training data, and is readily accessible in geographic processing and statistical software packages (Langley et al., 2001). It also automatically converts unprocessed image data into meaningful information provided the classification accuracy is high as shown in Figure 1.

However, one major drawback of unsupervised classification is that it must be repeated as new data samples are added (Al-doski et al., 2013). In supervised classification, smaller sections are created on the image (training fields) that comprise predictor variables recorded in the sampling units and allocates prior classes to the sampling units. Several algorithms are used in supervised classification. Minimum distance, maximum likelihood, and Support Vector Machines (SVM) are among the most widely used classifiers. The maximum likelihood decision rule allocates every pixel having pattern characteristics "X" to a class "c" whose units may have given rise to feature "vector x", assuming a Gaussian distribution. The SVM performance relies on the

Structural Risk Minimization principle, that is an inductive principle for model selection and aims to provide a trade-off between hypothesis space complexity and quality of fitting the training data. SVM has shown promising applications with high accuracy(Natya & Rehna, 2016; Thakur & Maheshwari, 2017).

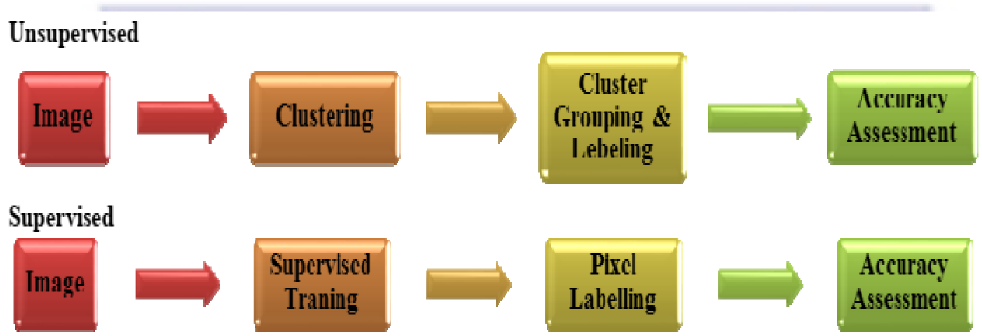


Figure 1: The steps involved in supervised and unsupervised classification
Source: Al-doski et al. (2013)

The challenge of selecting a classification method is complex since numerous elements including spatial resolution, multi-sensor data, and accessibility of multiple classification software are concerned, and each classification approach has its advantages and disadvantages (Kamavisdar et al., 2013; Prasad et al., 2015). Over the years, considerable researchers have adapted supervised classification techniques in image classification; despite its shortcomings in its accuracy.

Object-based classification techniques are gaining popularity in recent times with considerable progress in terms of technological advancements and the advent of high spatial resolution imagery. Object-based image classification divides pixels into size and geometry-based vector shapes (Uca Avci et al., 2011). Consistent growth has been observed in the use of object-based classifiers as searches on Google Scholar reveal a surge in the use of the classification technique.

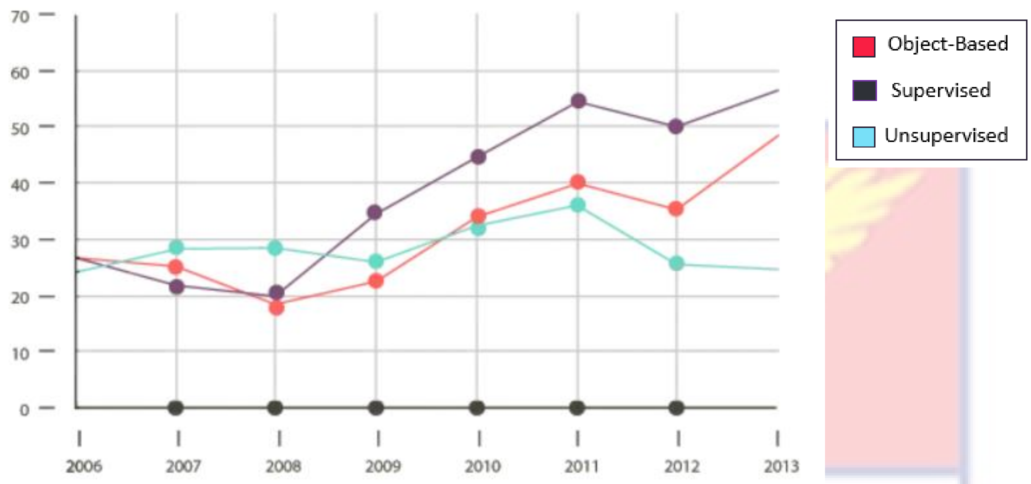


Figure 2: Showing the use of classifiers in publications from 2006 - 2013
Source: *Blaschke (2010); https://gisgeography.com/image-classification-techniques-remote-sensing*

Weih and Riggan (2008) compared Object-based classification to pixel-based classification (Supervised and Unsupervised) by assessing their accuracy in LULC classifications to discover how important each factor was, using multi-resolution image datasets. The authors confirmed that high resolution images provided the highest accuracy with object-based classifiers. Makinde et al. (2016) affirmed the significance of object-based algorithms in image classification through RapidEye satellite images, which proved the algorithm's accuracy at over 7% higher than pixel-based algorithms. By default, object-based classifiers have more complex algorithms and thus are more difficult to develop compared to pixel-based ones, although it is rarely mentioned in image classification assessment review studies. Object based algorithms are practical in all fields, however, Aryaguna & Danoedoro (2016) found that in forest classifications, pixel-based vegetation composition mapping is more effective than object-based vegetation composition mapping.

Algorithms have improved in recent years with the advent of sophisticated computers in a rapid changing technological world. Recently, machine learning and deep learning algorithms in image classification are pushing out traditional pixel-based approaches with the development of complex neural networks.(Kadhim & Abed, 2020; Liu et al., 2020; Mustapha et al., 2010; Rodrigues et al., 2011).They require training data sets which could be tedious but produce significantly accurate results. All classifiers have their merits and demerits and the conclusion on a particular algorithm should be upon testing the data (imagery) with pixel-based, object-based or machine learning algorithms and assessing their accuracy with in-situ data.

Landscape fragmentation in coastal wetlands

Landscape changes are often associated with habitat fragmentation and subsequent biodiversity losses (Duarte et al., 2008; Teixido et al., 2010). Strategic conservation is specifically challenging in highly fragmented landscapes. Coastal wetlands, like most natural environments, have elevated ecological benefits and are therefore extremely prone to a range of threats. Human activities, combined with climate change, cause wetland fragmentation, especially in urbanized coastal areas where human pressures continue to increase. By hastening their degradation and impeding biodiversity conservation, habitat fragmentation affects the long-term ecosystem services that wetlands provide. By definition, habitat fragmentation is a landscape-level process where a specific habitat is gradually subdivided into smaller, geometrically modified, and more disconnected fragments due to both natural and anthropogenic activities. It involves changes in landscape composition, structure, and function at many scales and occurs against a backdrop of a natural patch mosaic generated by altering landforms. As the size of the patch diminishes, so does the number of flora and fauna they contain. Habitat fragmentation and degradation are frequently linked to the 'edge effect phenomenon'. When a habitat is fragmented, the boundary of the habitat expands, resulting in new borders with increased edge effects. Edge effect is the outcome of an abrupt transition between two considerably dissimilar natural habitats that are adjacent to one another in the same ecosystem. It is essentially caused by a breach in the connectivity of two nearby habitats, resulting in environmental changes and the biology of species. Edge effects are one of the primary reasons of extinction and can even be created by a common human intervention such as road construction. Furthermore, habitat fragmentation disrupts habitat continuity, lowering reproductive success, genetic exchange, and, as a result, species genetic diversity.

Adade et al. (2017) discovered that fragmentation of wetland landscapes diminishes species richness and taxon variety, as well as the effectiveness of ecosystem functionality. Fragmentation likewise, disrupts habitat continuity, resulting in fragmented areas that sustain lesser species which may encourage local extinction of species. Over the years, landscape ecologists have created landscape metrics for measuring landscape fragmentation. In particular, advancements in spatial technologies such as Geographic Information System (GIS) and Remote Sensing (R.S.) have benefited wetland study by designing and applying landscape metrics. In coastal forests such as mangroves, Kanniah et al. (2021) confirmed the efficacy of fragmentation analysis to detect the impacts of land use changes and as a mechanism to prescribe appropriate management strategies for sustainable management and improved economic value. However, since fragmentation analysis is spatial based, depending solely on the output of patch analysis to describe landscape, management approaches may be addressing just a part of the problem. This is because coastal issues are the output of the interplay between numerous biological, physical and economic entities in the coastal area. To this effect, the study published by Plantinga et al. (2010) is noteworthy as it stressed the need for consideration of societal and economic perspectives in fragmentation analysis since coastal resources have varying functions that change in response to economic incentives, evolving regulations and policies, and environmental degradation whose interactions bring shifts in demand for resources and can alter socio-economic characteristics of environments including income and population. The effects of fragmentation on Urbanized landscapes are numerous. Barr et al. (2015) reported changes in genetic connectivity and diversity in plants as fragmentation increased.

Again, Sevick (2016) predicted the negative effects of fragmentation on coastal nekton, although the methodology did not conclusively prove the impacts of fragmentation but rather that of varying habitat types on the species. In certain agricultural and economic circles, some scientists do not oppose land fragmentation arguing that it reduces the spread of diseases among species in ecosystems (Sundqvist & Andersson, 2006).While correlation may not necessarily be causation and the sources of habitat fragmentation and mechanisms for regeneration of fragmented landscape are not thoroughly understood, it is yet agreeable that habitat fragmentation places stress on urban landscapes, and there is the need for inclusive research and management structures to be put in place to tackle them.

Stakeholder involvement in coastal wetland management

Stakeholder participation (S.P.) refers to a variety of methods for promoting awareness, recognizing objectives, agreeing on criteria and policy, and developing adaptive capacity to address coastal issues while taking into account the diverse perspectives, interests, and values that different groups may hold. Stakeholders in the coastal zone are often made up of;

(i) those in control of the legislative instruments of the coast, such as various levels of government.

(ii) tourism, aquaculture, and chemical production plants and coastal businesses whose activities are or must be restricted.

(iii) individuals and groups that live on the coast or utilize coastal resources, such as NGOs that represent diverse interests (e.g. biodiversity, fishermen)

(iv) those participating in coastal administrative functions, decision-makers, and researchers.

The general opinion of the management and development of the urban coastal wetlands frequently interferes with the regional interests of coastal cities because, the stakeholders involved in policy planning processes seek to develop the urban areas as a whole yet have to consider the role of the environment. It may seem challenging to include the unique characteristics of both parties. Yet, multiple values (economic, social, and cultural) must increasingly be incorporated into sustainability and environmental management programs. The importance of taking into consideration the intrinsic values associated with ecosystems, as well as adopting a systematic approach that embodies a wider range of values, namely the local, cultural, and economic values which emanate from the interaction between humans and environment, has been highlighted in the Millennium Ecosystem Assessment (MEA). While ecological and, more recently, economic values are taken into account when defining and designing environmental management plans, stakeholder interests are not often taken into account (Naidoo et al., 2008). After recognition of stakeholder values; the values must have a geographic dimension in order to be merged with spatially specified biophysical, environmental, and economic data for incorporation into geospatial management plans (Ivanić et al., 2019).

Kismartini & Yusuf (2015) carried out a stakeholder analysis for coastal management with socio-economic dimensions although important geospatial or environmental aspects of use were not reported. In effect, stakeholder assessments and inclusion allow managers to identify locations that people appreciate and the reasons for their worth, and to become aware of the need to give certain regions more attention when developing management strategies. Moreover, in instances where several user groups exist, it highlights areas of potential conflicts and aids managers in comprehending the implications of alternate management scenarios (Ruiz-Frau et al., 2011).

Mackenzie et al. (2019) also noted the significance of stakeholder engagements in coastal management and outlined how sustainable integrated ocean management systems will provide enhanced economic, social, and environmental advantages by including all stakeholders in forming effective partnerships. In coastal wetland studies, stakeholder involvement and communication are unquestionably crucial, and to the success of any coastal project in achieving long-term progress and economic gain.

Management frameworks for coastal management

All integrated coastal management (ICM) efforts have the same goal in mind- coastal ecosystems and its related ecosystems must be maintained, restored, or improved in certain conditions. ICM is unique, in that, it serves both developmental and humanitarian concerns as well as conservation in geographically defined locations (Olsen, 2003). For this to work, coastal management plans must be customized to take into consideration the reality of current legislative and institutional frameworks, as well as contain strategies for altering policies, when necessary. Community-based social marketing tactics, as well as education and awareness initiatives and information, can help to raise community knowledge and comprehension of coastal concerns as a management intervention but this is best accomplished at the community level, and all stakeholders need to be involved in its development and implementation.

According to Inácio & Umgiesser (2019), a systems approach framework (SAF) is the best option for coastal management problems of today since it requires a holistic view focusing on the relationships between components of a system. The SAF has been adjusted to offer a systematic approach for ICZM that ensures a comprehensive (ecosystem-based) approach to handling complex systems by including environmental, socio-economic, and cultural factors. Finlayson et al. (2017) also emphasized the need for inclusion of climate change policy considerations in local management frameworks as a critical aspect of governance in the face of changing global climatic conditions. Traditional management approaches, which emphasize socio-cultural norms, are widely regarded as a means of regulating wetland resource consumption in West Africa. In most coastal cities in Ghana, fishing is restricted in certain lagoons on sacred days or seasons, and particular plants and animals are protected (Adjei-Mensah et al., 2019). However the case may be, coastal managers need to consider the environmental, social, economic and cultural values of the coastal area in adapting or developing a sustainable framework for its management, while enacting instrumental checks in monitoring frameworks to curb the rise in lack of implementation of critical coastal issues in national policy-making and the marginalization of coastal-related issues/solutions in national resource allocation (Quesada et al., 2018).This can only be achieved through stronger stakeholder involvements and partnerships between public, private and economic sectors who collectively use or have an interest in any coastal resource or whose actions affect management activities in the coastal area.

CHAPTER THREE

MATERIALS AND METHODS

This Chapter details the materials and methods used in the research. The study area is described in detail, accompanied by an illustrative map. The text is interspersed with charts, and images to explain the methods adapted for the study. The tools and software used to analyze the data are also listed.

Study Site

Butuah Wetland

The study was conducted on the Butuah wetland located in Takoradi in the Western Region of Ghana. The study area encompasses the Butuah lagoon, mangrove forest, salt marsh, mud flats and adjoining pools. The wetland lies between 1°44′51.99″ W, 4°54′45.00″ N and 1°44′53.11″ W, 4°54′10″ N. The average annual temperature of the area is 25.8 °C and the recorded rainfall level is 1366 mm per year. The Butuah lagoon is a semi-closed lagoon system which is cut off by a sand bar and a man-made sea defense constructed with boulders against coastal erosion of the New Takoradi community. An analysis of the faunal community in the Butuah lagoon by Aheto et al. (2011), reported 14 species belonging to 4 families, of which 10 were fishes and 4 were crabs. The dominant fish species of the lagoon at the time were *Odaxothrissa mento* and *Sarotherodon melanotheron.* Earlier studies also reported brackish water species such as *Periopthalmus barbarous;* and marine species such as *Callinectes amnicola, Liza dumerilii, Liza falcipinnis, Mugil bananensis,* and *Mugil curema,* among others (Aheto et al., 2010).

Vegetation in the wetland consists of forests and scattered marshes along the landscape. Mangrove trees are loosely scattered along the banks of the lagoon, although the majority of them appear scanted. Ferns and Nipa trees also adjoin the mangrove trees as they move towards the boundaries of the wetland. Sedges and cattails (*Typha sp.)* are the dominant vegetation of the intertidal marshes in the area. Also, *Cardosoma armatum* is the dominant species in the mudflats and it is exploited for economic gain by resource users.

The wetland is bordered on the east by the Monkey Hill Forest and to the west by oil tanks that belong to various oil companies across the nation; as a result, gas pipelines line the perimeter of the wetland from the harbor to the oil tanks. Located in a densely populated area, the Butuah wetland is surrounded by urban communities within the Sekondi-Takoradi Metropolitan Assembly.

The fast expansion of the Takoradi city is also gradually eating into the wetland. Residential structures and shops have encroached the wetland's perimeter, especially on its southern part, which is closest to New Takoradi, a neighboring community to the south. Sewage from some houses in the New Takoradi Community is released into the wetland through interconnected pipes. To the immediate south of the wetland, community members and resource users have constructed local ovens for smoking of fish as well as pigsties and pens for animal husbandry. Small-scale agricultural farms (mainly plantain) can also be found along the northeastern part of the lagoon.

Over the years, the wetland, in general, has undergone a series of events that has altered the physical topography of the land and its chemical composition.

This has evolved the need for revitalization of the institutional and management structures of the area. In September 2011, mass mortality of fishes (over 40,000 fishes) was recorded in the lagoon. The incident called for an analysis of samples of fishes, water and sediment collected form the area, which was carried out by the Ghana Standards Authority (GSA) upon request by the Sekondi-Takoradi Metropolitan Assembly (STMA). The chemical analysis revealed the presence of high doses of the chemical “Paraquat” in the water and sediment. Based on the declaration of the lagoon as polluted and its fishes poisoned, the assembly banned all fishing activities in the area (Ghana News Agency, 2011). Until 2020, community members in conjunction with conservation groups advocated for the revival of the lagoon and the entire wetland as an ecotourism site. However, in 2020, a proposal was made by oil firms surrounding the wetland to turn the area into an oil tank farm. The notion was vehemently protested by some stakeholders and began stronger advocacy for proper management and conservation of the area.

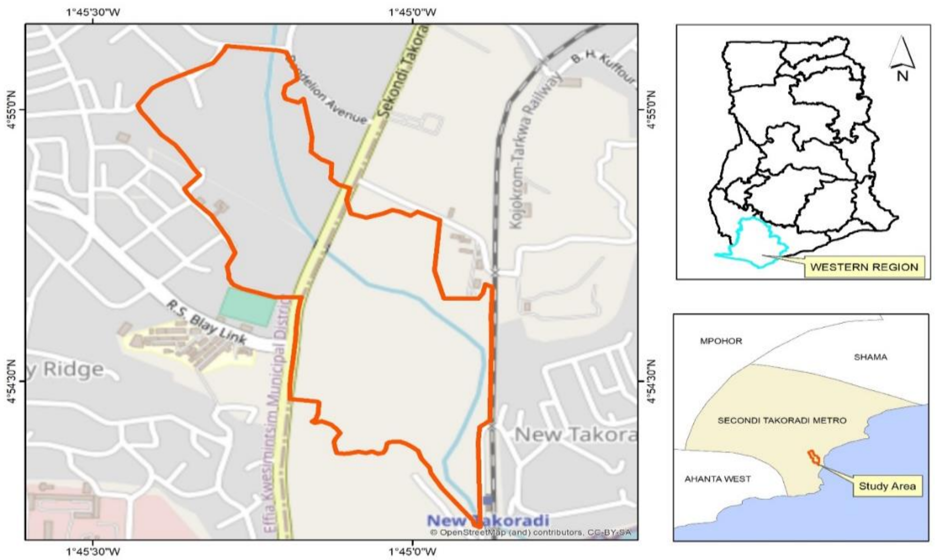


Figure 3: Map of the study area

Community entry and reconnaissance

The study began with direct observation of the resources in the area. As part of a planning phase, the current state of the forest was inspected, as well as the lagoon and the location of the remaining mangrove trees in the area. This was followed by interviews with opinion leaders in the New Takoradi community to understand the various uses of the resources in the area and how the acquisition of direct services in the watershed had changed in view of the pollution and subsequent ban on fishing activities in the area. Key informants, including the Assembly man, traditional council representatives, and the youth leader, were interviewed on the state of the resources, the changes they had observed over the years in the wetland, and the anthropogenic pressures imposed on the ecosystem by users. A questionnaire was developed from the preliminary information generated from direct observations, key informant interviews, and existing literature.

Aerial images of the Butuah wetland

Aerial images of the Butuah wetland were taken using the Phantom 3 Pro UAV. The New Takoradi community borders the wetland to the south as well as oil tanks owned and operated by private oil companies in the country.

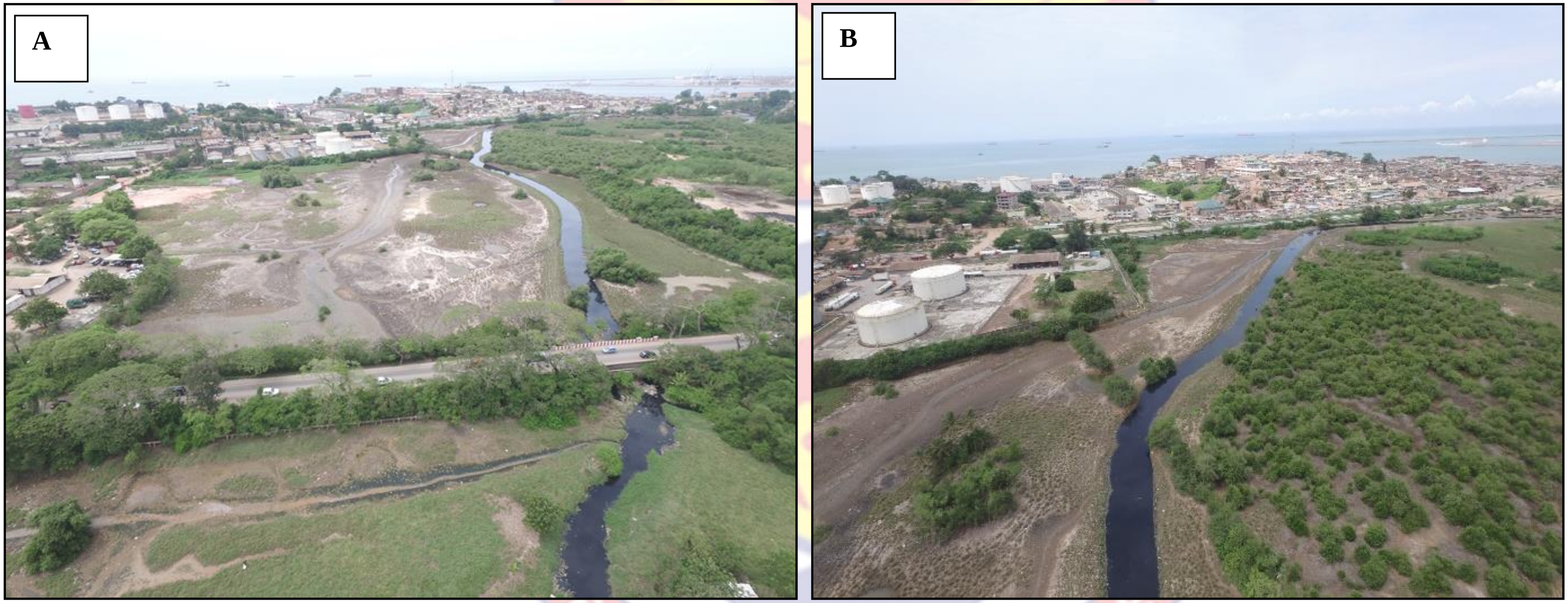


Figure 4: Aerial images of the Butuah wetland showing the (A) Northern boundary; and (B) Southern boundary of the Butuah lagoon

Questionnaire design and pre-test

The questionnaire was designed primarily to suit the objectives of the study and to probe further into the reconnaissance information obtained from resource users. Social data on respondents including age, highest educational attained and occupation were collected. Also, to solicit answers on the total economic value ascribed to the resources within the wetland, the questionnaire was designed based on The Economics of Ecosystems and Biodiversity framework and the Millennium Ecosystem Assessment categorization of Ecosystem services (Millennium Ecosystem Assessment, 2005).

As part of measures towards the development of a management plan that suits resource users and governing authorities of the wetland, respondents were also required to suggest strategic options for appropriate management of the wetland as part of the sampling phase.

To test the instrument, a one-day pre-test was conducted ahead of the actual survey. After the questions were answered, the respondents were asked to bring forth any suggestions to improve the validity of the instrument. Consequently, the questions were revised to incorporate the suggestions of the respondents and thus, vague questions as well as those with terminologies that made their comprehension difficult were rephrased.

Sampling procedure

The sampling frame consisted of individuals that directly depended on the wetland. The traditional elder in charge of development in the New Takoradi community was consulted and a list of all registered direct wetland resource users was requested. The total number of all current resource users was 47. The fewer numbers of registered resource users allowed for a more comprehensive approach to be adapted. Therefore, every registered resource user was contacted and visited. The study was explained to the respondents after which the questionnaire was administered.

Figure 5: Data collection from resource users.

Mapping the wetland types in the study

Image acquisition and pre-processing of image

Three high resolution (HR) images were purchased. The images were purchased for the years 2007, 2014, and 2021. Radiometric and geometric corrections as well as color balance and orthorectification were carried out on the images as part of image processing.

Table 1: Satellite data used for the study

Satellite	Spatial Resolution	Acquisition Date	Number of Bands	Pixel Depth
Quickbird-2	0.5m	15/2/2007	4	16-Bit
Geoeye-1	0.5m	26/3/2014	4	16-Bit
Geoeye-1	0.4m	25/01/2021	4	16-Bit

Image segmentation

Image Segmentation is the process of partitioning a digital image into different segments (of pixels) called Image Objects, which reduces the image's complexity and makes image analysis easier. To partition and group, a specific set of pixels from the images, image segmentation techniques were used. Thus, labels were assigned to pixels using ARCGIS Pro, and pixels with the same label were grouped together based on their structural similarities.

Image classification

The overall goal of image classification techniques is to group all pixels in an image into land cover groups or themes. Bands 1,2,3,4 were employed in the image categorization process. Both unsupervised and supervised classification techniques were used in this investigation. First, unsupervised classification was conducted as a precursor to understanding the spatial distribution of wetland types. After a thorough field study, aerial pictures and ground-based knowledge were used to pick training samples for the supervised classification. Again, Maximum likelihood, Random trees and Support Vector Machine (SVM) classifiers were used to classify all three images using selected training points after image segmentation, and the most accurate algorithm's output maps were used for subsequent analysis. The Ramsar classification scheme for wetland types was used to categorize the wetland subtypes.

Accuracy assessment

Land cover mapping in remote sensing demands classification accuracy in order to assess the dependability of the final map output. According to Foody (2002), the primary goal of accuracy assessment is to guarantee classification quality and user confidence. Since most regions of the wetland were swampy, a random sampling technique was used to select 156 sample locations from various wetland types in-situ and from Google Earth images. The sample sites from the various wetland classes were selected using the Juno SD GPS. The in-situ points and points chosen from Google Earth were converted to shape files for the assessment. The assessment was conducted by creation of a set of random points from the ground truth data which were taken using GPS, and comparing that to the classified data in a confusion matrix. Thus, the process required the comparison of different classification approaches and data training sites using the software generated geoprocessing tools of Accuracy Assessment Points, and Confusion Matrix Computation.

Quantification of error matrix

The error matrix is recognized as the standard descriptive reporting tool for assessing the accuracy of remotely sensed data. An error matrix is a square array of integers grouped in rows and columns that indicates the number of sample units (i.e., pixels and clusters of pixels) assigned to a specific category in comparison to the real category as indicated by reference data (Congalton, 1996). The discrepancy between the user classification and the reference data is shown in the accuracy evaluation.

In this analysis, two statistics were performed to measure classification accuracy. The Over-all Accuracy and the Kappa coefficient were calculated using the error matrix. The number of correctly classified pixels (i.e., the sum of the diagonal cells in the error matrix) divided by the total number of sampled pixels gave the Over-all Accuracy (OA) (Equation 1).

$$\text{Overall Accuracy} = \frac{\textit{Number of correctly classified pixels}}{\textit{Total number sample pixels}}$$

Equation 1

On the other hand, the Kappa coefficient is an estimate of the overall consistency between image data and reference (in-situ) data. The Kappa coefficient has a minimum of zero (0) and a maximum of one (1), with one (1) indicating total consistency. It is sometimes multiplied by 100 to produce a percentile measure of classification accuracy.

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}$$

Equation 2

Where;

N is the total number of sites in the matrix,

r is the number of rows in the matrix,

xii is the number in row i and column i,

$x{+}i$ is the total for row i, and

$xi{+}$ is the total for column i

Assessment of the changes in the wetland types

Change detection

Change detection generally entails the observation of change in terms of location and extent, as well as the quantification of the identified change. The post-classification change detection technique, which incorporates an overlay of independently classified pictures, was utilized to identify changes in wetland classes in terms of aerial area, points of change, and the course of change. Wetland change maps were created using the corresponding wetland maps for the years 2007, 2014 and 2021. The wetland maps were loaded into ArcGIS Pro's geospatial analyzer tool to show changes over time in the form of a change map and change matrix, which were then used in the study.

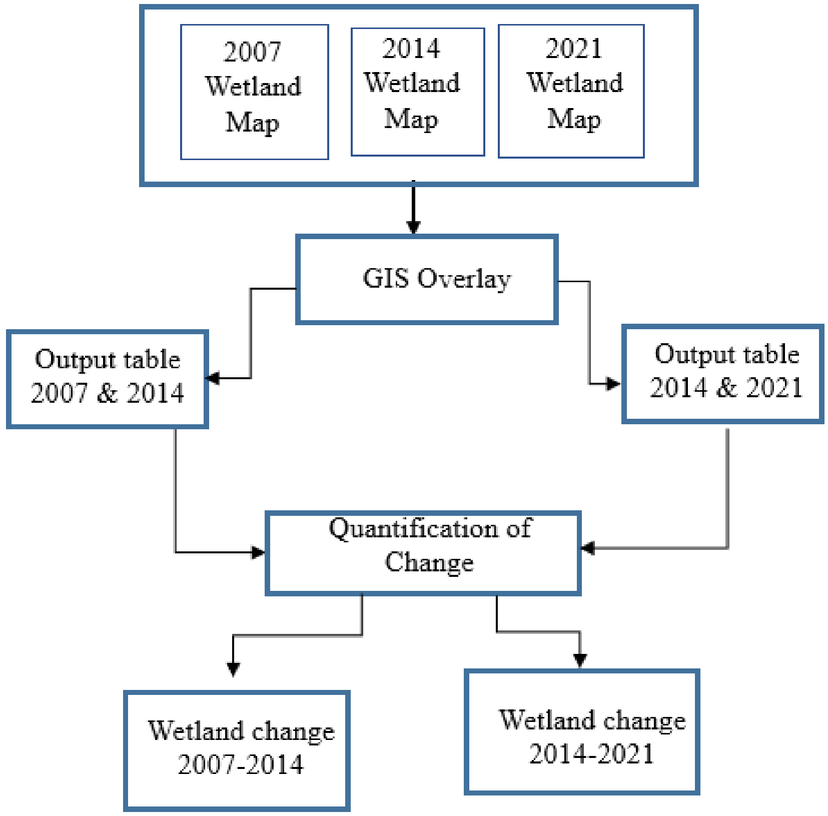


Figure 6: Illustrative diagram for change detection process.

Analysis of landscape pattern changes in the Butuah wetland

Fragmentation analysis

Wetland fragmentation is generally accompanied by changes in the landscape structure. These changes in the landscape are typically followed by a corresponding decrease in landscape variety and an increase in landscape layout by creating smaller regions. This study used landscape configuration and composition and diversity analysis to interpret the fragmentation of the

Butuah wetland landscape. The fragmentation of the various wetland types in the research area was examined using the FRAGSTATS program version 4.4. For all three years, fragment analysis was carried out to analyze the dynamics in the composition and spatial layout of wetland classes.

Selection of landscape metrics

To measure the many components of landscape pattern, a number of landscape metrics have been established. As just a few fundamental measurements can be obtained from patches (patch type, area, edge, and neighbor type), and all metrics are generated from such primary measures, these indices are very redundant and dependent on one another. Based on the literature and the ability of each metric to best depict wetland landscape fragmentation, eight indices were chosen for this investigation. These indices were calculated for each of the wetland maps and compared across time to define and quantify the fragmentation pattern in the research area. The landscape composition and configuration measures utilized in the study are shown in Table 2.

Table 2: Landscape metrics for composition and configuration used in the study

Composition	Configuration
Shannon diversity index	Number of patches
Simpson's diversity index	Patch density
Aggregation Index	Edge density
Contagion index	Largest Patch Index

The fragmentation study was carried out on two different spatial scales. To get information on wetland types, various indices were generated at the class level first. As a result, four of the eight indices were evaluated at the class level: Number of Patches (NP), Patch Density (PD), and Edge Density (ED). At the landscape level, the remaining four indices, Contagion (CONTAG) and Shannon's Diversity Index (SHDI), Aggregation Index (AI) and Simpson's Diversity Index (SIDI) were evaluated. The assessment at multiple spatial scales will expedite development- appropriate and diverse policies for various types of wetlands. Figure 5 depicts the flowchart of the process used in FRAGSTATS 4.4 to calculate the indices.

Number of Patches (NP)

A basic measure of the extent of subdivision or fragmentation of a patch type is the number of patches of that type. Although the number of patches in a class is critical to a variety of biological processes, it often has limited interpretive value because it does not transmit information regarding patch area, distribution, or density. The number of patches of the respective patch type is equal to Number of Patches (class). It is calculated as:

$$\mathrm{NP} = \mathrm{n_i} \qquad \text{Equation 3}$$

Where n_i = number of patches in the landscape of patch type (class) i

Patch Density (PD)

A patch is a portion of land that is covered by a single land cover class. On a per-area basis, the patch density (PD) expresses the number of patches within the total reference unit. The indicator reflects the degree to which the landscape has been fractured. This index is useful for evaluating landscape architecture since it allows for comparisons of units of various sizes.

It is calculated as:

$$PD = \frac{NP}{A}$$ Equation 4

Where:

PD = Patch Density

NP = Number of Patches

A = Area

Largest Patch Index (LPI)

Largest patch index (LPI) is the ratio of the area covered by the largest patch in the landscape divided by the total area of landscape. Largest patch index at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance. It is useful for measuring varied areas with different spatial extent. It can be considered as a measure of fragmentation of the wetland landscape into smaller discrete patches versus a dominant score. LPI decreases when landscape becomes more fragmented. It is calculated as:

$$LPI = \frac{\max_{j=1}(a_{ij})}{A}(100)$$ Equation 5

Where,

a_{ij} = area (m^2) of patch ij

A= Total Landscape Area (m^2)

Edge Density (ED)

Another indicator of fragmentation is edge density, which counts the overall length of patch edges. It is calculated by dividing the overall landscape area by the sum of the lengths (m) of all edge segments involving the appropriate patch type. With increasing fragmentation, the overall length of a wetland class's edge grows. Edge density, in contrast to patch density, considers the form and intricacy of the patches. The index is calculated as:

$$ED = E/A\ (10{,}000) \qquad \text{Equation 6}$$

Where;

E = total edge (m)

A = total area

Contagion Index (CONTAG)

The dispersion and interspersion of patch types within a landscape is measured by contagion. Edge density has an inverse relationship with contagion. Contagion is strong whenever edge density is low, such as when a single class occupies a substantial fraction of the terrain, and vice versa. Low patch type dispersion and patch type interspersion (i.e., an unequal distribution of pairwise adjacencies) leads to high contagion, and vice versa.

It is computed as:

$$\text{CONTAG} =$$

$$\left[1 \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}\left[p_i \circ \frac{g_{ik}}{\sum_{k=0}^{m} g_{ik}}\right] \circ \left[\ln\left[p_i \circ \frac{g_{ik}}{\sum_{k=0}^{m} g_{ik}}\right]\right]}{2\ln(m)}\right](100)$$

Equation 7

Where;

P_i =proportion of the landscape occupied by patch type (class) i.

g_{ik} =number of adjacencies (joins) between pixels of patch types (classes) i and k based on the double-count method.

m = number of patch types (classes) present in the landscape, including the landscape border if present.

Aggregation Index

Aggregation index shows the frequency with which different pairs of patch types (including like adjacencies between the same patch types) appear side-by-side on the map. Aggregation index takes into account only the like adjacencies involving the focal class, not adjacencies with other patch types. At landscape level, this index is computed simply as an area-weighted mean class aggregation index, where each class is weighted by its proportional area in the landscape. The index is scaled to account for the maximum possible number of like adjacencies given any landscape composition. Mathematically, it is represented by

$$AI = \left[\sum_{i=1}^{m}\left(\frac{g_{ii}}{\max\to g_{ii}}\right)P_i\right](100)$$

Equation 8

Where;

g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the single-count method.

Max gii = maximum number of like adjacencies (joins) between pixels of patch type (class) i (see below) based on the single-count method.

Pi = proportion of landscape comprised of patch type (class) i.

Shannon's Diversity Index (SHDI)

Shannon's diversity index (SHDI) is founded on Shannon and Weaver's information theory (1949). It's used to compare distinct landscapes or the same scene at different times as a relative index. Species richness is more responsive to Shannon's variety index than evenness. As a result, unusual kinds have a disproportionately big impact on the index's size. Mathematically, it is written as:

$$SHDI = \sum_{i=1}^{m}(P_i \circ \ln P_i)$$

Equation 9

Where;

Pi = proportion of the landscape occupied by patch type (class) i.

Simpson's Diversity Index (SIDI)

In contrast to Shannon's diversity index, Simpson's diversity index (SIDI) is not based on information theory (Simpson 1949). Specifically, the value of Simpson's index represents the probability that any type selected at random would be different. Thus, the higher the value the greater the likelihood that any 2 randomly drawn patches would be of different patch types (i.e., greater diversity). It is calculated as:

$$SIDI = 1 - \sum_{i=1}^{m} P_i^{2}$$

Equation 10

Where Pi = proportion of the landscape occupied by patch type (class) i.

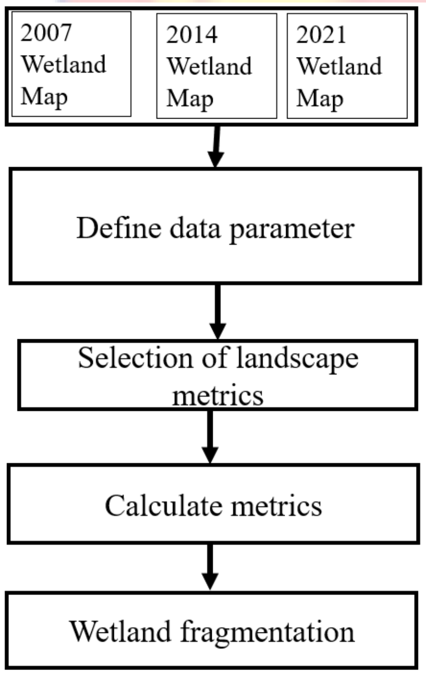


Figure 7: Summary of fragmentation analysis procedure

Estimation of the total economic value of the wetland's resources

In conformity with the mangrove ecosystem services valuation study by Aheto (2011), the services to be valued were grouped into use values and non-use values as shown in the schematic diagram in Figure 8.

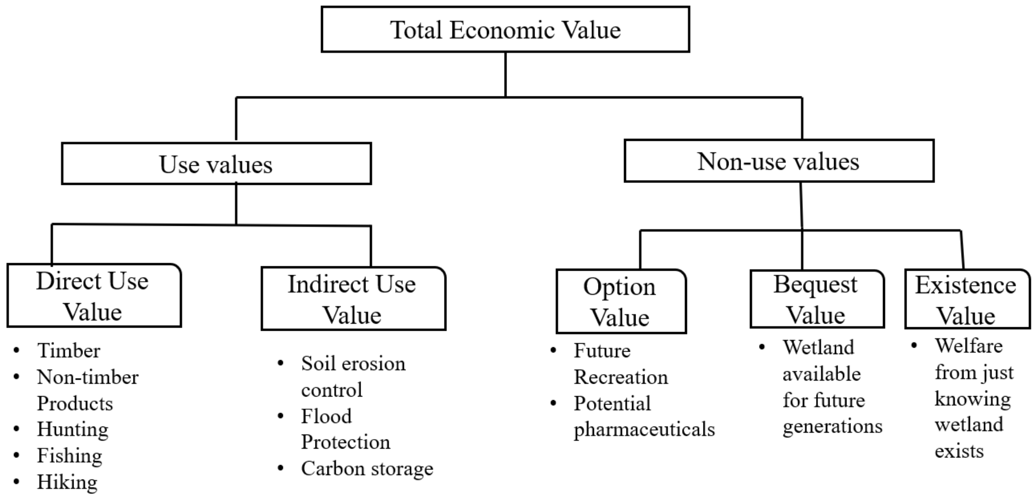


Figure 8: Showing the composition of use-values and non-use values

The use values were further divided into direct use values and indirect use values. Although not all environmental goods and services that are consumed directly (i.e., have direct use value) are traded in the market, in this case, direct use values referred to the value of goods and services derived from the services provided by the wetland that are used directly by resource users, whereas indirect use values are those goods and services that the resource users in the wetland indirectly use. Furthermore, the non-use values, often loosely referred to as "passive" values, were grouped into option, bequest, and existence values. Although resource users may not currently benefit from or use certain goods and services provided by the wetland, the option of future use still exists. Hence, the value placed on possible future uses of resources by the respondents was grouped as option values. Bequest values refer to the value imposed on the wetland and its associated resources with the knowledge that future generations will have the option of benefiting from the resources whereas existence values are the values placed on the wetland and its resources by individuals due to the mere fact that it exists. Questions for the estimation of direct use values were based on the market prices as the goods collected were available for sale in many markets across the country.

On the other hand, indirect use values were estimated by approximating the cost of providing substitutes and the cost of avoided damage as a result of the availability of the wetland. Similarly, option, bequest, and existence values were estimated through the contingent valuation approach where respondents estimated the amount, they were willing to pay for various goods and services. As with all other natural resource valuation methods, the contingent valuation method has some drawbacks, including whether it accurately gauges people's willingness to pay for ecosystem services (Diamond and Hausman, 1994). Thus, assessment of a person's willingness to pay requires awareness of the ecosystem service in question to solicit their expression of preferences in the contingent market in the same way as they would in a genuine market. To address this, a comprehensive, distinct and meaningful explanation of the services was given to respondents prior to the valuation.

Computation of Total Economic Value (TEV)

The calculation of TEV was achieved by the summation of all use values and all non-use values as shown below.

$$\text{TEV} = \text{Use Values} + \text{Non-use values} \qquad \text{Equation 11}$$

Social data analysis

To support the data collected on economic value, and to analyze any relationships between resource use trends and social characteristics; demographic data was collected.

Information on gender, age, marital status, income level, number of dependents, occupation, educational level and number of years of resource use were grouped using frequency distribution charts in the Statistical Package for Social Scientists (SPSS). Standard deviation, mean and percentages were used to analyze the data. To ascertain the role of gender in the exploitation of the wetland's resources, the percentage of males and females for each criterion was also calculated.

Assessment of the economic benefits of the wetland's local use

Data on harvested quantity, price and cost of operation were collected for resources with Direct Use Values and was analyzed using the DUV equation:

$$\mathrm{DUV} = \sum_{i=0}^{n} (P_i, Pa * Q_{i} - \mathrm{Ci}) \qquad \text{Equation 12}$$

Where:

DUV = Direct Use Value

P_i = Price of marketable products

P_a = Estimated Price of non-marketable products

Qi = Quantity collected

Ci = Total collection cost

i refers to the item under description (various species in this analysis)

n = Total number of respondents

Further economic analysis was performed using the Total Economic Value formula, Net Present Value (NPV) and the Benefit Cost Ratio (BCR).

Note: A real interest rate of 14 % (Bank of Ghana average, 2021) was used in the calculation in this study.

Benefit-Cost Ratio (BCR)

BCR is the discounted value of a project's benefits divided by the discounted value of the project's costs**.** The cost benefit analysis adds up the potential benefits of a situation or action, then subtracts the overall costs of pursuing that action (Aurland-Bredesen, 2020). The ratio enables project managers to keep expenses under control while maximizing return on investment and other project advantages. This is because a project with greater BCR usually indicates profitability.

$$BCR = \frac{|PV\ [Benefits]|}{|PV[Cost]|} = \frac{\sum_{t=0}^{N} \frac{|CF_t[Benefits]|}{(1+i\ )^t}}{\sum_{t=0}^{N} \frac{|CF_t[Costs]|}{(1+i\ )^t}}$$

Equation 13

where:

BCR = Benefit Cost Ratio

PV = Present Value

CF = Cash Flow of a period (classified as benefit and costs, respectively)

i = Discount Rate or Interest Rate

N = Total Number of Periods

t = Period in which the Cash Flows occur

A project with higher BCR will take priority over the other with lower ratios although there may be other economic risks that may need to be addressed when the project commences. Therefore, a project is approved if BCR is greater than 1**.**

Net Present Value (NPV)

Net present value is a capital accounting measure used to assess a project's or investment's viability. Hence, the difference between the present value of benefits and present value of costs over a period of time is used in the calculated.Net present value is the balance of the present value of returns and outflows by discounting the flows at a predetermined rate, as the name implies.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

Equation 14

Where;

Co= total initial investment costs

Ct= net cash inflow during the period t

T= total number of periods

t= time of cash flow

r= interest rate

The NPV method accepts all independent projects whose NPV is greater than 0 and ranks all mutually exclusive projects by their NPVs, selecting the project with the higher NPV.

Assessment of the anthropogenic threats the Butuah wetland

Habitat Risk Assessment (HRA)

The Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) software presents a collection of models that allows Governments, NGOs, Institutions and individuals involved in Ecosystem services and management of Ecosystems to map and value ecosystem goods and services.

Evidently, the wetland has experienced a lot of drastic changes over the years and the InVEST Habitat Risk Assessment model was used to evaluate the extent of human-posed risks on the wetland and the resulting consequences on the ability of the wetland to persist in delivery of ecosystem services. A CSV file providing information and scores on the Habitat & Stressors in the wetland together with a CSV file scoring the various criteria under each habitat &stressor was developed for the assessment. The stressors and their impacts on the ecosystem were rated from 1 to 3 based on the increasing intensity of their potential harm on the environment.

Stakeholder analysis for development in the wetland

Stakeholder analysis was conducted as part of the initiative to develop a framework for the management of the Butuah wetland.

Stakeholder description

In coastal zone Management, Stakeholders are individuals who may, in one way or the other be affected by the management of a specific ecosystem, or individuals who are involved/will be involved in the management or implementation activities in the area. Persons who have the mandate to oppose or support impending research or development of a project in the area were also regarded as stakeholders.

Identification of key Stakeholders

To determine the key stakeholders in the study area, a list of all possible stakeholders was enumerated. The list was subdivided into persons directly affected by the watershed and management decisions on its resources and persons indirectly affected by the decisions and had no connection with the management of the area. The participants in the stakeholder analysis were persons who had an interest in the use and management of the watershed.

For that matter, the identification yardstick for stakeholders targeted involved individuals and groups that;

1. were part of the public authorities, research institutions and civil societies/businesses that were interested in the management or use of the Butuah watershed as part of their activities.
2. Played a role in the framework of the watershed, either as consumers (harvesters and land users), policy makers, and research and technical experts.
3. were beneficiaries of management interventions
4. Could possibly be negatively affected by management and use
5. Had influential power to sway management decisions and resource users, or provide funds for development.

A stakeholder list with important characteristics such as geographical scope of interest, related sector of activity, institutional affiliation, contact persons and role was established. Where necessary, emails were sent to stakeholders to explain the research to them while requesting for their cooperation to state their interest. Alternatively, phone calls were made to some identified stakeholders.

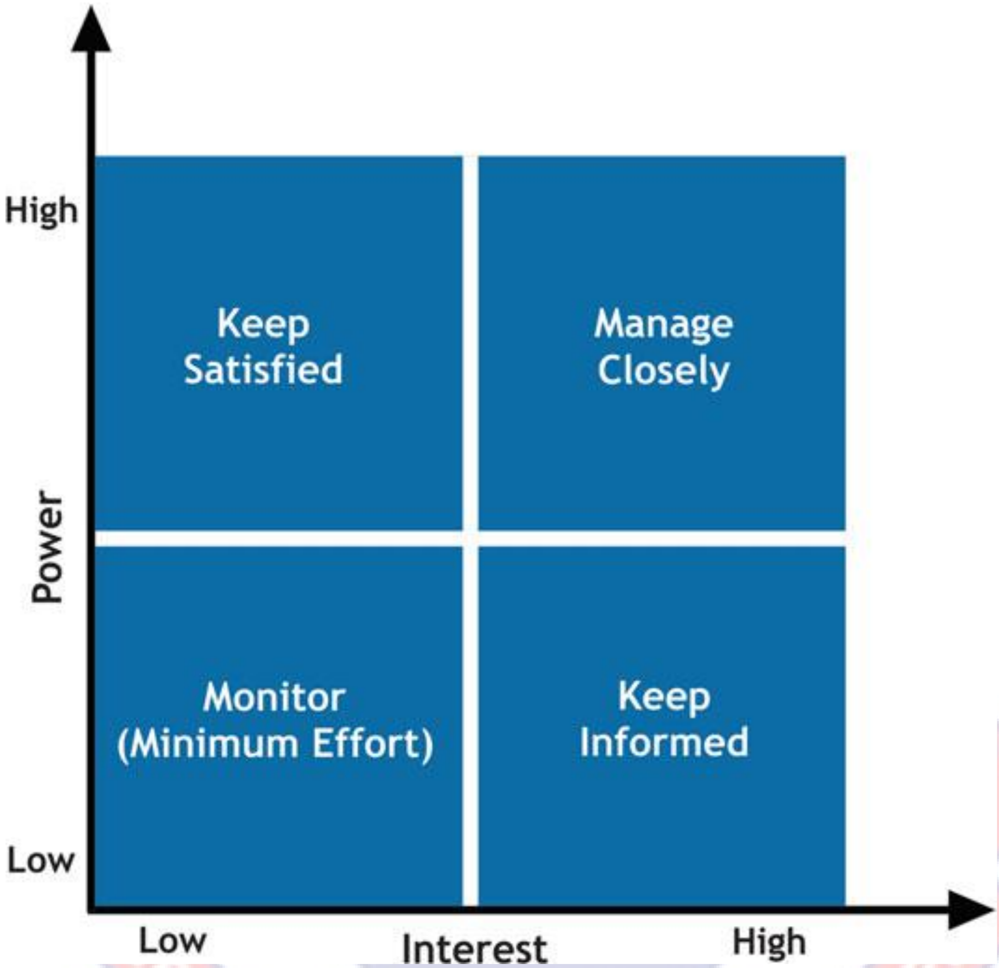


Figure 9: Stakeholder analysis map showing the various sections of categorized resource users.

Next, Stakeholders were prioritized based on assessment of their level of influence in the watershed and level of interest in its management as shown in Figure 9. The need to uncover the particular stakeholders to invite at each developmental process and to understand the existing networks among stakeholders necessitated the prioritization. The quadruple helix model was adapted to group stakeholders into four groups following a categorization of individuals and groups as science, policy, industry, or civil society for inclusion in effective management options for the wetland.

Stakeholder validation

Identified stakeholders were contacted through email and invited for a focus group discussion on the preliminary findings of the research and its implications for management of resources in the area. The participants at the meeting included the head of Physical Planning at Sekondi-Takoradi Metropolitan Assembly, the Director of the western region division of the Environmental Protection Agency, the Director of Ghana Tourism Authority(western Region), the head of the Hydrological Services Department in the Western Region, the Director of the Wildlife Division of the Forestry Commission, the Assemblyman of New Takoradi, the Director of the Western Regional Fire Service Department and staff of Friends of the Nation, Ghana as shown in Figure 10.

Prior to that, a stakeholder meeting had been organized by the stakeholders where a zoning plan was proposed for the management of the wetland. There, the design was set to benefit the stakeholders and their respective interests. The preliminary plan was analyzed as part of this study; in consideration of the land use assessments, social surveys, habitat fragmentation and risk assessment that were conducted as part of the research. The findings from the study as well as the possible implications of the zoning plan was communicated to the stakeholders for validation in another stakeholder meeting, after which recommendations were made to permit ecological considerations in any projects undertaken in the area.

Figure 10: Meeting with stakeholders on management of the Butuah wetland.

Methodology Summary

The study used an integrated assessment approach following the natural capital and ecosystem management concept. Hence, the research was divided into three main aspects: Environmental (From a geographic standpoint), social and economic. The Geographic aspect involved the acquisition of satellite images, processed using classification algorithms and the creation of land use maps as well as landscape pattern analysis. The social aspect was conducted through a survey of resource users followed by analysis of the social data. The economic aspect also involved the use of valuation methods to estimate the total economic value of the resource. A chart of the steps is shown in Figure 11.

The goal of this integrated assessment was to provide a holistic understanding of the ecosystem to resource managers as well as a comprehensive perspective for the establishment and enactment of policy.

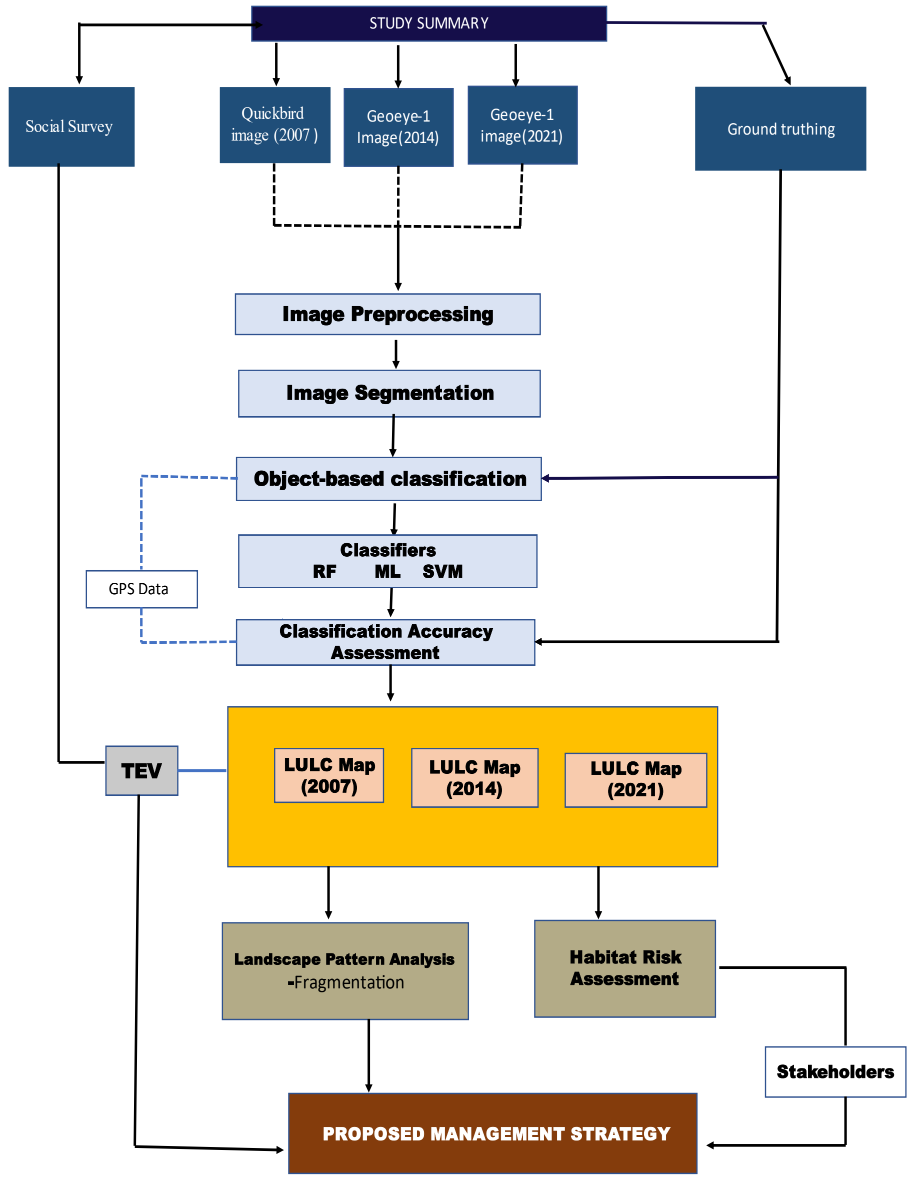


Figure 11: Summary of methodology

Chapter Summary

In this chapter, the materials and methods used to conduct the research, as well as the study location, are detailed in depth. In addition, the statistical analytical tools and software used to analyze have been listed.

CHAPTER FOUR

RESULTS

Results obtained from conducting assessments on land cover changes and the resulting impacts on ecosystem services and values in the study area are presented in this chapter. The chapter commences with a description of each of the ecosystems in the Butuah wetland. It also presents the changes in percentage coverage of the habitats across the time periods under study and the total economic value of the ecosystem services. Furthermore, results on fragmentation analysis, anthropogenic pressures exerted on the ecosystem and the results of the Habitat Risk Assessment of each of the habitats studied are presented.

Wetland types in the Butuah wetland

The wetland types in the Butuah wetland were grouped according to the Ramsar classification scheme. They include the Intertidal forested wetland (Figure 12 A), intertidal marshes (Figure 12 B), a coastal lagoon, and intertidal mudflats.

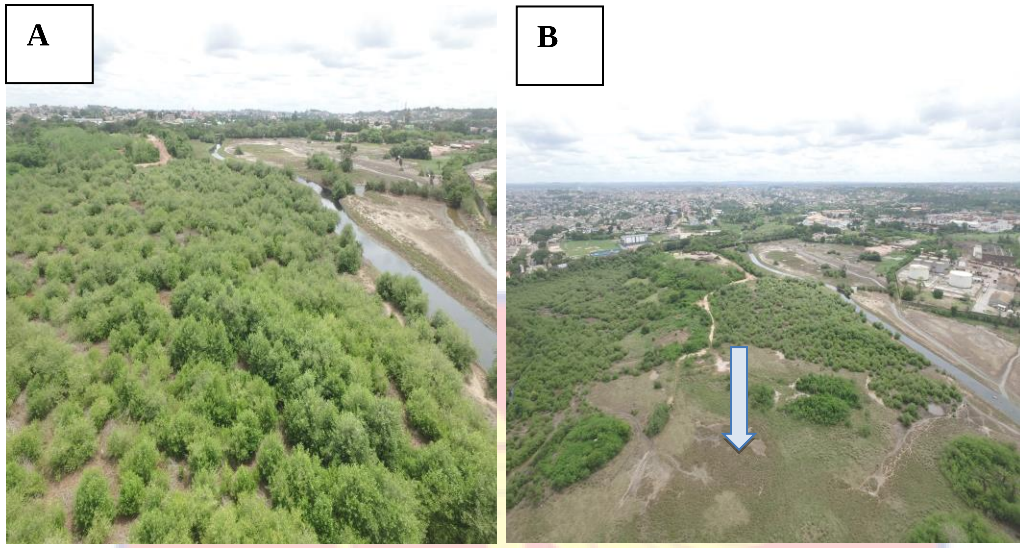


Figure 12: Wetland types (A) mangroves (Part of intertidal forest) along the bank of the Butuah Lagoon and (B) intertidal marshes.

Figure 13: The study area showing (C) Lagoon and (D) Mudflats along the bank of the lagoon

Categorization of wetland types in the study area

Table 3: Description of Butuah wetland categories based on Ramsar classification system for wetland types

Wetland class	Description
Inter-tidal forested wetlands	Constitutes Mangrove swamps, nipa swamps and tidal freshwater swamp forests.
Intertidal marshes	Comprises salt marshes and tidal brackish and freshwater marshes with emergent vegetation waterlogged for at least most of the growing season.
Intertidal mud flats	Intertidal land without vegetation that is frequently covered by water.
Lagoon	Brackish lagoon with at least one relatively narrow connection to the sea.

Source: Ramsar Convention Secretariat (2013)

Habitat Maps of Butuah wetland for 2007, 2014 and 2021

The satellite images for year 2007,2014, and 2021 were classified using the Ramsar classification scheme shown in Table 3. The classified maps for year 2007, 2014 and 2021 are shown in Figures 14,15, and 16.

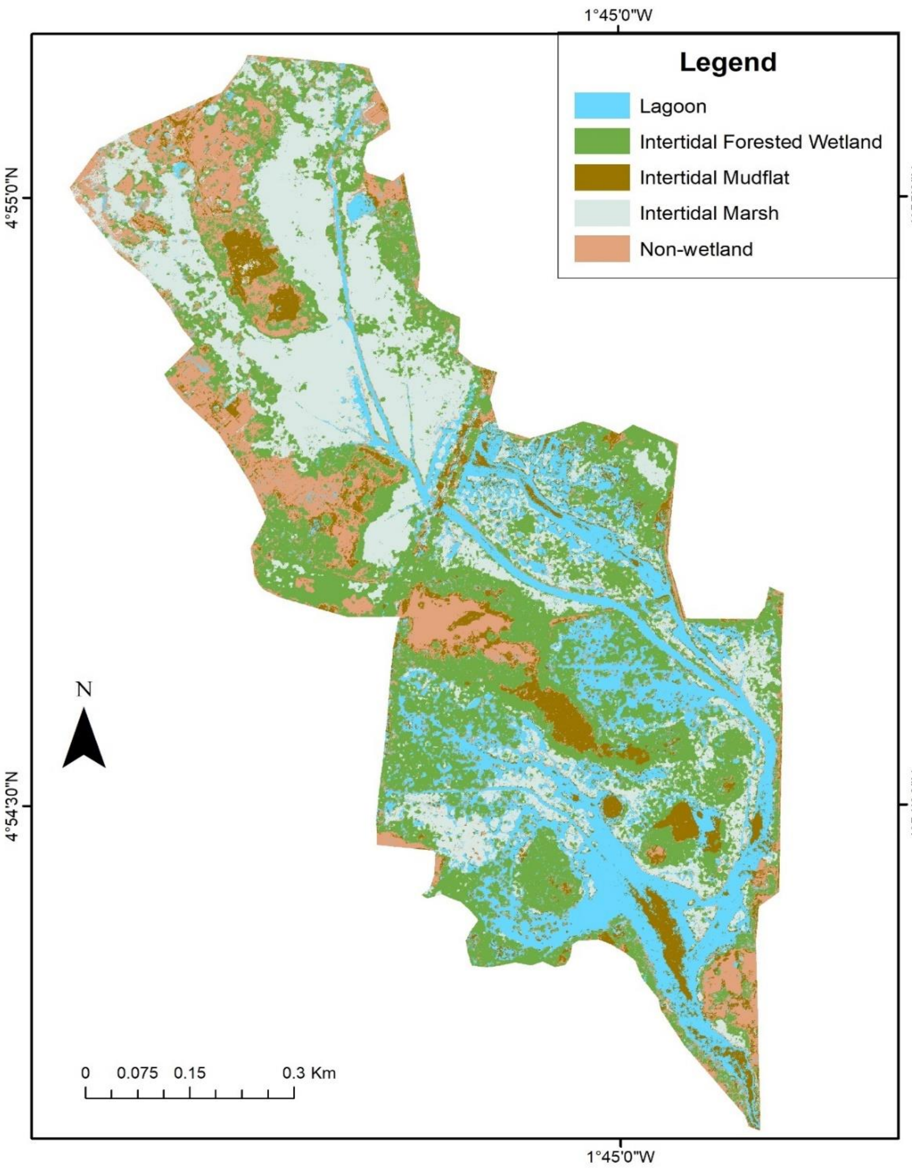


Figure 14: Land cover map of Butuah Wetland in 2007

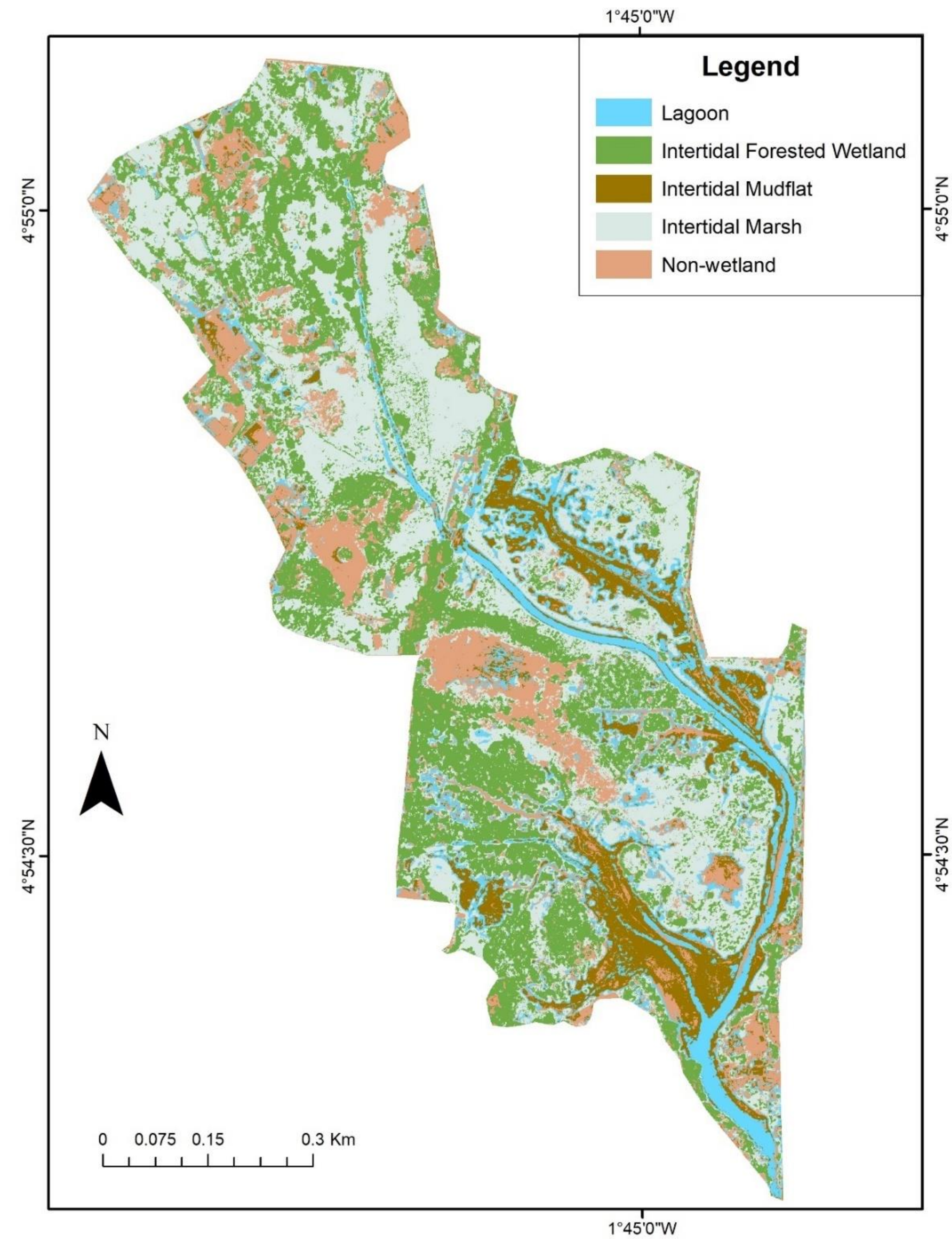


Figure 15: Land cover map of Butuah Wetland in 2014

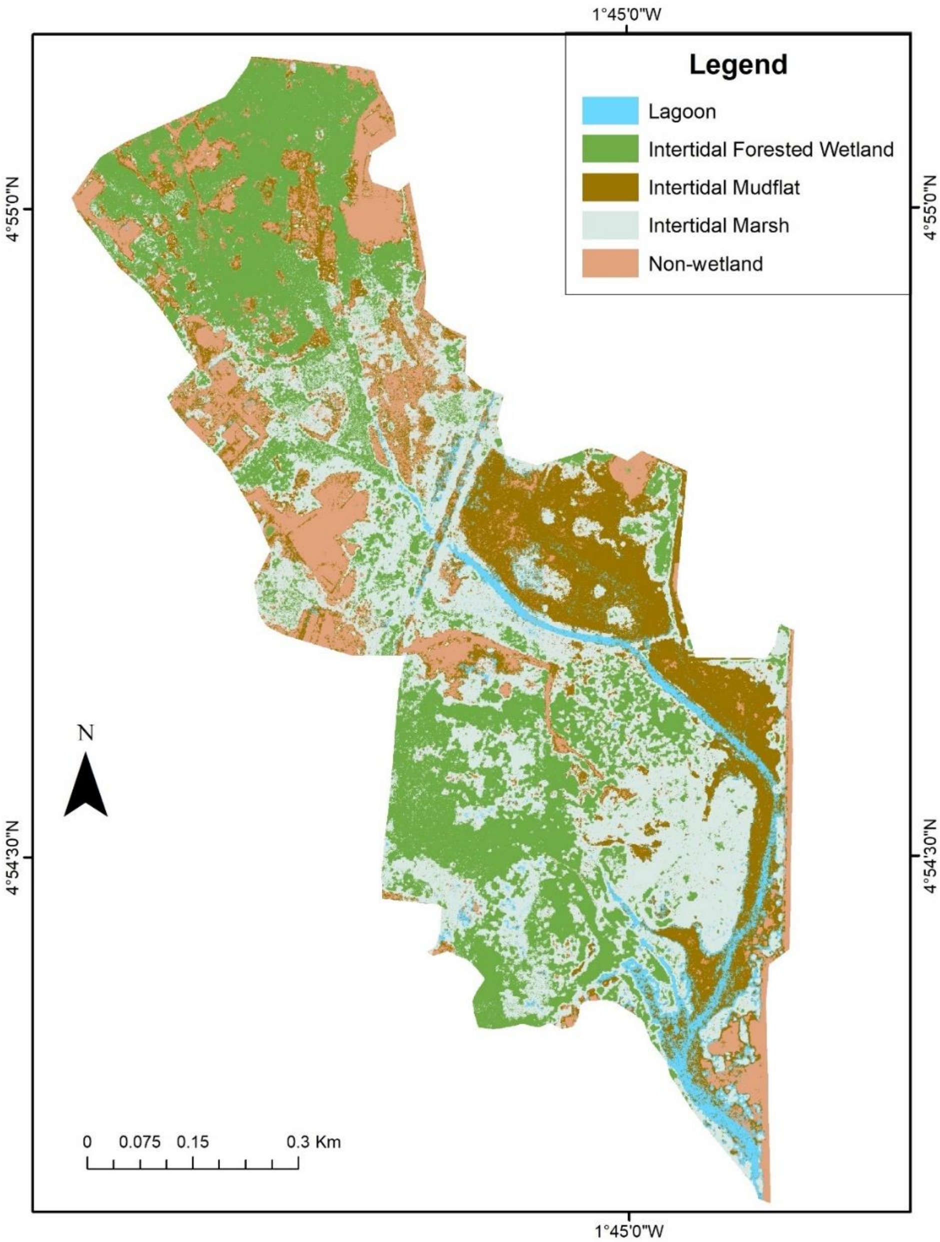


Figure 16: Land cover map of Butuah Wetland in 2021

Changes in wetland types in the Butuah wetland

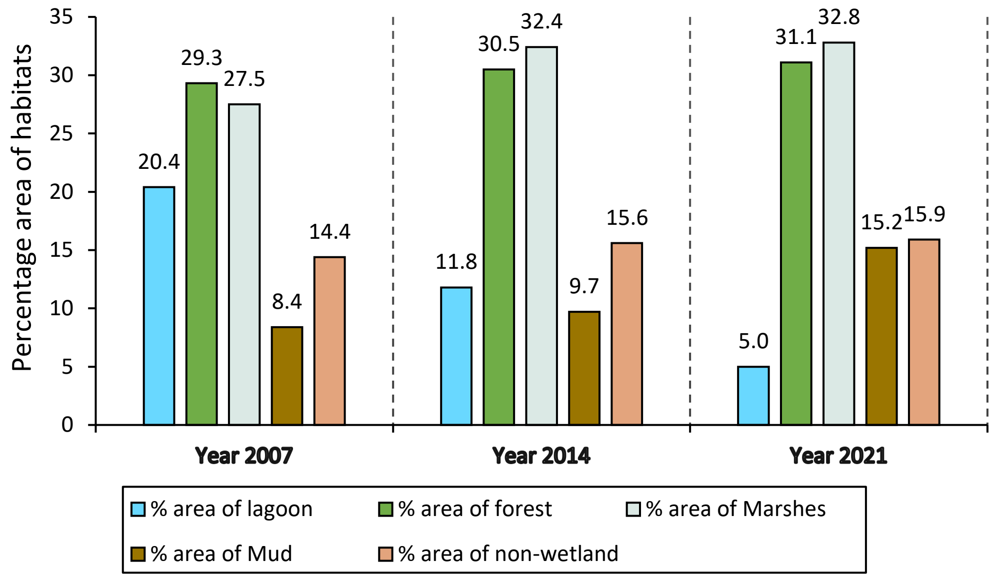


Figure 17: Wetland habitat Percentage change from 2007 to 2021

NB*: Non-wetland areas refer collectively to bare lands and built-up areas in the wetland*

Over the 14-year period there had been changes in the surface area of the various habitats. To visualize the land-use impacts on the wetland, the percentages of surface area for the sub-ecosystems were compared for 2007;2014 and 2021.The surface areas of the lagoon continually decreased from 2007 to 2021. However, surface areas of Intertidal Forested Wetlands, Intertidal Marshes, and mudflats and non-wetland areas increased across the three time periods of satellite data collection as shown in Fig 17.

The changes in area of habitats between the years 2007 and 2014 as well as 2014 and 2021 are presented below. (Fig 18). There was a 57.8 % reduction in lagoon area from 2007 to 2014; and a 42.4 % reduction from 2014 to 2021.The area of non-wetland had increased by 7.7 % in 2007 to 2014.

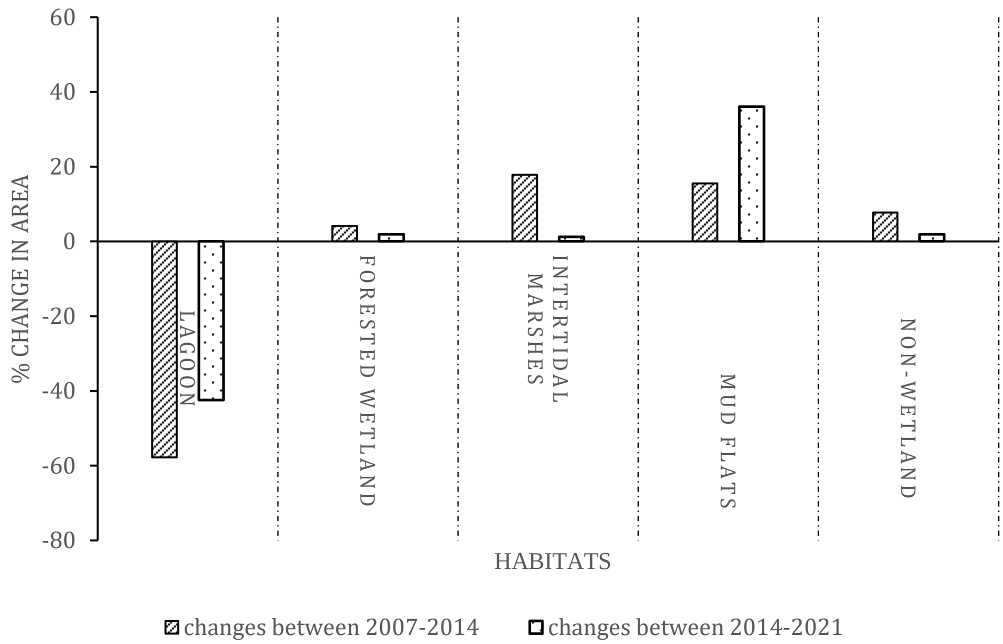


Figure 18: Changes in Wetland area between 2007 and 2021

Table 4: Land cover conversion from 2007 to 2014

Conversion(from-to)	Percentage
Lagoon-Lagoon	27.2
Non-wetland- Non-wetland	5.0
Forested Wetland-Non-wetland	3.8
Intertidal Marshes-Non-wetland	2.0
Non-wetland-Intertidal Marshes	3.8
Forested Wetland-Intertidal Marshes	11.3
Intertidal Marshes-Intertidal Marshes	13.9
Intertidal Marshes-Forested Wetland	5.8
Non-wetland-Forested Wetland	3.8
Forested Wetland-Forested Wetland	13.3
Forested Wetland-Mudflats	0.8
Non-wetland-Mudflats	0.7
Intertidal Marshes-Mudflats	1.7
Mudflats-Non-wetland	2.1
Mudflats-Intertidal Marshes	2.1
Mudflats-Forested Wetland	1.5
Mudflats-Mudflats	1.2

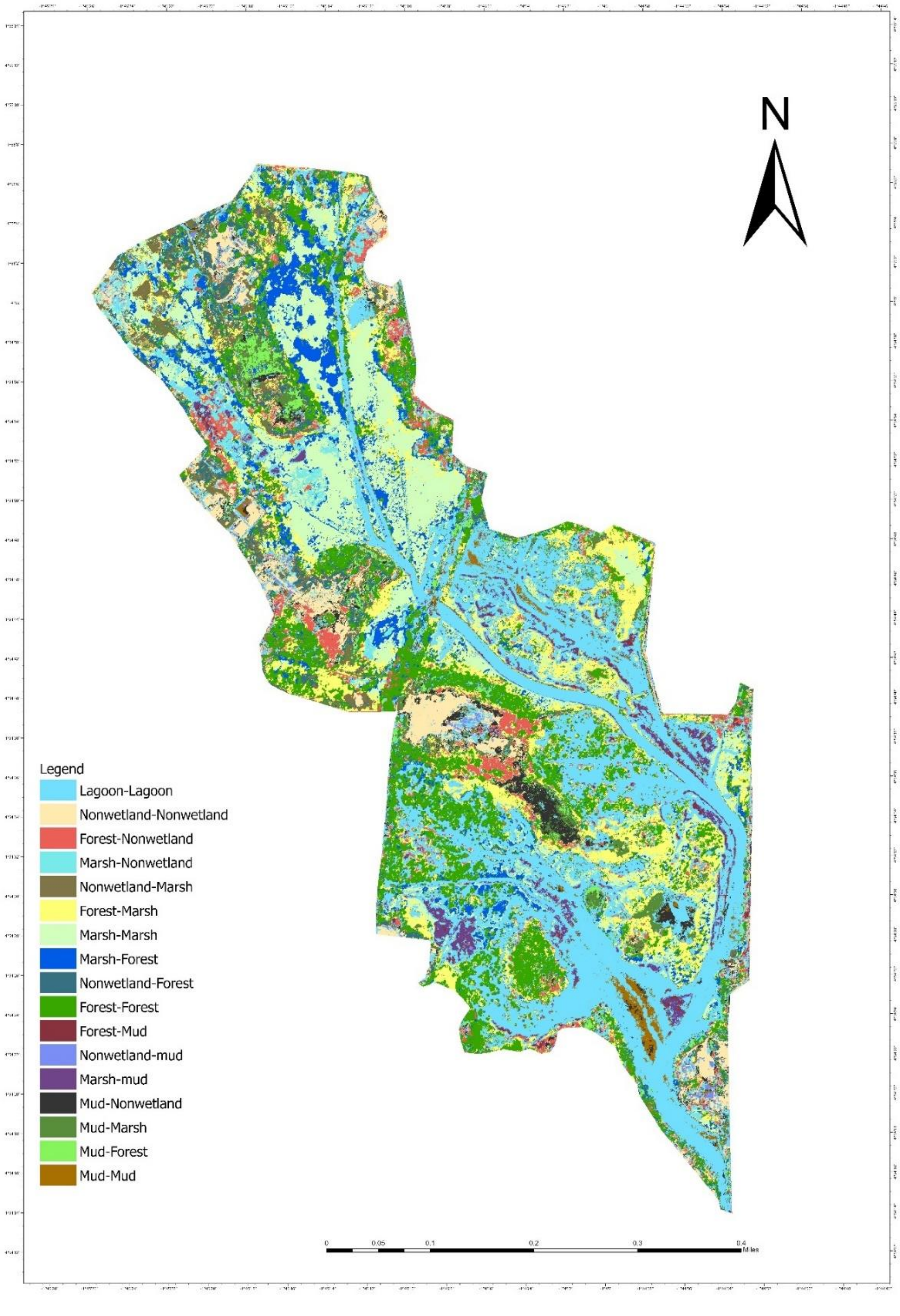


Figure 19: The conversion of land cover from 2007 to 2014

Table 5: Land cover conversion from 2014 to 2021

Conversion(from-to)	Percentage
Lagoon-Lagoon	14.7
Non-wetland-Non-wetland	4.9
Non-wetland-Mudflats	2.5
Non-wetland-Intertidal Marshes	4.0
Non-wetland-Forested Wetland	3.7
Intertidal Marshes-Non-wetland	4.7
Intertidal Marshes-Forested Wetland	10.0
Intertidal Marshes-Mudflats	5.8
Forested Wetland-Forested Wetland	13.1
Forested Wetland-Non-wetland	3.1
Mudflats-Forested Wetland	1.6
Mudflats-Non-wetland	0.8
Forested Wetland-Mudflats	2.5
Intertidal Marshes-Intertidal Marshes	13.2
Forested Wetland-Intertidal Marshes	9.0
Mudflats-Mudflats	4.1
Mudflats-Intertidal Marshes	2.2

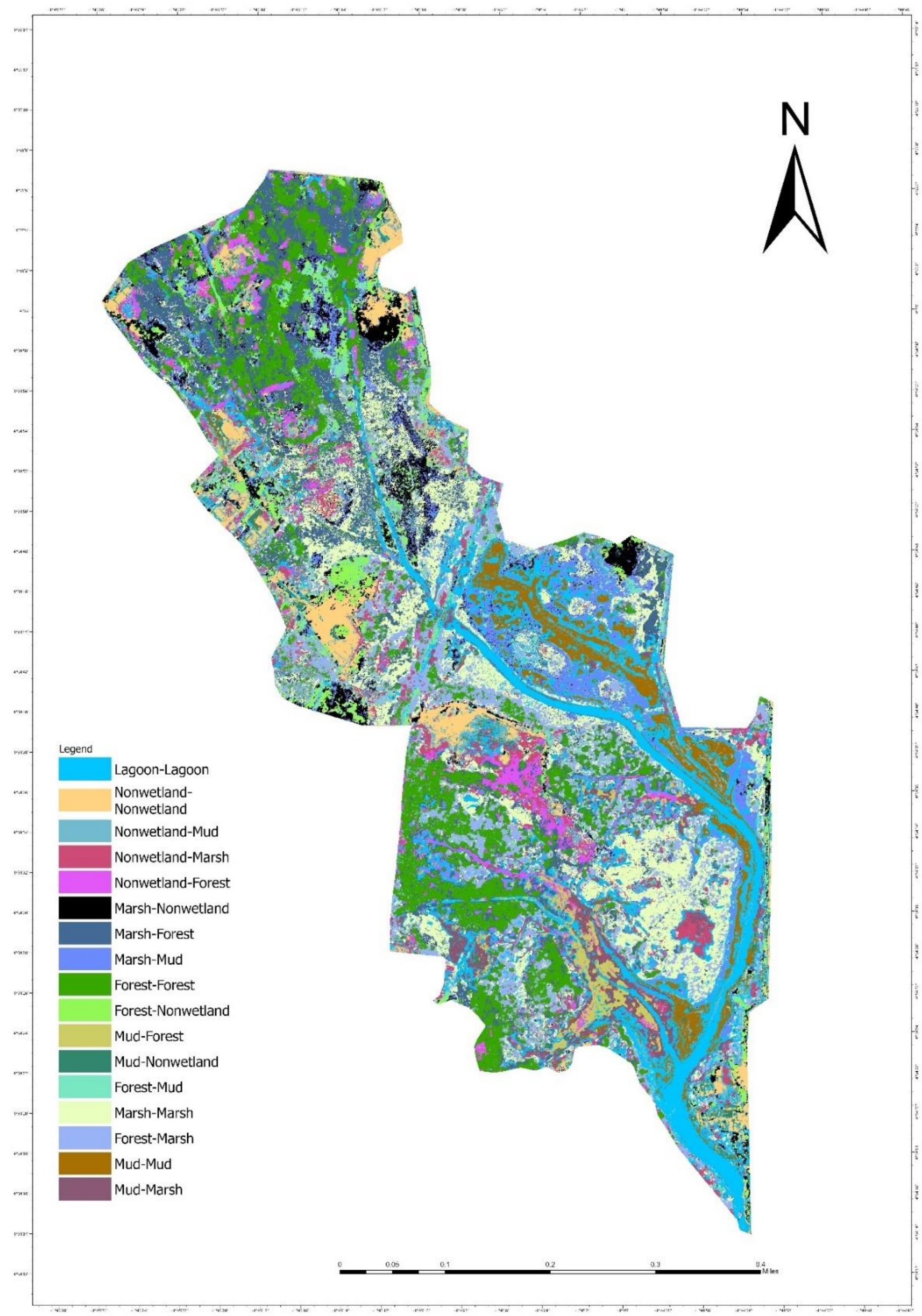


Figure 20: Land cover changes from 2014 to 2021

Landscape Pattern changes in the wetland

The changes in landscape are shown in the figures 21, 22, 23, 24, 25, 26, 27, 28 below. The largest Patch index, number of patches, edge density and patch densities for 2007, 2014 and 2021 are displayed together with changes in landscape diversity over the study period.

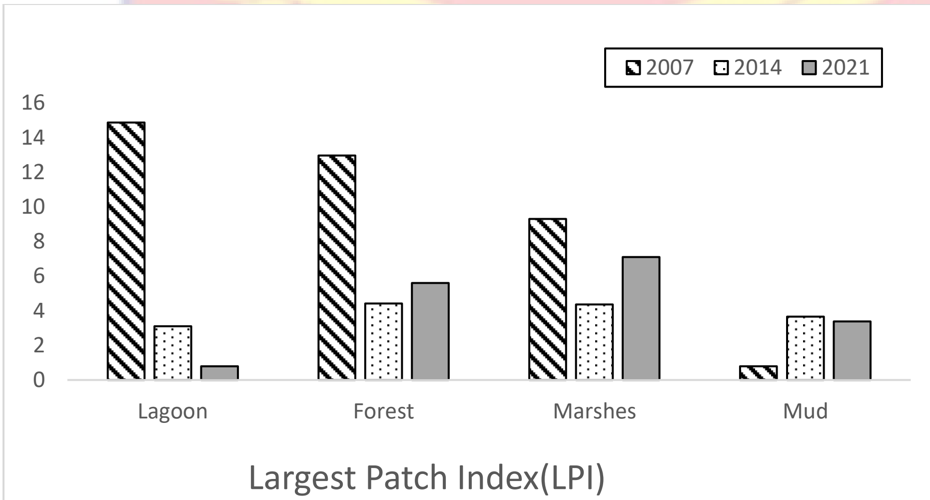


Figure 21: Largest Patch indices of habitats in the Butuah Wetland

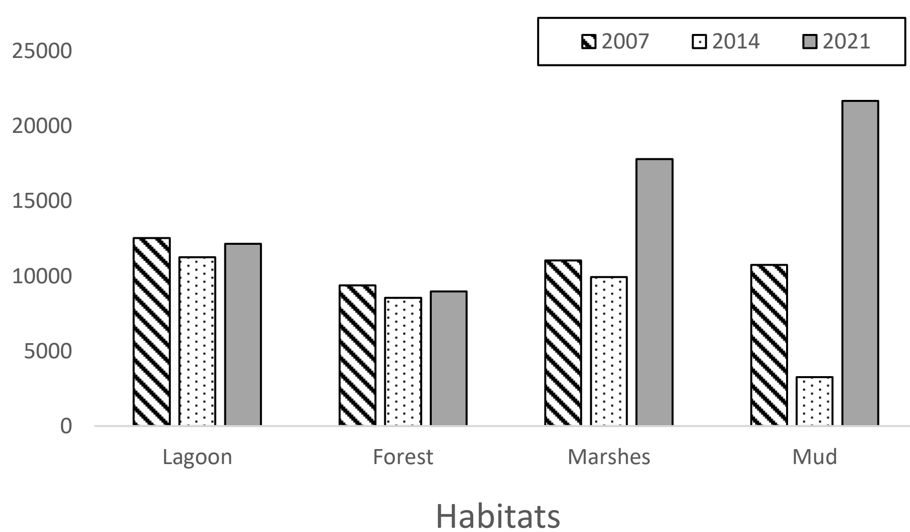


Figure 22: Number of patches in habitats in the Butuah Wetland

Figure 23: Edge density of habitats in the Butuah Wetland

Figure 24: Density of Patches in habitats in the Butuah Wetland

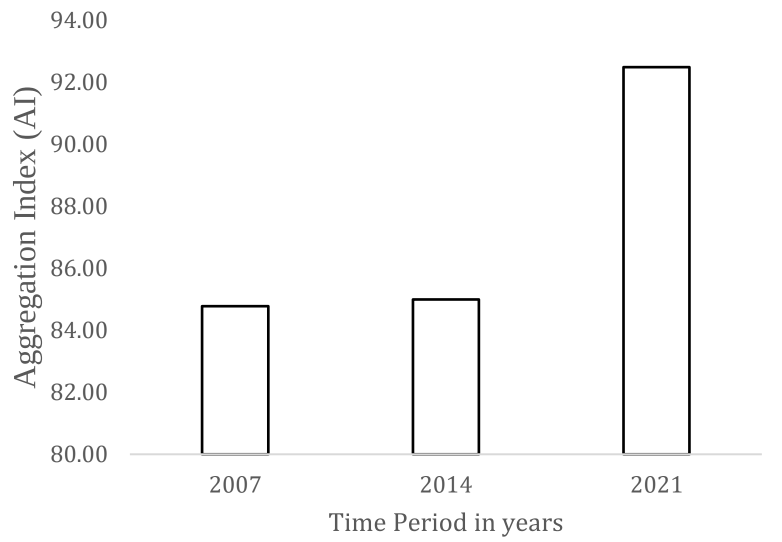


Figure 25: Aggregation Index of landscape in the Butuah Wetland

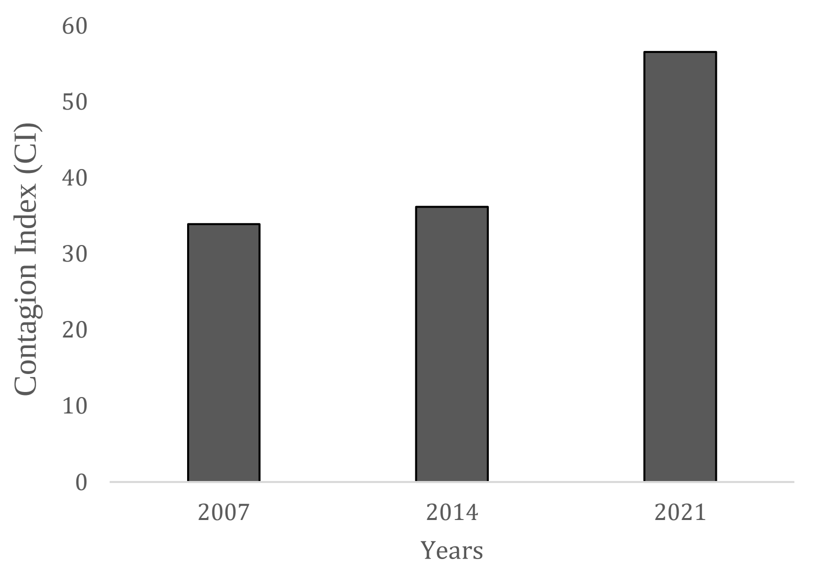


Figure 26: Contagion Index of landscape in the Butuah Wetland

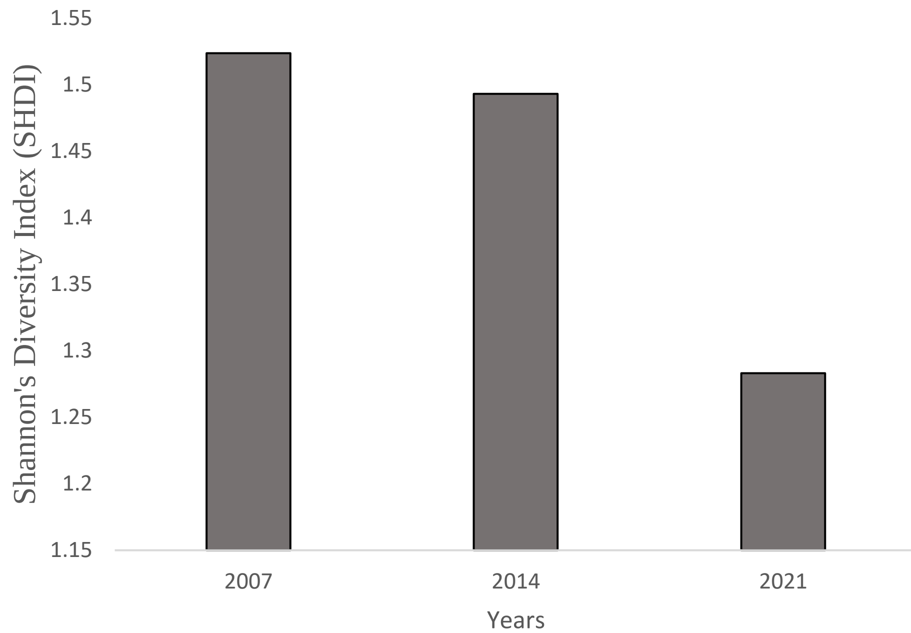


Figure 27: Shannon's Diversity Index in the Butuah Wetland from 2007 to 2021

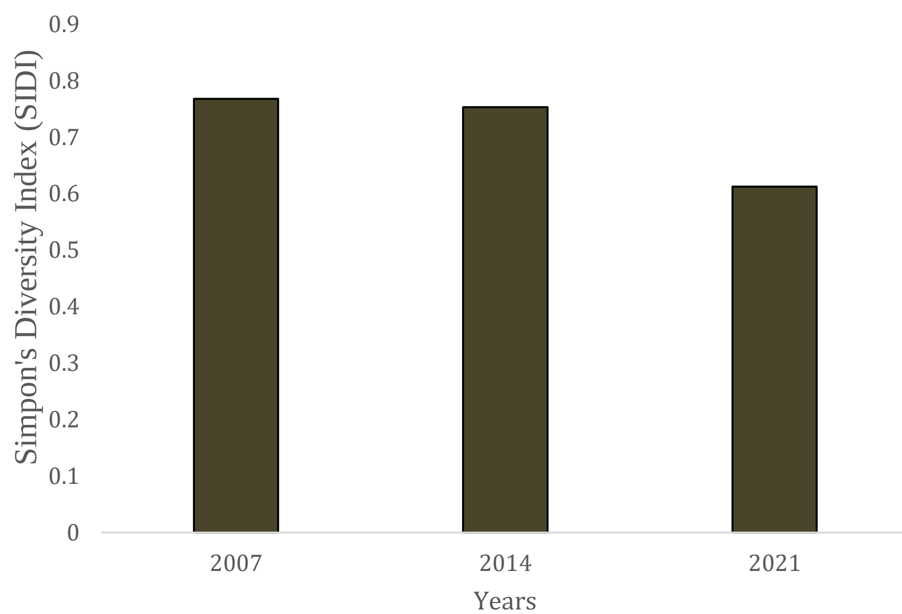


Figure 28: Simpson's Diversity Index in the Butuah Wetland from 2007 to 2021

Economic value of the wetland's resources

Socio-economic characteristics of respondents

The number of female resource users (28) exceeded the number of male users (19) in the study area. A greater number of resource users were between the ages of 40 and 50 years old. On education, the Junior High School level was the highest attained educational limit for most of the respondents; although none of the respondents had a university degree. About 17% of the female respondents had no formal education as opposed to the recorded 6 % of males in the same category. Also, about 62% of the respondents had at least one (1) person depending on them as shown in Table 6.

Table 6: Demographic Information of resource users

Variables	Frequency		Percentage	
	Males	**Females**	**%Males**	**%Females**
Age(years)				
Up to 19	7	1	14.89	2.13
20-30	2	7	4.26	14.89
31-40	4	7	8.51	14.89
41-50	6	7	12.77	14.89
51-60	0	5	0	10.64
Above 60	0	1	0	2.13
Total	*19*	*28*	*40.43*	*59.57*
Education				
No formal education	3	8	6.38	17.02
Primary	4	11	8.51	23.4
JHS	9	7	19.15	14.89
High School	3	2	6.38	4.26
Total	*19*	*28*	*40.43*	*59.57*
Dependents				
None	9	9	19.15	19.15
1	1	0	2.13	0
2	3	8	6.38	17.02
3	2	4	4.26	8.51
4	2	3	4.26	6.38
5	1	3	2.13	6.38
Above 5	1	1	2.13	2.13
Total	*19*	*28*	*40.43*	*59.57*

Figure 29 shows a chart of the economic activities in the Butuah wetland. The activity that most of the respondents engaged in is firewood collection followed by the collection of medicinal plants

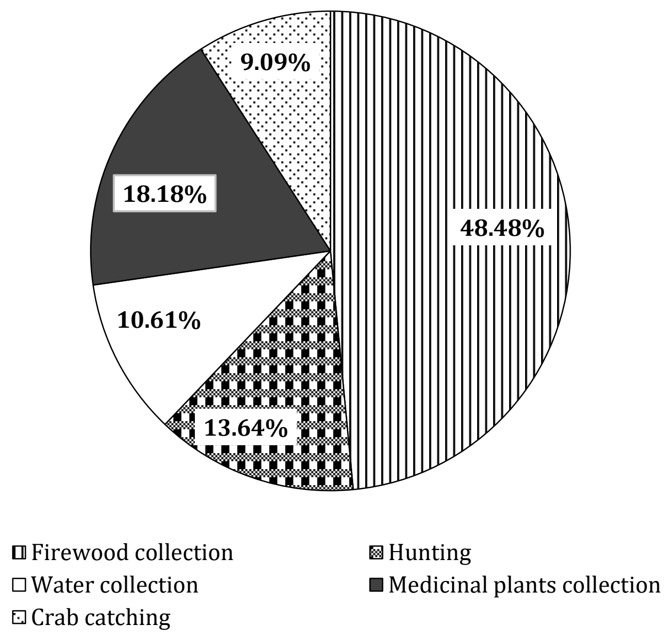


Figure 29: Economic activities in the Butuah wetland

Considering resource use distribution from the perspective of the ecosystem, the gender of resource users for all habitats were determined. The results as presented in Figure 30 show that no female derived marketable products from the mudflats; the higher number of DUV dependents on the marshes are female. Also, the dependence on forest and lagoon resources are higher for men than for women in the Butuah wetland.

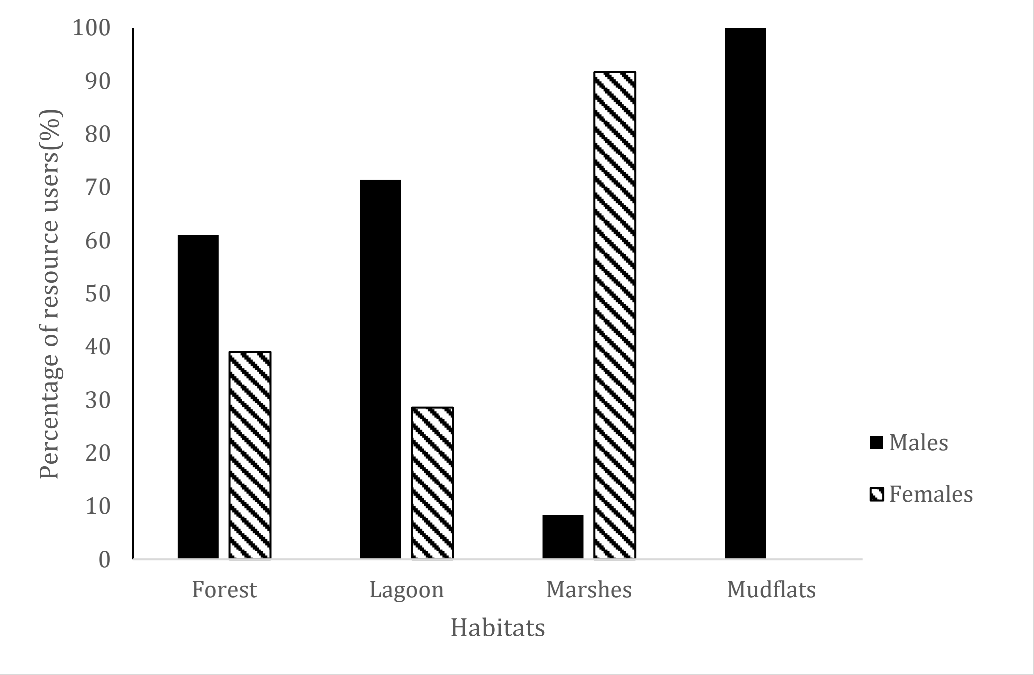


Figure 30: Percentage distribution of resource users in each habitat

The major occupations of resource users were grouped. As shown in Figure 31, the dominant occupational groups of the resource users are local Fish processors (32 percent); all of whom are women.

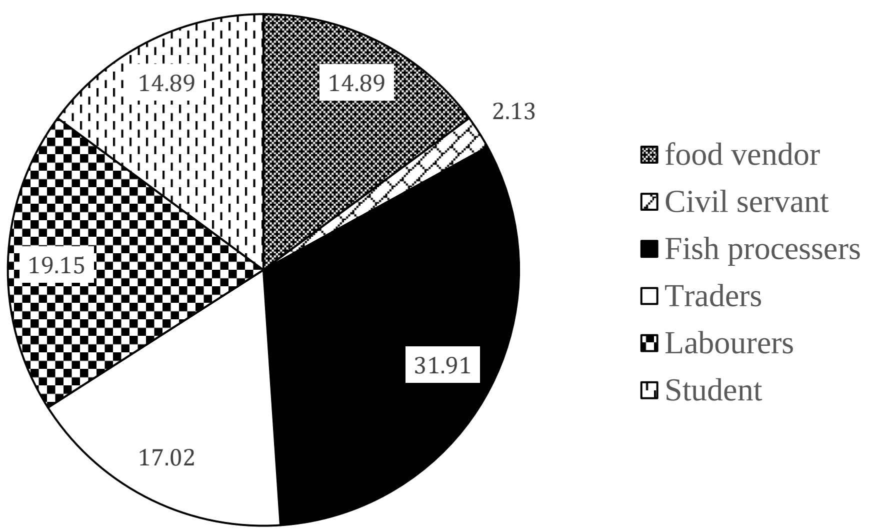


Figure 31: Major occupations of respondents

The average numbers of trips that males and females make to collect firewood from the wetland per year are the same, although male resource users invest more, and have higher returns. There are no female hunters or crab collectors and males who invest in harvesting those resources make about two times and 8 times the average investment per year respectively as shown in Table 7.

Table 7: Average yearly investments and returns of resource use in the wetland.

	Average No. of trips /yr		**Average investment/yr (USD)**		**Average return/yr (USD)**	
	Males	*Females*	*Males*	*Females*	*Males*	*Females*
Firewood collection	43	43	15.3	12.75	170.68	125.46
Hunting	39	0	27.2	0	65.45	0
Herb collection	12	73	2.21	2.55	1.19	14.11
Water collection	60	66	3.91	2.975	67.83	55.76
Crab catching	32	0	3.57	0	29.75	0

Note: Herb collection refers to collection of vegetables as well as medicinal plants. Yearly Investment also refers to operational costs incurred by resource users whereas the yearly return refers to the cash inflow per year. Gender determines interest in a particular activity hence the investment an individual makes. Hunting is generally considered a male-dominated activity across the country. Although crab catching is a gender-neutral activity, only male resource users engage in the activity in the Butuah wetland.

Total Economic Value (TEV)

The values placed on ecosystem services were grouped into Direct Use values (DUV), Indirect Use values (IV), Bequest Values (BV), Option values (OV), and Existence values (EV); all of which added up to the total Economic Value (TEV). Table 8 shows the contributions of the various values to the Total Economic Value.

Table 8: The values of the total economic value and the use and non-use values

Habitats	DUV/Ind /ha (USD)	IUV/Ind /ha (USD)	BV/Ind /ha (USD)	OV/Ind /ha (USD)	EV/Ind /ha (USD)	TEV/Ind /ha (USD)
Lagoon	18.39	56.88	32.79	24.67	32.08	164.81
Intertidal Marsh	0.57	74.33	38.44	25.41	13.15	151.91
Intertidal Forested Wetland	16.00	211.18	127.85	68.63	57.93	481.58
Mudflats	2.82	56.15	35.43	44.42	37.42	176.24
Total						**974.54**

Non-market valuation methods in estimating the value of goods and services that are not traded in markets

Economic benefits of the wetland's local use

Scenario analysis, which is based on mathematical and statistical principles, is a method for estimating changes in the value of a project based on the occurrence of various scenarios. It allows for a comprehensive study of all conceivable scenarios. As a result, managers can put their decisions to the test, understand the possible impact of specific variables, and spot potential dangers. The economic benefits of local use of wetland resources over a 25-year period were analyzed based on the value current Direct Use Value products obtained from the wetland using NPV and BCR. The results of the analysis are shown in Table 9 and Figure 32 respectively.

Table 9: Projected Net Present Value of DUV per hectare

	Net Present Value per hectare per year (USD)			
Project life in years	Lagoon	Forest	Marsh	Mudflats
0-5	447.2	1200.1	23.0	59.2
6-10	242.6	604.6	11.3	33.3
11-15	127.7	283.8	4.8	17.7
16-20	63.0	110.2	1.0	8.4
21-25	26.3	11.4	-1.3	2.7

Note: The discount rate and the NPV usually have an inverse connection in Net Present Value estimation. When the outflows exceed the inflows, the net present value (NPV) is negative.

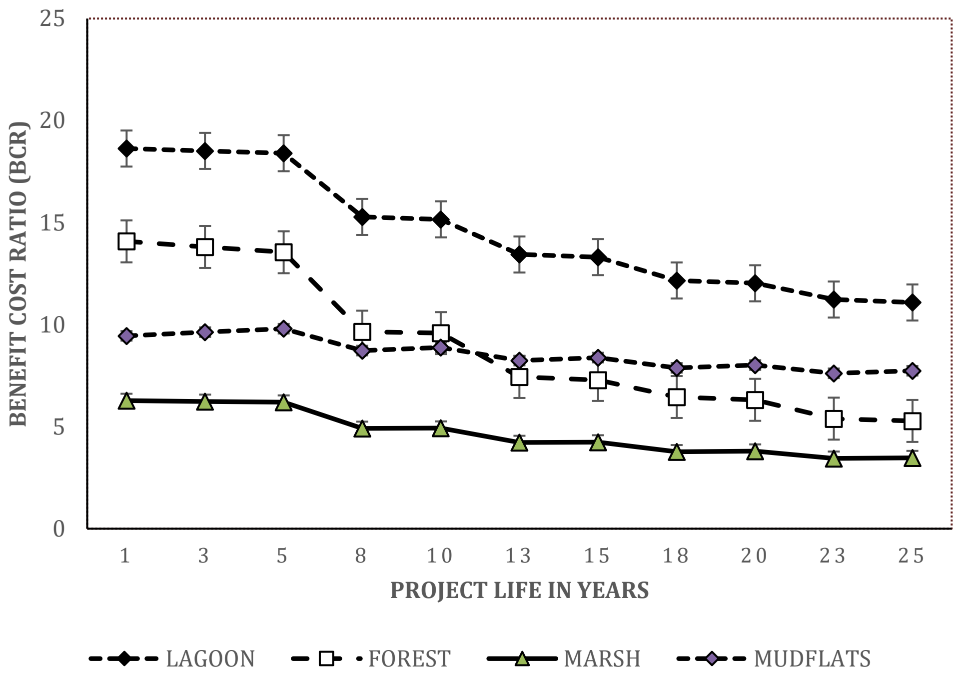
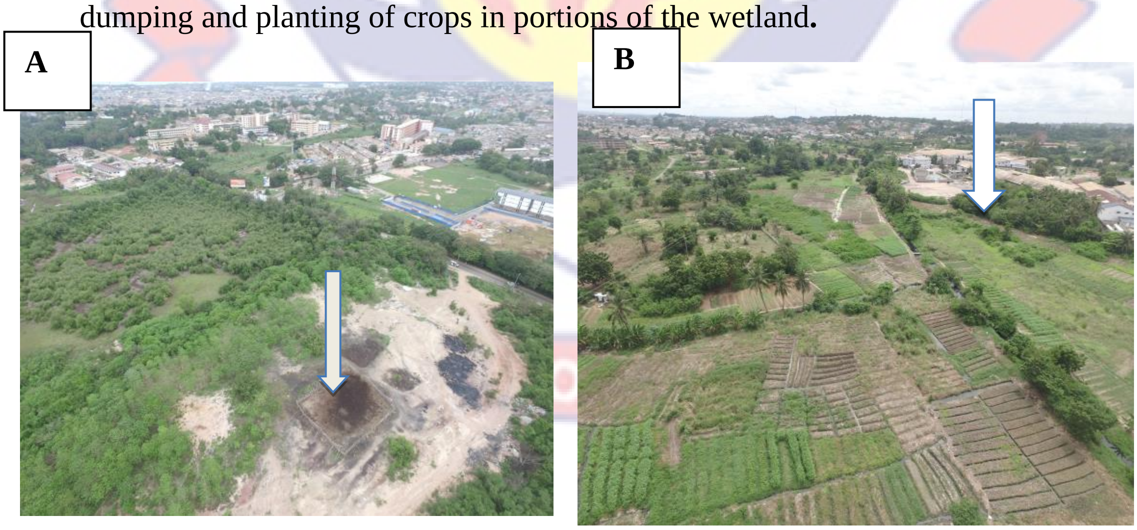


Figure 32: Projected Benefit Cost Ratio of DUV per hectare

Anthropogenic threats posed to the habitats in the Butuah wetland

The anthropogenic threats posed to the Butuah wetland include unauthorized construction of houses, construction of pens for animal husbandry, refuse dumping and planting of crops in portions of the wetland.



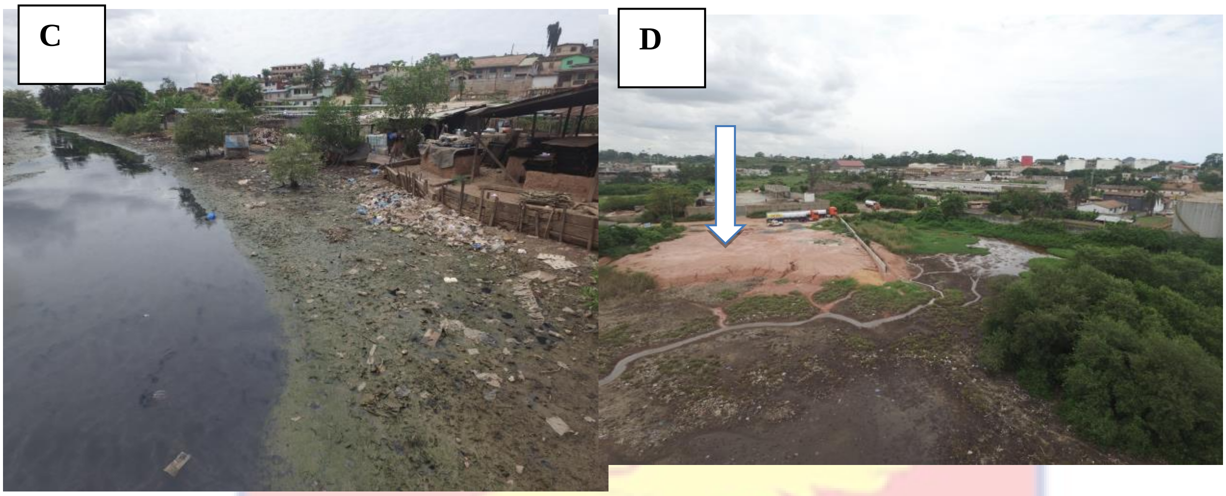


Figure 33: Anthropogenic threats(A) Agricultural farms (B) refuse dumping (C) pens for animal husbandry (D) landfill for construction in the Butuah Wetland

Habitat Risk Assessment

The data used in the assessment of the existing risks to the various habitats are presented in Table 10. The identified stressors in the area as well as the level of ecosystem's exposure to them and the consequences of exposure are also presented in Table 10. The sources of data used in the assessment are also listed.

Table 10: Scores of Ecosystems' Exposure to Pressures and Consequences

	Lagoon					**Intertidal Forested Wetland**					**Intertidal Marshes**					**Intertidal Mudflats**				
Criteria	**OG**	**FI**	**DF**	**RD**	**ID**	**OG**	**FI**	**DF**	**RD**	**ID**	**OG**	**FI**	**DF**	**RD**	**ID**	**OG**	**FI**	**DF**	**RD**	ID
Consequences of exposure																				
Frequency of disturbance	$0^{a,b,c}$	$2^{b,c,d}$	$0^{a,b,c}$	$1^{a,b}$	$3^{a,b}$	$1^{a,b}$	$3^{a,b}$	$1^{a,b}$	$2^{a,b}$	$3^{a,b}$	$1^{a,b}$	$2^{a,b}$	$2^{a,b}$	$1^{a,b}$	$3^{a,b}$	$1^{a,b}$	$2^{a,b}$	$0^{a,b}$	$1^{a,b}$	$3^{a,b}$
Change in area rating	$0^{a,b}$	$3^{a,b}$	$0^{a,b}$	$1^{a,b}$	$3^{a,b}$	$1^{a,b}$	$2^{a,b}$	$2^{a,b}$	$1^{a,b}$	$2^{a,b}$	$2^{a,b}$	$2^{a,b}$	$1^{a,b}$	$1^{a,b}$	$2^{a,b}$	$1^{a,b}$	$3^{a,b}$	$0^{a,b}$	$1^{a,b}$	$2^{a,b}$
Change in structure rating	$0^{a,b}$	$3^{a,b}$	$1^{a,b}$	$1^{a,b}$	$3^{a,b}$	$2^{a,b}$	$2^{a,b}$	$2^{a,b}$	$1^{a,b}$	$3^{a,b}$	$2^{a,b}$	$2^{a,b}$	$2^{a,b}$	$2^{a,b}$	$3^{a,b}$	$3^{a,b}$	$1^{a,b}$	$0^{a,b}$	$2^{a,b}$	$3^{a,b}$
Exposure of ecosystems to pressure																				
Temporal overlap rating	$0^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$1^{a,b}$	$2^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$1^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b,d}$	$3^{a,b}$	$1^{a,b}$	$3^{a,b}$	$3^{a,b}$	$1^{a,b}$	$3^{a,b}$	$1^{a,b}$
Management effectiveness	$3^{a,b}$	$3^{c,b,d}$	$3^{a,b}$	$3^{a,b,c}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b,c}$	$3^{a,b}$	$3^{a,b,d}$	$2^{a,b,d}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$2^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$2^{a,b}$
Intensity rating	$1^{a,b}$	$3^{a,b}$	$0^{a,b}$	$2^{a,b}$	$1^{a,b,c}$	$2^{a,b}$	$3^{a,b}$	$3^{a,b}$	$1^{a,b}$	$1^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$3^{a,b}$	$2^{a,b}$	$1^{a,b}$	$3^{a,b}$	$0^{a,b}$	$3^{a,b}$	$2^{a,b,c}$

Pressures: OG = Overgrazing; FI = Fertilizer input; DF = Deforestation; RD = Refuse Dumping; ID= Infrastructural Development

Scoring components: a Land use assessment; b Drone imagery of the study area; c Resource users survey; d Literature

Table 11:Mean Risk Scores and Percentage level of risk of Habitats

Ecosystem	**Stressors**	**Mean risk**	**Risk (% high)**	**Risk (% medium)**	**Risk (% low)**
Forest	All Stressors	0.0	0.0	3.6	96.4
	DF	0.0	0.3	0.0	99.7
	FI	0.1	3.6	0.0	96.4
	ID	0.0	0.3	0.0	99.7
	OG	0.1	3.9	0.0	96.1
	RD	0.0	0.0	0.0	100.0
Lagoon	All Stressors	0.0	0.0	0.0	100.0
	DF	0.0	0.2	0.0	99.8
	FI	0.0	0.4	0.0	99.6
	ID	0.0	1.4	0.0	98.6
	OG	0.0	0.0	0.5	99.5
	RD	0.1	0.0	6.7	93.3
Marsh	All Stressors	0.0	0.0	0.0	100.0
	DF	0.0	0.3	0.0	99.7
	FI	0.1	3.6	0.0	96.4
	ID	0.0	0.0	0.3	99.7
	OG	0.1	3.9	0.0	96.1
	RD	0.0	0.0	0.0	100.0
Mud	All Stressors	0.0	0.0	0.0	100.0
	DF	0.0	0.0	0.0	100.0
	FI	0.1	2.8	0.0	97.2
	ID	0.0	0.0	0.8	99.2
	OG	0.1	0.0	3.4	96.6
	RD	0.1	2.7	0.0	97.3

Pressures: OG = Overgrazing; FI = Fertilizer input; DF = Deforestation; RD = Refuse Dumping; ID= Infrastructural Development

Source: InVEST 3.9.0 Summary statistics

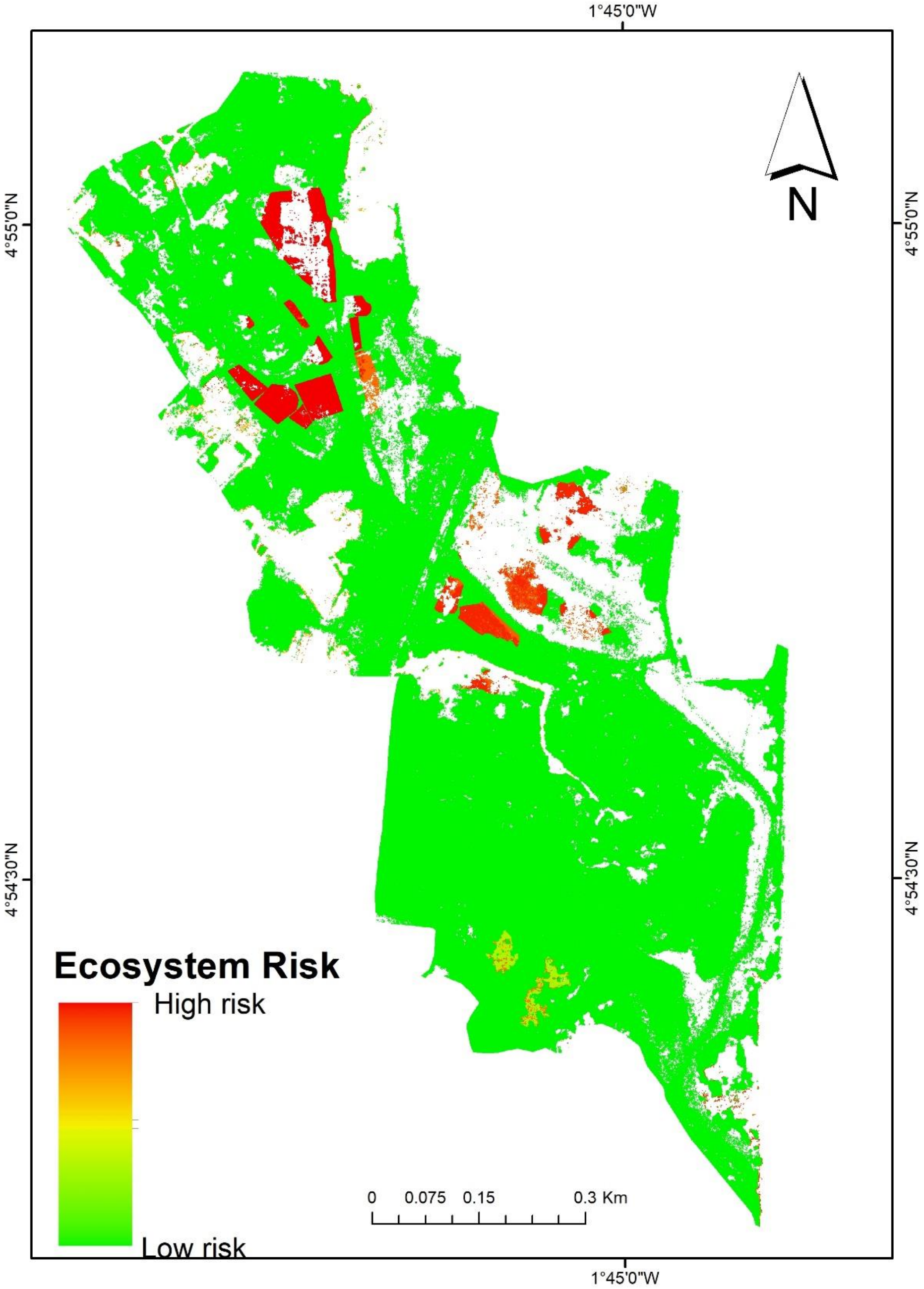


Figure 34: Ecosystem Risk Map of the Butuah Wetland

Stakeholder integration in management planning

Steps towards development of management intervention

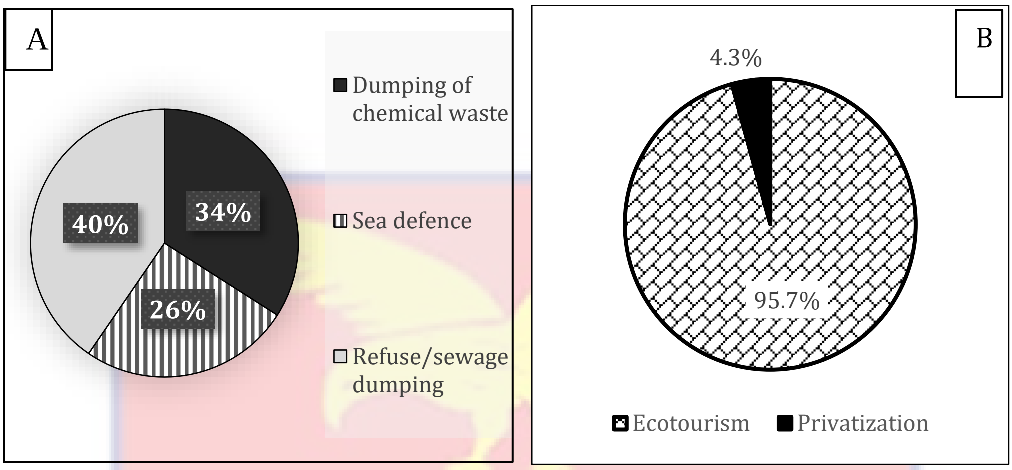


Figure 35: Management interventions proposed by resource users

Figure 35 (A) reports management problems identified by resource users and (B) proposed management solutions to address them. The highest number of resource users attributed the degradation of the wetland to refuse and sewage dumping. To address the challenges posed to the wetland 95.7% of the resource users agreed that the area needs to be converted into an ecotourism site.

All stakeholders of the Butuah wetland were grouped to develop a stakeholder interest-influence matrix towards the development of a management framework in the area as shown in Table 12. All groups who have been or would be affected by or can affect management plans for the area were grouped into 4 sectors (Public authorities, Economic Sector. Civil Groups and Knowledge Providers).

Table 12: Stakeholder groups associated with the management of the Butuah wetland

Sector	Agencies Involved
Public authorities	
	-Sekondi-Takoradi Metropolitan Assembly
	-Forestry Commission (FC)
	-Wildlife Division of Forestry Commission
	-Effia-Kwesimintsim Municipal Assembly (EKMA)
	-New Takoradi Assemblyman
	-Kwesimintsim Assemblyman
	-New Takoradi Traditional Council
	-Ghana Tourism Authority (GTA)
	-Coastal Development Authority (CDA)
Economic Sector	
	-Oil Companies
	-Local fish processors
	-Agricultural Commercial Users
	-Subsistent resource users
Civil Groups	
	-Friends of the Nation, Ghana (FoN).
Knowledge Providers	
	-Centre for Coastal Management
	-Ghana Standards Authority (GSA)

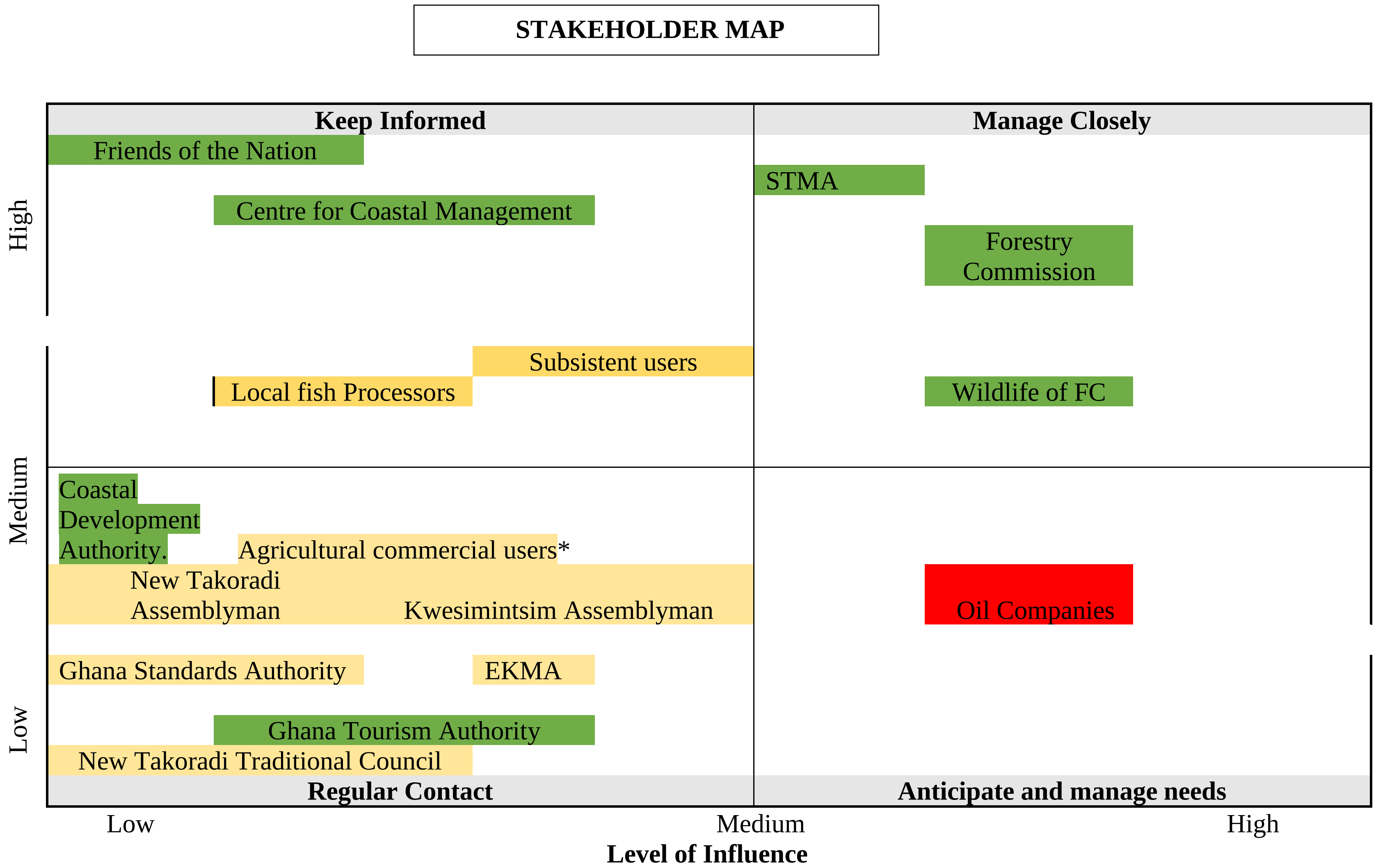


Figure 36 : Interest-influence matrix of stakeholders for conservation in the Butuah wetland

*: Potential to be a future blocker based on disposition on proposed management strategy Color key: Green- Advocate Yellow- Neutral Red- Blocker

Figure 36 presents a matrix showing the level of interest and level of influence of identified stakeholders. The names are colour-coded to show whether a particular stakeholder or group of stakeholders will be open to supporting an environmentally-tuned management option (Advocates); May not conclusively object or fully support the plan (Neutral); and those that may object the plan (Blockers). This matrix is to help in the management of all stakeholders as environmentally-sustainable plans are put in place for the attainment of optimal results.

Key

-High-power, high-interest stakeholders need to be managed closely: Any conservation project must completely engage these individuals and make every attempt to incorporate their needs and suggestions into plans.

-High-power, low-interest stakeholders need to be kept Content: The conservation project would need to have channels that ensure satisfactory communication with them about their interests and those of the project, and how both can be aligned.

-Low-power, high-interest stakeholders need to be kept Informed: They should be sufficiently informed and conversed with to ensure that no serious concerns arise. This group of people can be really useful when it comes to the finer points of the conservation project.

- Low-power, low-interest stakeholders just need Monitoring: They do not need to be informed about every single detail of the conservation project.

Proposed zoning plan by stakeholders.

The preliminary plan for zoning of the Butuah wetland in the interest of all stakeholders in presented in Figure 38. The considerations for the zoning are also provided in Figure 37. The plan seeks to leverage the economic interests of the strongest financial power in the area- the oil companies- to develop conservation projects in the area while protecting the floral and faunal biodiversity in the area.

For that matter, the stakeholders allocated portions of the wetland to be used for development of the proposed tank farm by the oil companies alongside recreation and nature parks in the interest of stakeholders whose concerns are skewed towards environmental conservation. The design also proposed a minimum buffer of 20 feet (0.000185806 hectares) between the activities in the oil tank farm and the nature reserve and recreation centre (Figure 38)

Proposed zoning options from stakeholders

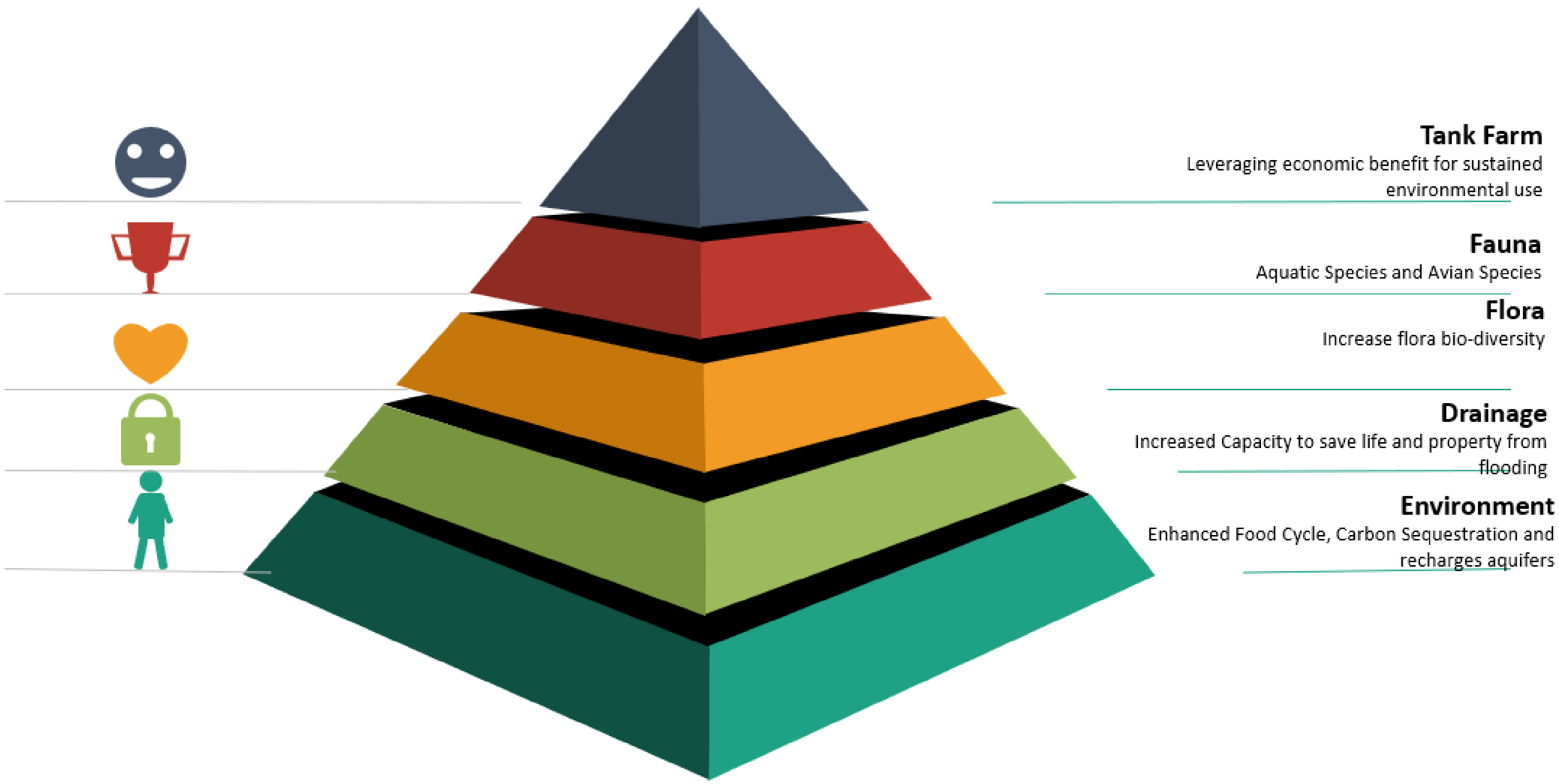


Figure 37: Factors considered by stakeholders in zoning of the Butuah Wetland

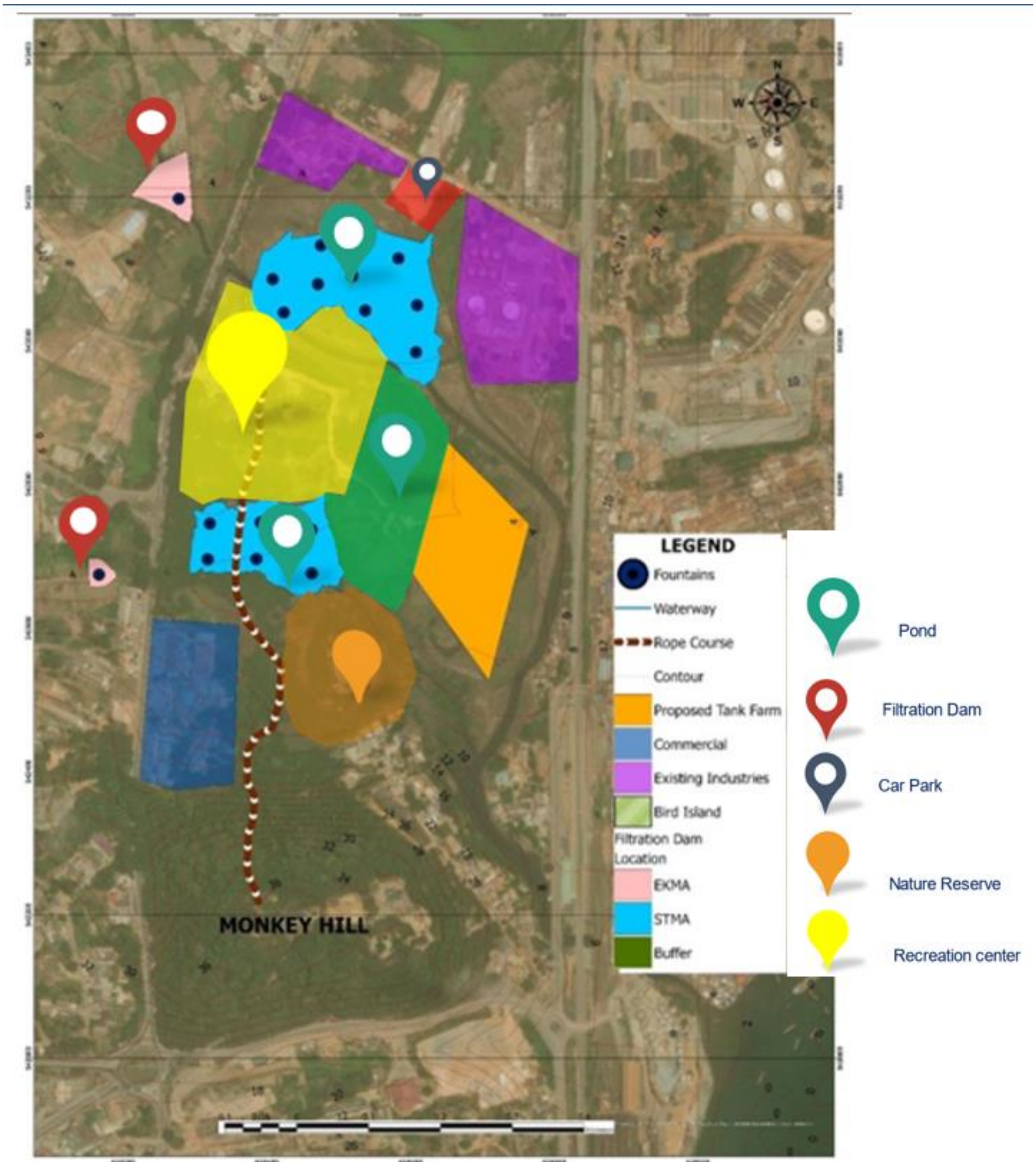


Figure 38: Preliminary zoning plan for the Wetland as proposed by stakeholders

Framework for Sustainable Management of the Butuah Wetland

The Butuah wetland has various resources utilized by multiple stakeholders and governing bodies (Figure 39) which call for the set-up of an inter-institutional management approach. A suitable approach would be an integrative structure with the lead agency working in tandem with all the other institutions in the area. Thus, a shared governance/ co-management framework as proposed in figure 40 would be appropriate for the management of the wetland. Currently, institutional roles in the management of the wetland are independent of one another. However, the proposed framework presents a horizontal integrated approach where all institutions work together to effectively manage the wetland's resources.

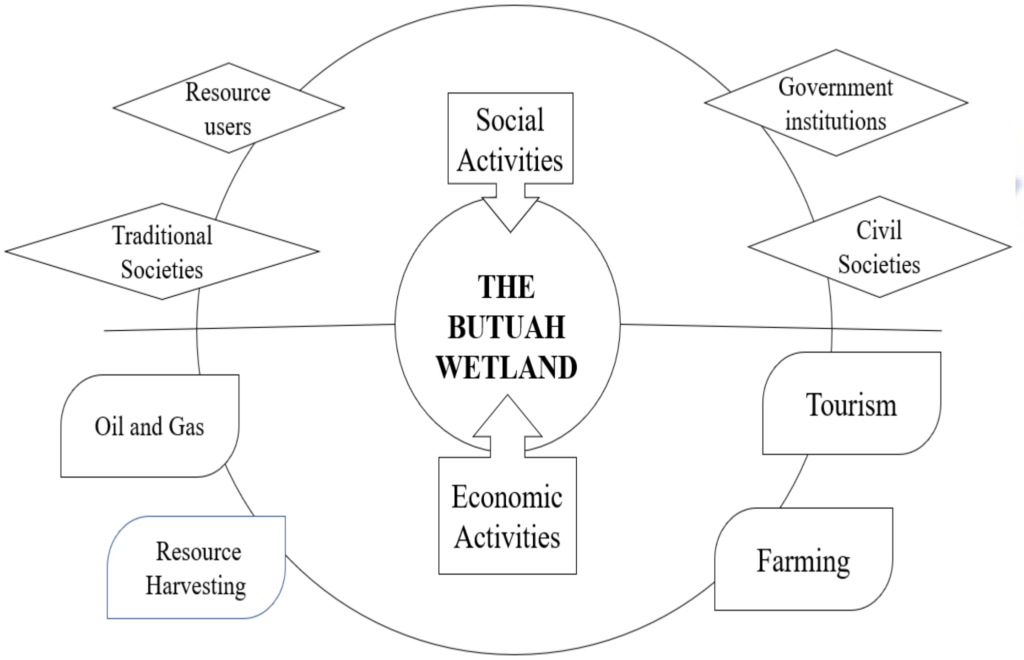


Figure 39: Coastal Zone relationships in the Butuah wetland

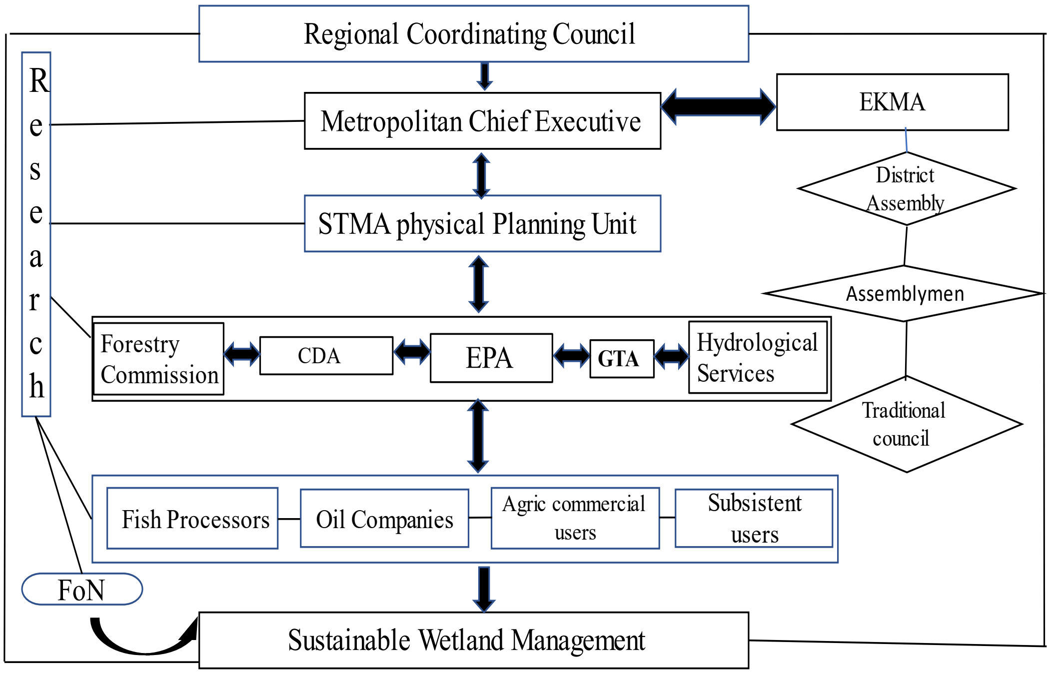


Figure 40: Co-management framework for the Butuah Wetland

CHAPTER FIVE

DISCUSSION

Results obtained from the various assessments conducted on the habitats in the Butuah wetland are discussed in this chapter. The discussion is based on the need for conservation and sustainability in the area. An appropriate management plan according to the assessment conducted is also discussed, followed by a final discussion on the zoning plan proposed by stakeholders for the management of the area.

Drivers of land-use changes in the Butuah wetland

Over the years the cascade of ecological impacts in the wetland have usually been triggered by human-caused alterations that resulted in species mortality and an abnormal lagoon water regime. Specifically, the discovery of oil in commercial quantities in the Western region, where the wetland is located resulted in massive land-use alterations in the area (Adogla, 2010). The adjacent Takoradi harbour was extended and additional projects and policy provisions that had far-reaching repercussions for the immediate environment were developed to accommodate the oil and gas sector (Aduah & Baffoe, 2013; Adjei Mensah et al., 2019); which included the initial construction of oil tank farms in portions of the wetland (Figure 4). The increase in human activities drove an increase in infrastructure development, land reclamation, water extraction, eutrophication and pollution, overharvesting and overexploitation that is noticeable in the maps of the area (Figures 14, 15 and 16). The unification of the multiple stressors at play in the area have in turn, set the economic and social limits of resource use and biodiversity adaptations in the area.

State of the ecosystems in the Butuah wetland

Lagoon

Lagoons are structurally controlled systems with high salinity and hydrodynamic fluctuations, which are powered by their sandbar's intermittent connection to the sea (Kjerfve, 1994). Thus, the presence of the sea is most likely the critical element that influences the form and function of the lagoon as well as their biotic communities (Conde et al., 2015). However, as with the Butuah lagoon, choked lagoons have restricted access to tidal flow due to a thick sand barrier that connects a narrow channel to the adjacent sea. Therefore, tidal inflow in the area is reduced due to the natural processes of sand bar formation and the construction of a sea defense along the boundaries of the lagoon to prevent erosion of the adjacent New Takoradi community. As a result, the Butuah Lagoon appears narrower with many of its tributaries reduced in 2021 as compared to 2014 and 2007 (Fig 14). In fact, about three quarters of the area of the lagoon had been lost by 2021, with only a quarter remaining as seen in Figure 17. The pressure from the surge in urbanization in the surrounding communities following the years after the discovery of commercial quantities of oil in the region in July, 2007 could have also increased the deterioration of the lagoon.

Globally, the practice of modification of natural hydrology of closed lagoons to maintain their ecological function is rampant (Conde et al., 2015) and in Ghana, some closed lagoons are opened during festivals and cultural activities for that reason (Baffour-Awuah, 2014). However, the cultural practice is often based on communal integration due to a high dependence on the resources of the lagoon, which is often uncommon in urban areas (Ikurekong, et al., 2009; Aheto et al.,2016). The combined negative effects of increased industrialization and a shift of focus from ecosystem benefits from the lagoon to improving oil production, could have affected the ecological health of the lagoon and led to the observed decrease in its area as stipulated by Cetin (2009).

Intertidal forested wetland

The intertidal forested wetland appears sparsely distributed along the banks of the lagoon. Generally, the vegetation appears disturbed which alludes to the impact of urbanization and industrialization in areas covered by coastal vegetation (Lucrezi et al.,2021). The degradation however seems severe in portions closest to the non-wetland areas where the strands of vegetation are massively disconnected by bare lands, heaps of refuse and/or infrastructure. Among the forest vegetation scattered along the landscape, the mangroves are the most affected by the on-going degradation; this is consistent with findings from Tutu (2000) about the increased preference of mangrove species over other coastal vegetation by fish processors in coastal communities of Ghana; thus, with the highest number of resource users being fish processors, the high rate of deforestation in the areas dominated by mangroves can be inferred. However, it is interesting that the mangroves closest to the lagoon (mainly white mangroves) are thriving with young sprouts emerging along the lagoon in 2021 (Figure 4A). As species adapted to hypersaline and hypoxic conditions, the wetland has suitable substrate to support mangrove growth and extension (Rogers, 2021) which explains this phenomenon. This characteristic for natural regeneration is a testament to how well mangrove restorative efforts could fare in the wetland. Furthermore, in 2017, the Forestry Commission in the area embarked on a small-scale tree planting exercise towards the inland portions of the wetland which could have contributed to the increase in forested wetland by 2021 which can be seen in Figure 16.

Intertidal marshes

The area of marshes in the wetland assumes a parallel relationship with the area of forested wetland; in that, across all time periods. an increase in forest area coincides with an increase in marshes as seen in Figure 17. Averagely, marshes such as sedges and cattails have shorter growth spans, hence the ability of marshes to reclaim the exposed areas from a shrinking lagoon are higher (Jiang et al., 2009). Thus, allegorically, in unison with findings from Walker & Del Moral (2003), exposed areas are more likely to undergo secondary ecological succession where colonization by persistent emergent marshes occurs faster. Moreover, while over-exploitation remains a looming threat for coastal vegetation in Ghana, the reduced preference for marsh vegetation in urban areas could explain the continual increase in area as seen in figure 17. Accordingly, the percentage of resource users that harvest herbs from the wetland (an activity that occurs in the marshes) is relatively lower than that of the forest, as is the average yearly return from the venture (Table 7).

Mudflats

Mudflats are very volatile ecosystems. Continuous lack of water and high evaporative rates in any area has the capacity of converting a mudflat to bare land and ridding it of the organisms that depend on it. Due to this, mudflats are strategically located around lagoons to allow for regular inundation. Contrastingly, a decrease in area of lagoons can expose parts of the lagoon's substrate as mudflats. That is usually the case before a lagoon 'disappears'. On one hand, the increase in area of mudflats could be advantageous yet alarming on the other side. While the increasing area of mudflats can provide habitats for numerous crabs and reduce competition for space among the species, the increase in mudflats could also be shedding light on the impending disappearance of the lagoon. In agreement with Flaux et al. (2012), the inverse relationship between lagoon and mudflats in the Butuah wetland observed in Figure 17 could be a precursor to the "dying lagoon" phenomenon which has led to the loss of a number of coastal lagoons in the country already (Boadi & Kuitunen 2002; Essel et al., 2019).

Landscape pattern changes in the Butuah wetland

Changes in the landscape configuration

The spatial character, arrangement, and context of the elements in a landscape constitute its configuration. These elements interpret the landscape's spatial pattern or heterogeneity. Configuration is spatially explicit because it refers not only to the variety and abundance of patch types, but also to their placement or location (dispersion) in the landscape. Graphs of Number of Patches (NP) in Figure 24, Patch Density (PD) in Figure 22, Largest Patch

Index (LPI) in figure 21 and Edge density (ED) in Figure 23 used in this study showed the landscape configuration of the Butuah wetland.

Habitat fragmentation in coastal areas is caused by a number of natural and anthropogenic factors. Among these, are flooding and drying out of ecosystems (lagoons or rivers), infrastructural development, agriculture and logging or deforestation. The presence of extensive hydrophytic plants around a relatively wider lagoon in 2007 could have contributed to the fragmentation within the lagoon and the forest, where an interspersion of water and forest vegetation increased the LPI, NP, and PD of the two habitats in the area. Similarly, the number of patches in both habitats decreased in 2014 and 2021 as lagoon area decreased and the area of mudflats increased. The number of patches in marshes and mudflats, on the other hand, tend to increase in 2021.The natural disparities in the indices are enhanced by an increase of human pressures in the area where destructive deforestation, refuse dumping and encroachment for infrastructure and agricultural lands is propelled by a lax in enforcement of regulations against them.

In ecology, the term "edge effects" refer to variations in floral or faunal communities that occur at the boundary of two or more habitats (Laurance et al.,2007). For instance, where a road is constructed between a patch of vegetation, it can lead to forced behavioral adaptation in the species found there. Thus, in habitats, increasing edge effects could mean increasing fragmentation that affects biological developmental processes in most species. The edge densities of habitats in the Butuah wetland increased in 2014 for all the wetland types which is in line with the surge in urbanization that occurred following the construction of oil tanks in the wetland after the oil discovery in 2007. The decrease in edge effects by 2021 (Figure 23) also commensurate with the observed increase in intertidal forested area and marshes in Figure 16.

Structurally, the fluctuations in NP, PD, LPI and ED in the habitats throughout the period of the study indicated reduced fragmentation but an increase in habitat loss in these wetland ecosystems. Evidence from the maps (Figures 15 & 16) suggested that between 2014 and 2021 portions of wetland area were completely removed around the north eastern and north western sections of the study area as they became replaced with non-wetland areas. These findings (drawn from the fragmentation analysis) confirm the study by Lam et al., (2018) which found that habitat loss was the underlying factor leading to fragmentation in coastal areas. Thus, the increase in non- wetland areas in the landscape definitely contributed to the disparities in landscape configuration in the wetland. The residual effects could be a decline in population densities in flora and fauna in the Butuah wetland, distorted species interactions and a decline in species richness in the area.

Changes in landscape connectivity (Contagion/Interspersion)

Habitat fragmentation results in Spatio-temporal isolation of habitats. Therefore, understanding the interconnectedness (Aggregation/Contagion) of landscape can explain biodiversity patterns and support implementation of biodiversity conservation policy. Connectivity indices inform on the dispersion and interspersion in patch types. Calculating AI values across classes in the same landscape allows for reasonable comparisons between the classes whereas CI measures general landscape aggregation (He et al., 2000).

Furthermore, AI measurement provides a quantitative foundation for correlating spatial patterns with processes that are usually class specific. Contagion Index (CI) and Aggregation Index (AI) measures 'clumpiness' of ecosystem features. Thus, low patch type dispersion (i.e., a large proportion of like adjacencies) and patch type interspersion (i.e., an unequal distribution of pairwise adjacencies) lead to high Aggregation and contagion, and vice versa. Essentially, an area with a low contagion index would support greater biodiversity as mobile species and species that propagate by means of water transportation can freely move and reproduce within their habitats. Figure 25 and 26 show aggregation index and contagion index increasing in the Butuah Wetland over the period of the study. Thus, unequivocally, biodiversity in the region now is lower than that of previous years. The high contagion and Aggregation indices also allude to the increasing anthropogenic pressure that is evident in increasing non-wetland areas and anthropogenic threats.

Changes in landscape diversity

All ecological studies revolve around the concept of diversity. At the landscape scale, diversity generally relates to interactions between a landscape's composition and connectivity. Quantity and proportions of the various classes or types of habitats found in the landscape can be used to elucidate the interconnectedness of species, and populations, as well as their interactions with the ecosystem. Shannon's Diversity index and Simpson's Diversity Index measured diversity in the landscape (Figure 27 and 28 respectively). The results show that the wetland classes' richness and evenness are dwindling, and that the ecosystems' diversity in terms of landscape is deteriorating. This could be due to the removal of vegetation through deforestation, construction, and/or agricultural practices and animal husbandry operations- all of which have negative impacts on the wetland's functionality.

The economic value of the wetland resources

Land use activities and gender dynamics in the wetland

Human-wetland relationships are motivated by resource dependence which is in turn fueled by a need for exploitation. In Ghana, local fish processing in coastal areas is a female-dominated activity (Boohene & Peprah, 2012; Ameyaw et al.,2020). Traditionally, fishes are laid out on metallic meshes separated by wooden bars and placed in mud ovens designed with holes in them where pieces of burning wood are placed as a source of fuel. The activity requires the use of several pieces of fuelwood daily. A regular source of fuelwood (possibly a close-by forest) is crucial for the activities of coastal fish processors and may determine their total operational cost and yearly return. As more of the resource users are fish processors, this could be the motivation for the high-dependence on the intertidal forested wetland observed in the study. The comparatively low operational costs and the high return from the collection of fuelwoods as seen in table 7 could also be a contributing factor. Conventionally, men in coastal communities in Africa are fishermen who harvest fishes from surrounding coastal water bodies such as estuaries or lagoons for fishmongers (mainly females) to purchase for retail or processing (Odebode & Adetunji, 2013). This is, however, not the case in the Butuah wetland. Following the ban on fishing activities due to the pollution of the lagoon that resulted in mass fish mortality in 2012, fishermen have resorted to other activities such as hunting and fuelwood collection for survival; while women who initially acquired fishes from the lagoon acquire them from fishermen in other communities. Owners of animal husbandry farms within the wetland use water from the lagoon to clean their pigsties and pens to reduce their operational cost from having to buy and transport clean water from adjoining communities. Evidently, these uses of the wetland may not be sustainable, and could explain the deterioration in wetland cover and quality of provisioning services over the years.

Resource utilization and implications of property rights

Human interaction with natural resources is facilitated by ownership rights and resource entitlements. Natural resources in a given space are commonly classified into four ownership and use regimes by resource management experts: open access, private property, communal property, and state property (Feeny,2002) The absence of well-defined property rights is known as open access where the resource is unrestricted, free, and accessible to everybody. Private property rights prevent others from exploiting a resource and provide an individual (or a group of individuals, such as a cooperative body) the power to manage its use. Under communal property rights, resources are held by a recognized society of interdependent users. Thus, outsiders are excluded, while local residents are regulated in their use. Finally, under state property, all rights to the resource are held solely by governments, who make choices about access to the resource as well as the extent and form of exploitation. The Butuah Wetland is state-Owned, although the nation's decentralized management system allows for a somewhat communal ownership since the Metropolitan Assembly manages the resources locally in consideration of cultural norms advised by the Traditional authorities.

Interest, value-placement and individual willingness to conserve or 'abuse' a resource is nurtured by property rights. Typically, when individuals have a claimed ownership to coastal resource, they feel the need to sustain it for their interests. The stance on privatization/conservation was hedged on the personal/economic interests of resource users (Figure 35 B). Individuals who used the area for animal husbandry, and collected resources for that purpose opted for privatization -perhaps with intentions of acquiring greater portions of the wetland for their pigsties and pens and expanding their trade further into the wetland. On the other hand, a greater percentage of users (mainly subsistent) opted for the ecotourism option that could sustain their dependence.

Economic value of the Butuah wetland

Clearly, the habitats in the wetland supply goods and services that are beneficial to locals (Table 6). The results displayed in table 8 display how non-market values make up a far larger portion of the total economic value TEV. This shows that, for the resource users, the wetland's ecological and socio-cultural significance outweigh its current local direct use value. Certainly, commercial resource exploitation in many coastal urban areas is different from rural areas. The high cost of living in many coastal urban areas in Africa coupled with the rapid conversion of resource areas into infrastructural project sites for coastal resource developers means that many resource users harvest on a part-time base; while performing other jobs alongside. Indirect use values Option, existence and bequest values are rated as traditionally embedded values. Having the option to use the wetland resources in future, the pride of its existence as well as for the potential benefits they hold for future generations may be inherent in traditional values of inheritance. This could explain the relatively lower values recorded for OV, EV and BV compared with IUV as many urban dwellers do not ascribe the high traditional heritage significance to these systems as rural areas do.

The total economic value of the entire wetland area as well as each of the habitats in the wetland can also be observed in Table 8. At $974.54/ha/year, the TEV of the Butuah wetland and is higher than the value of wetlands reported by (Aheto et al., 2011) in a valuation of mangroves study conducted in the country. However, the economic value of resources is affected by national economic factors such as inflation and location-dependent value, which determines how a resource is perceived and utilized. Consequently, coastal resources in the urban city of Takoradi where Butuah is located, would not have the same value as rural areas where similar works have been conducted.

Furthermore, the profitability of the wetland's local use in the values obtained in NPV and BCR displayed in Table 9 and Figure 32 respectively. The estimation was focused solely on the direct use benefits derived from the wetland. While the DUV accounts for just a minimal percentage of the TEV, the results indicate that harvesting marketable products from the wetland is very profitable with the highest benefits occurring within the first 15 years of project life. To increase profitability, sustainable management plans would need to be put in place to improve ecosystem services and ensure continual supply of benefits. Again, all alternative project proposals need to be adequately weighed for future benefits and compared with the benefits derived from ecosystem services. The comparison would not undermine the services provided by the ecosystems but rather put the spotlight on the relevance of the Butuah wetland and the need for its conservation.

Anthropogenic threats and their impacts on the Butuah wetland

Per the Habitat Risk Assessment (HRA) performed to evaluate the impact of multiple human activities on the ecosystems understudied, the results indicated that in the exception of the intertidal forested wetland which is at a medium risk from the cumulation of all stressors, all remaining ecosystems in the area are at low risk of the pressures assessed. Individual ecosystems within the wetland were at various levels of risk due to each or a combination of the anthropogenic pressures assessed. These display areas of concern that should be considered when developing conservation measures for the area.

Lagoon

The negative influence of urbanization is evident in the lagoon as heaps of plastic waste are packed within certain portions in the upper reaches and along the banks of the lagoon (Musah et al, 2021). Even though a combination of all stressors put the lagoon at low risk, the impacts of waste disposed along the lagoon could be deleterious. Aside the damage it causes to biodiversity, plastic pollutants reduce the aesthetic value of the resource. By means of intervention, authorities need to enforce punitive measures against dumping waste into or around the lagoon to deter perpetuators and conserve the lagoon.

Intertidal forested wetland

The intertidal forested wetland in the Butuah wetland was classified as having low–to–medium risk cumulatively for the combination of all pressures examined.

However, the ecosystem is particularly at high risk to Fertilizer input from agricultural farms, overgrazing, infrastructural development and deforestation in certain areas. The effects of these pressures can be detrimental to the health of the ecosystem. Certain fertilizers contain harmful chemical substances which when released into the wetland which could alter the soil's chemistry and give rise to invasive species (Sharma & Singhvi, 2017). Overgrazing, and infrastructural development could also increase fragmentation in the wetland, and exacerbate the current negative implications of isolated patches posed to biodiversity in the area.

Intertidal marshes

Cumulatively, the marshes in the area are at low risk. However, high risks of overgrazing from surrounding animal husbandry farms and fertilizer input may lead to further degradation if management procedures are not put into place to address them.

Mudflats

Although the cumulative risk of all stressors to the mudflats is low, Fertilizer Input and dumping of plastic waste persist as high risks to its structure and function. As the preferred habitat for crabs in the wetland, the plastic waste scattered within the mudflat area poses the risk of suffocation to the organisms that inhabit the area (De Moura & Vianna, 2020). This could eventually lead to mortality of organisms. The results of fertilizer leakage into the mudflats could be more severe than plastic pollutants. It could lead to mutation of species, altering the biology and ecology of the area as well as lead to mass mortality of species in the exposed mudflats.

Developing Eco-based tourism as a response to the conservation needs in the Butuah area

Zoning options for management

The aim of ecologically-centered tourism and ecological conservation in general is to safeguard the ecological integrity of ecosystems while exploring sustainable approaches to obtain maximum economic benefits from them (Brandt & Buckley, 2018). As with Marine Protected areas, zoning in coastal resource management can be an issue of conflict. Zoning plans in conservation management range from no-entry zones, which are used to protect all marine resources in a completely restricted access regime, to vast, multiple-use protected zones, which use regulatory mechanisms to allow for limited take of specific species in multi-species fisheries management. While establishing no-take areas contributes significantly to the recovery and protection of marine ecosystems and serves as a benchmark for evaluating the success of management regimes, they also prevent traditional users of the resources from accessing the resources, putting their survival and well-being in jeopardy. Multiple-use zoning can help with this by regulating resource extraction and enabling recreational and other economic activities that are in line with the ecotourism objectives. Multiple-use zoning has the potential to boost economic activity, and is normally welcomed by residents. The study found that the many ecosystems understudied have varied values, varying levels of danger from various influences, and diverse conservation needs hence multiple-use zoning maybe ideal for the area.

Stakeholder opportunities for managerial planning

The success or failure of any managerial enterprise hinges on the commitment and involvement of stakeholders. The stakeholder list generated in Table 12 groups stakeholders into their institutional capacities. Hence any conservation project in the area could leverage their roles and integrate them into management plans. Fig 39 displays the interest and influence of every stakeholder. Unsurprisingly, stakeholders who are involved in the environmental management sector are branded as advocates to the potential environmentally sustainable management agenda as are those that depend on the supply of ecotourism services for their livelihoods. This coincides with assertions by Rawlins (2006) that, individuals are more likely to support a course that benefits their personal needs and interests. Again, Oil companies are considered potential blockers in conservation planning because their interest in the Butuah wetland have purely been economic proposing to extend their activities into the wetland at a point in time. Agricultural farms when managed sustainably may fall in line with the conservation goals. However, the use of certain biocides and fertilizers at the expense of the environment in hopes of increasing their financial gain may eventually go against the environmental sustainability agendum.

Stakeholders at the meeting concluded on an all-inclusive managerial approach for the wetland. In effect, stakeholders agreed to pull resources from one another towards the wetland's management. As seen in Fig. 37, the basis of all management projects was proposed to be the environment (landscape), such that, when a particular project proposed by any investor would cause harm to the area, it would be rejected. After the environmental interest the drainage of the area was the next most important aspect in the view of the stakeholders, followed by a consideration of the projects ability to cause harm to the unique flora and fauna within the ecosystem. In that case, any project that passes the environmental test stage (Assessment of effects on food cycle, carbon sequestration and aquifer recharge) could still be rejected if it posed harm to the wetland's flora or fauna. Although this four-tier argument is sound, a comprehensive Environmental Impact Assessment (EIA) at the first stage could eliminate the need for a further consideration of the drainage, flora and fauna since they collectively make up the environment. Preferably, Stakeholders could structure a holistic environmental assessment process for all proposed projects in the wetland that would be conducted by independent bodies from which they can determine the ecological feasibility of the project.

Again, the oil tank farm was placed at the apex of the pyramid to indicate the need for leveraging economic benefits from them. Oil companies in the wetland have strong financial capacities, but in as much as the establishment of tank farms following the expansion of the Takoradi Port will serve the nation's oil and gas needs well, it can also be very detrimental to the environment (Chang et al., 2014: Dib et al., 2018; Zhang et al., 2019). There is the issue of spillovers, habitat destruction as well as loss of economic value and livelihood support for resource users in the community.

Implications of the zoning Options proposed by Stakeholders

i) The wetland is currently 'in use'. Each of the zoned areas are habitats to diverse flora/or fauna and have resource users depending on them for economic gain and livelihood support. Any change in structure can affect the biology of the area, the biodiversity of the area and its ability to provide ecosystem services on which users depend. Even the placement of a minor facility such as a filtration dam could be detrimental if not implemented in primary consideration of environmental resources rather than economic gain.

ii) Economic value depreciation is also a reason for concern in the current proposed option. For instance, placement of a tank farm in the mudflat reduces its value as a mudflat. While the tank farm may have benefits (economic/social) of its own; the socio-economic value of the mudflat in the area ceases to exist. This applies to all the areas that will be converted. There is the need for projected analysis of no-zoning and zoning scenarios for reconsideration of trade-offs vis-à-vis the location and benefit from the proposed ventures as well as the local use scenarios similar to the illustrations in Fig. 32 and Table 9.

iii)Another issue for consideration is the delineation of the buffer zone which raises the question-Is the buffer zone really enough? A buffer zone is often set up in conservation areas to restrict the actions of one designated zone from interfering with another. In the case of oil tanks and biodiversity, oil pollution from spillages and leakages can be very toxic to the wetland's flora and fauna and could possibly lead to another mass mortality that would be difficult to control.

iv)Furthermore, Institutional frameworks for the area need to be renewed. Even with the existence of laws to address encroachment of the Butuah wetland, land reclamation is ongoing within the boundaries of the wetland (Figures 14, 15, 16). The issues of encroachment will need to be addressed before any proposed project can be implemented to ensure that every stakeholder, sector or venture stays within their designated boundaries. This can be done through stronger and inclusive stakeholder involvement. The accomplishment of this task will heighten partnerships and prevent conflicts among stakeholders in the area.

Co-management framework for sustainable management of the Butuah wetland

The co-management framework for the wetland is premised on the resources, how they are managed and how stakeholders can form stronger collaborations towards conservation and sustainable management of the area as shown in Figure 39. The success of co-management depends on institutional analysis and integration of governmental, civil and community participation (Plummer & Fitzgibbon, 2004). The co-management/shared governance approach has been used successfully in Vietnam for the management of similar systems according to reports by Spelchan et al. (2011). For this study, the tiered co-management framework displayed in Figure 40 is hinged on collaboration among governance bodies at all levels. The governing bodies include the regional governing bodies for the Western Region of Ghana as part of the decentralized national governance structure; the supporting governmental environmental institutions and the resource users. The general plan for sustainable development of the region is outlined by the lead- regional council as part of the national development goals set out for the nation. The Metropolitan and Municipal assemblies work hand-in-hand with regular input from the district assemblies and traditional councils who would observe ongoing activities in the wetland as part of their administrative duties. The Planning Unit of the Metropolitan Assembly which is responsible for zoning and management of land use would work with other governmental bodies in charge of environmental management in the area on the use of resources and how to integrate sustainability plans into the wetland's administrative plans. The users would be the primary determinants of the success of the developmental goals in the wetland by adhering to sustainable management plans by institutions in the top tiers who will be collectively advised by research institutions in the area. The civil society, Friends of the Nation (FoN), serves as the independent body that consults with researchers to review the plan and ensure that all institutional structures are aligned towards the goal of sustainable management in the Butuah wetland.

To accelerate decision-making, an electoral process can be put in place where representatives would be selected from the environmental institutions and the resource users to serve as proxies at regional discussions of wetland management and integration.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The study was conducted in efforts to understand the social and environmental implications that land-use changes have on urban coastal wetlands with the Butuah wetland as a focal point. Thus, the study was categorized into three aspects; ecological, social and economic. As part of the environmental components; the wetland types in the study area were mapped for the years 2007, 2014, and 2021 using satellite images and the changes in the wetland types was calculated for the generated maps. This was to show the percentage changes that had occurred within the period of study and quantify the changes in land-use in the area. Fragmentation metrices were used to analyze changes in landscape composition, connectivity and diversity for all the wetland types over the period of study to reveal how land-use had caused discontinuities in the landscape by breaking them into patches.

Furthermore, the present total economic value of the area was estimated to show the connection between land-use and economic value and bring into view the need to conserve and sustainably manage the wetland's resources.

The anthropogenic threats posed to the habitats in the Butuah wetland was assessed using the InVEST model. The distributed risks highlighted the areas that were at low risks and those that had high risks due to anthropogenic threats and how those threats could be addressed through effective conservation management. The study was concluded with a stakeholder validation meeting where the research findings were discussed as well as zoning options that had been proposed by stakeholders.

Conclusions

Coastal urban ecosystems in Ghana provide a wide range of services to surrounding communities and for that matter their conservation is crucial. However, over the years negligence of their benefits in search of alternative economic interests have laid waste to a number of them. As a coastal wetland in the heavily industrial city of Takoradi, the Butuah wetlands needs to be conserved for the following reasons:

- The area supports critical ecosystems (a lagoon, an intertidal forest, intertidal marshes and mudflats). These systems support diverse flora and fauna that could become endangered when the anthropogenic threats in the wetland persist.
- Fragmentation in the wetland is high and has increased over time. The disintegration of ecosystems into fragments, if not addressed, would lead to decreased biodiversity and eventual extinction of critical species.
- The total economic value of the resources in the wetland is high and the market value of direct use values as an investment is highly profitable. Where sustainable management practices are enhanced, the wetland has the potential to support an even greater proportion of the community.
- Risk assessment conducted shows that wetland habitats are at risk of anthropogenic degradation from waste disposal, fertilizer inputs, over-

grazing, deforestation and infrastructural developments- which could increase fragmentation, cause mass mortality of organism and massively decrease the ecosystem services that the various habitats provide.

Recommendations

As part of efforts to conserve the resources in the Butuah wetland, the study recommends the following:

i. A follow-up assessment of the biodiversity in the Butuah wetland and the Monkey Hill Forest needs to be conducted. The findings could be compared with the geospatial and economic assessments from this study to explain species distribution and diversity.

ii. Hydrological assessments of the entire watershed should also be carried out. This would shed more light on the decrease in lagoon area by showing the flow direction and accumulation from upland areas.

iii. Finally, an ecological health assessment of the lagoon and adjoining habitats in the wetland should be conducted to assess the chemical and toxicological implications of anthropogenic activities in the area.

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APPENDICES

APPENDIX A: QUESTIONNAIRE FOR SURVEY

QUESTIONNAIRE SURVEY ON BUTUAH WATERSHED

Respondent's background

Respondent code:	Gender of Respondent:
Age of Respondent:	Income Provider in family:
Marital Status:	Number of dependents:
Are you the income owner: Yes No	Per-capita amount used daily:
Current occupation:	Number of years spent in occupation:
Do you still use the resource: Yes No	
If no, when did you stop using the resource?..	
If yes how long have you been using the resource?..	

PART A: ESTIMATION OF DIRECT USE VALUES OF THE BUTUAH WATERSHED

DIRECT USE: Forestry products (E.g.: Food, Medicine, Raw Materials, Fuelwood)

Resources	Quantity per trip	Trip number per week or per month	Market Price	Variable (Operational cost)	Equipment	Price of the equipment	Longevity of equipment	Amount spent on equipment repairs monthly
I.								
II.								
III.								
IV.								
V.								

How much are you willing to pay for a 2hour guided tour and hiking through the watershed?..

DIRECT USE: Fisheries resources (Food, medicine. raw materials)

PART TWO: ESTIMATION OF INDIRECT USE VALUES

INDIRECT VALUES

How much are you willing to pay for the avoided economic loss by flood regulation from vegetation and soils?

………………………………………………………………………

How much are you willing to accept (WTA)as compensation for the destruction of fish nursery grounds and habitat areas?.................

How much are you willing to accept (WTA)as compensation for clearing 1 acre of the forest?...

PART THREE: ESTIMATION OF OPTION VALUES OF THE BUTUAH WATERSHED

Option Values: cultural heritage

Do you consider the watershed as a part of your cultural heritage?

☐Yes ☐No

If yes, give reasons……

How much are you willing to pay (WTP) to preserve the option of using the watershed in the future by yourself? (Such as future fishing and harvesting, recreation, and for future ecotourism benefits of the area)

………

PART FIVE: ESTIMATION OF EXISTENCE VALUES OF THE WATERSHED

Existence Value: Welfare from just knowing watershed exists

Do you derive satisfaction from knowing the watershed exists?

Yes No

If yes, how much are you willing to pay for the satisfaction you derive from the resource?

……

PART SIX: MANAGEMENT STRATEGIES

Categorize the watershed ecosystem in order of relevance to you.

(The monkey hill forest, the mangrove forest, the wetland pools, the lagoon)

I…………………… II…………………………….III………………………………… IV………………………………………

What management plans should be put in place for the watershed?

a. Conserved as an ecotourism site

b. Privatization (area for farming operations)

c. Industrialized (sold to industries)

d. Other………………………………………………………

What anthropogenic activities destroy the watershed?

a………

b………

c………

How has the pollution of the lagoon and clearing of the forest affected your income?

APPENDIX B1: Economic assessment of Lagoon (NPV)

YEAR	Return/ha/yr	cost/ha/yr	Net cash flow(Ct)	(1+r)	(1+r)^t	Ct/(1+r)^t
1	136	7.3	128.7	1.14	1.14	112.8947
2	138.27	7.446	130.824	1.14	1.2996	100.6648
3	140.54	7.592	132.948	1.14	1.481544	89.73611
4	142.81	7.738	135.072	1.14	1.68896	79.97347
5	145.08	7.884	137.196	1.14	1.925415	71.2553
6	147.35	9.5676	137.7824	1.14	2.194973	62.77181
7	149.62	9.7552	139.8648	1.14	2.502269	55.89519
8	151.89	9.9428	141.9472	1.14	2.852586	49.76088
9	154.16	10.1304	144.0296	1.14	3.251949	44.29025
10	156.43	10.318	146.112	1.14	3.707221	39.41281
11	158.7	11.6892	147.0108	1.14	4.226232	34.78531
12	160.97	11.9184	149.0516	1.14	4.817905	30.93702
13	163.24	12.1476	151.0924	1.14	5.492411	27.5093
14	165.51	12.3768	153.1332	1.14	6.261349	24.4569
15	167.78	12.606	155.174	1.14	7.137938	21.73933
16	170.05	13.8108	156.2392	1.14	8.137249	19.20049
17	172.32	14.0816	158.2384	1.14	9.276464	17.05805
18	174.59	14.3524	160.2376	1.14	10.57517	15.15225
19	176.86	14.6232	162.2368	1.14	12.05569	13.45728
20	179.13	14.894	164.236	1.14	13.74349	11.95009
21	181.4	15.9324	165.4676	1.14	15.66758	10.56115
22	183.67	16.2448	167.4252	1.14	17.86104	9.373766
23	185.94	16.5572	169.3828	1.14	20.36158	8.318743
24	188.21	16.8696	171.3404	1.14	23.21221	7.381478
25	190.48	17.182	173.298	1.14	26.46192	6.548959

APPENDIX B2: Economic assessment of Forest (NPV)

YEAR	Return/ha/yr	cost/ha/yr	Net cash flow(Ct)	1+r	(1+r)^t	Ct/(1+r)^t
1	378.8	26.9	351.9	1.14	1.14	308.6842
2	382.5	27.438	355.062	1.14	1.2996	273.2087
3	386.2	27.976	358.224	1.14	1.481544	241.791
4	389.9	28.514	361.386	1.14	1.68896	213.9695
5	393.6	29.052	364.548	1.14	1.925415	189.3348
6	397.3	40.838	356.462	1.14	2.194973	162.3993
7	401	41.376	359.624	1.14	2.502269	143.7192
8	404.7	41.914	362.786	1.14	2.852586	127.1779
9	408.4	42.452	365.948	1.14	3.251949	112.5319
10	412.1	42.99	369.11	1.14	3.707221	99.56514
11	415.8	54.774	361.026	1.14	4.226232	85.42503
12	419.5	55.848	363.652	1.14	4.817905	75.47928
13	423.2	56.922	366.278	1.14	5.492411	66.68801
14	426.9	57.996	368.904	1.14	6.261349	58.91765
15	430.6	59.07	371.53	1.14	7.137938	52.05005
16	434.3	68.442	365.858	1.14	8.137249	44.96089
17	438	69.784	368.216	1.14	9.276464	39.69357
18	441.7	68.442	373.258	1.14	10.57517	35.2957
19	445.4	69.784	375.616	1.14	12.05569	31.15673
20	449.1	71.126	377.974	1.14	13.74349	27.50204
21	452.8	82.11	370.69	1.14	15.66758	23.65969
22	456.5	83.72	372.78	1.14	17.86104	20.87113
23	460.2	85.33	374.87	1.14	20.36158	18.41065
24	463.9	86.94	376.96	1.14	23.21221	16.23973
25	467.6	88.55	379.05	1.14	26.46192	14.32436

APPENDIX B3: Economic assessment of Marsh (NPV)

YEAR	Return/ha/yr	cost/ha/yr	Net cash flow(Ct)	1+r	(1+r)^t	Ct/(1+r)^t
1	8.16	1.3	6.86	1.14	1.14	6.017544
2	8.32	1.33	6.99	1.14	1.2996	5.378578
3	8.48	1.36	7.12	1.14	1.481544	4.805797
4	8.64	1.39	7.25	1.14	1.68896	4.292582
5	8.8	1.42	7.38	1.14	1.925415	3.832941
6	8.96	1.83	7.13	1.14	2.194973	3.248332
7	9.12	1.86	7.26	1.14	2.502269	2.901367
8	9.28	1.89	7.39	1.14	2.852586	2.590631
9	9.44	1.92	7.52	1.14	3.251949	2.31246
10	9.6	1.95	7.65	1.14	3.707221	2.06354
11	9.76	2.33	7.43	1.14	4.226232	1.758067
12	9.92	2.36	7.56	1.14	4.817905	1.569147
13	10.08	2.39	7.69	1.14	5.492411	1.400114
14	10.24	2.42	7.82	1.14	6.261349	1.248932
15	10.4	2.45	7.95	1.14	7.137938	1.113767
16	10.56	2.83	7.73	1.14	8.137249	0.949952
17	10.72	2.86	7.86	1.14	9.276464	0.847306
18	10.88	2.89	7.99	1.14	10.57517	0.755543
19	11.04	2.92	8.12	1.14	12.05569	0.673541
20	11.2	2.95	8.25	1.14	13.74349	0.600284
21	11.36	3.33	8.03	1.14	15.66758	0.512523
22	11.52	3.36	8.16	1.14	17.86104	0.45686
23	11.68	3.39	8.29	1.14	20.36158	0.407139
24	11.84	3.42	8.42	1.14	23.21221	0.36274
25	12	3.45	8.55	1.14	26.46192	0.323106

APPENDIX B4: Economic assessment of Mudflats (NPV)

YEAR	Return/ha/yr	cost/ha/yr	Net cash flow(Ct)	1+r	(1+r)^t	Ct/(1+r)^t
1	18.9	2	16.9	1.14	1.14	14.82456
2	19.467	2.04	17.427	1.14	1.2996	13.40951
3	20.034	2.08	17.954	1.14	1.481544	12.11844
4	20.601	2.12	18.481	1.14	1.68896	10.94224
5	21.168	2.16	19.008	1.14	1.925415	9.87216
6	21.735	2.54	19.195	1.14	2.194973	8.744984
7	22.302	2.58	19.722	1.14	2.502269	7.881647
8	22.869	2.62	20.249	1.14	2.852586	7.09847
9	23.436	2.66	20.776	1.14	3.251949	6.388785
10	24.003	2.7	21.303	1.14	3.707221	5.746352
11	24.57	3.04	21.53	1.14	4.226232	5.094372
12	25.137	3.08	22.057	1.14	4.817905	4.578131
13	25.704	3.12	22.584	1.14	5.492411	4.111855
14	26.271	3.16	23.111	1.14	6.261349	3.691058
15	26.838	3.2	23.638	1.14	7.137938	3.311601
16	27.405	3.54	23.865	1.14	8.137249	2.932809
17	27.972	3.58	24.392	1.14	9.276464	2.62945
18	28.539	3.62	24.919	1.14	10.57517	2.356369
19	29.106	3.66	25.446	1.14	12.05569	2.110704
20	29.673	3.7	25.973	1.14	13.74349	1.88984
21	30.24	4.04	26.2	1.14	15.66758	1.672243
22	30.807	4.08	26.727	1.14	17.86104	1.496385
23	31.374	4.12	27.254	1.14	20.36158	1.338501
24	31.941	4.16	27.781	1.14	23.21221	1.196827
25	32.508	4.2	28.308	1.14	26.46192	1.069764