UNIVERSITY OF EDUCATION, WINNEBA

HYDRO – MORPHODYNAMIC ASSESSMENT OF URBAN GROWTH ON THE MUNI LAGOON CATCHMENT

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MASTER OF PHILOSOPHY

2020

UNIVERSITY OF EDUCATION, WINNEBA

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A Thesis in the Department of Geography Education, Faculty of Social Sciences, submitted to the School of Graduate Studies, in partial fulfilment

of the requirements for the award of the degree of Master of Philosophy (Geography Education) in the University of Education, Winneba.

JUNE, 2020

DECLARATION

STUDENT'S DECLARATION

I, Okyere Yeboah Emmanuel, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: …………………………………………………………………..

DATE: ………………………………………………………………………..

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

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SIGNATURE: ………………………………………………………………….

DATE: ……………………………………………………………………….

DEDICATION

To my brothers, the late Boateng Bannor and Bright Agyei Mensah, and my mum, Madam Theresa Amofa. Also to all my siblings, family and friends.

ACKNOWLEDGEMENTS

I would like to express my special gratitude to Dr. Kofi Adu- Boahen for his supervisory role, advice and words of encouragements, and to Dr. Ishmael Yaw Dadson for his scholarly assistance. Their comments, constructive criticisms and guidance made it possible for me to complete this thesis and attain this level of my education. I am also grateful to all lecturers in the Department of Geography Education, my Uncle, Rev. Amofa Barima Dominic for his support throughout my education. I also thank my brothers and sisters who supported financially for me to come this far.

I am also highly indebted to Mr. Boniface Owusu Bempah and Hon. Sarpong Kumankuma for their support and encouragement. I am grateful to the staff of Wildlife Division, Director of Town and Country Planning (all of Effutu Municipal), Akosua Village community, Mr. Prince Owusu of Ecolab Legon, Mad. Felicity Ahafianyo of GMeT, Papa Kofi Damte Andoh, Mr. Sanda Mohammed, Mr. Bismark Mensah, Mr. Richard Oppong Agyeman Duah, Mr. Nelson Yeboah Boanu, Mr. Sender Kyeremeh and Ms. Loretta Annan (all of University of Education, Winneba). I pray God reward you accordingly.

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ABBREVIATION

AAS	–	Atomic Absorption Spectrophometry
APHA	–	American Public Health Association
ATSDR	–	Agency for Toxic Substances and Disease Registry
DNA	–	Deoxyribonucleic Acid
DSE	–	Department of Sustainability and Environment
ERDAS	–	Earth Resource Development Assessment Resource
FAAS	–	Flame Atomic Absorption Spectrophometer
FAO	–	Food and Agricultural Organization
HGM	–	Hydro Geomorphic Methods
ICLEI	–	International Council for Local Environment Initiative
IPCC	–	Intergovernmental Panel on Climate Change
IWRM	–	Integrated Water Resource Management
MEA	–	Millenium Ecosystem Assessment
MODIS	–	Moderate Resolution Imaging Spectroradiometer
NOAA	–	National Oceanic and Atmospheric Administration
OECD	–	Organization for Economic Cooperation and Development
SAR	–	Specific Absorption Rate
UN	–	United Nations
UNEP	–	United Nations Environment Programme
USEPA	–	United States Environmental Protection Agency
USGS	–	United States Geological Survey
WES	–	Water- related Ecosystem Services
WHO	–	World Health Organization

ABSTRACT

This study sought to conduct hydro-morphodynamic analysis occurring in the Muni Pomadze Lagoon. Laboratory analysis was employed to determine heavy metals (Cadmium, Lead, Iron, Manganese, and Zinc) present in water and fish samples within the Muni Lagoon. Remotely sensed images were used in modelling encroachment within the Muni catchment for the period 1990- 2019. Temperature and rainfall data were acquired from the Ghana Meteorological Agency to investigate climatic variations and its attendant effects on the catchment. Purposive sampling technique was employed to select ten (10) respondents to participate in interviews for multi-stakeholder cooperation and encroachment issues. Content analysis was used to support evidence gathered from the field. The study revealed that the Muni Lagoon and its tributaries are polluted with heavy metals (Cd, Pb, Fe, and Mn) comparing their concentrations with the USEPA and WRC limit. Fishes within the lagoon were found to pose no harm to consumers as traces of heavy metal were below the FAO/WHO maximum permissible limit. It was again revealed that there is a high rate of encroachment occurring within the catchment accompanied by variations in temperature and rainfall. There is lack of coordination between stakeholders responsible for conserving the Muni Lagoon catchment making the implementation of regulatory activities difficult. The study concluded that urban growth has increased anthropogenic pressures within the catchment that are negatively affecting functioning of the lagoon and its ecological resources. The study recommended that stakeholders should collaborate to regulate human activities within the catchment.

CHAPTER ONE

INTRODUCTION

Background to the study

Wetlands are transitional areas of land temporarily or permanently covered with water endowed with natural resources (Patel, Murth, Singh & Panigrahy, 2009). The Millennium Ecosystem Assessment (MEA, 2005a) estimates conservatively that wetlands cover six to seven percent of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services. Wetlands benefits are estimated at $20 trillion a year and contain about 12% of global carbon pool playing an important role in global carbon cycle (MEA, 2005a). Wetlands provide immense environmental, economic, and social, benefits (IPCC, 1996 cited in Patel et.al, 2009). Wetlands are characterized by a large number of ecological niches and harbour a significant percentage of world's biological diversity (Bergkamp & Orlando, 1999). According to NOAA (2018), wetland serves numerous functions in ecosystem balance such as acting as water filters, providing flood and erosion control, and furnishing food and homes for fish and wildlife. Moreover, wetlands absorb excess nutrients, sediments, and other pollutants before they reach rivers, lakes, and other water bodies and serving as best tourist sites globally.

According to the IPCC Second Assessment Report, climate change will alter the hydrological cycle which may have greater impact on regional water resources. Waters are expected to warm as temperature increases in lakes and rivers. In this sense, plant and animal species that find it difficult adapting to minor changes in temperature may have no other habitat leading to specie endangering. Coastal wetlands will have impact of salinity and change the homeostasis of ecosystem (Patel et.al, 2009).

Wetlands are highly dependent on water levels, and so changes in climatic conditions that affect water availability will highly influence the nature and function of specific wetlands, including the type of plant and animal species within them. It is generally understood, however, that increases in temperature, sea-level rise, and changes in precipitation will degrade those benefits and services (Bergkamp & Orlando, 1999). Wetland loss rates over the next 20 years in coastal Louisiana, due to the combination of sea-level rise and disruption of natural coastal processes, will continue to convert land to open water, threatening the region's fisheries, aquaculture and coastal agriculture, as well as commercial shipping and other industries located near the coast (Louisiana Coastal Wetlands Conservation and Restoration Task Force, 1998; Barras et al., 2003; U.S. Army Corps of Engineers, 2004a).

Urban development has had a significant impact on the surface water bodies and their riparian zones either by size reduction or complete reclamation as they get replaced by concrete structures and black-topped roads due to population (Laloo & Ranjan, 2017). Between 1973 to 1997, Ruiz-Luna and Berlanga-Robles (2003) studied the La Escopama and El Sabalo lagoons of Northwest Mexico and found out that their sizes reduced to less than half that estimated in 1973 as a result of doubling of urban area growing to the north and northeast towards the lagoons.

Urban sprawl is associated with loss of natural wetlands along with loss of core forest habitat, loss of prime farmland and increase of impervious surface (Hasse & Lathrop, 2003). As part of urbanization, industrial effluents, agricultural field run- off, refuse and sewage, domestic wastes like food remnants, soaps and detergents are dumped into bodies of water which are eventually broken to release nutrient serving as grounds for microscopic organisms to survive. This leads to release of carbon elements whiles some of these elements are converted into nitrates and phosphates that uses up lot of dissolved oxygen limiting the amount needed for aquatic life- forms to survive in a process called eutrophication (Gedam, 2016). Also, size of city urban wetland is decreasing rapidly as a result of encroachment. In some areas, governments themselves encroach on wetlands for construction of railway stations and new roads and even as official dumping sites as in the case Pallikaranai marshland in Bangalore (Laloo & Ranjan, 2017).

It is posited that anthropogenic activities through manufacturing and agriculture, industrial and urban waste are discharged into water bodies such as river and lagoons giving rise to detection of heavy metals (Yu, Tsai, Chen & Ho, 2000 cited in Bentum, Anang, Boadu, Koranteng-Addo, & Owusu Antwi, 2011; Obodai, Boamponsem, Adokoh, Essumang, Villawoe, Aheto, & Debrah, 2011).

Ghana has numerous wetlands (Muni-Pomadze, Densu Delta, Sakumo, Songor, Keta Lagoon Complex and Owabi) by virtue of drainage by several rivers. The coastal area is particularly noted for this due to the presences of four major rivers, over 90 lagoons, as well as marshes, estuaries and swamps (Finlayson, Gordon, Ntiamoa-Baidu, Tumbulto & Storrs, 2000).

Activities of people living or working in the immediate vicinity of Fosu lagoon has contributed to the gradual extinction of the lagoon through the activities of the mechanical garages, spraying shops, schools and the district hospitals waste were discharge into the lagoon enriching the lagoon sediment with heavy metals followed the sequence Fe > Pb > Cu > Zn which accumulate in fishes and other aquatic resources which may eventually get into human food chains (Bentum et.al, 2011).

Amatekpor (1994) cited in Gordon, Ntiamoa- Baidu and Ryan (2000) estimates evaporation rates from the open water surface of the Muni Lagoon as being in the order of 1600–1800 mm per year and mean annual temperature is around 27 ◦C partly due to urban growth leading to temperature rise. A study conducted by Tay, Asmah and Biney (2009), indicated high levels of heavy metals of Cd, Pb, Zn and Mg among others in the Muni Lagoon which accumulates in tissues of fishes finally affecting human consumers due to urban growth as the city grows towards the lagoon.

Statement of the problem

Lagoons are increasingly becoming sites of greater importance due to the range of biodiversity it houses and their importance to humans. With this, Patel et.al (2009) adds that wetlands or lagoons support diverse species of plants and animals, and support a wide range of the human population with food, fiber, and raw materials, controls flood, and storm, supply clean water and provides educational and tourist benefits.

The Muni Pomadze wetland or lagoon is one of the most important and internationally recognized lagoons that support the livelihood of the people living around it and elsewhere. Due to climate variability as evidenced in increasing temperatures, high evaporation and sea level rise, the lagoon and its catchment is experiencing changes in the form of reduced size and species of flora and fauna, reduced ecosystem services and water quality (Okyere, Adu- Boahen & Dadson, 2017). Patel et.al (2009) asserted that the main aspects of climate change that will affect wetland distribution and function are rises in temperature, changes in precipitation and sea level.

Due to the increasing population and quest for the development of infrastructure and housing, areas bordering lagoon has become one of the most preferred sites for these developments. In this process, people have encroached into the catchment of the Muni- Pomadze wetland. This has affected the lagoon with all the diverse effects that accompany urban growth. Coastal wetlands or lagoons are degraded through land development which limits the ability of lagoons to provide considerable ecosystem services that lessen the risk of living and working in coastal areas as active wetlands reduces storm surge, coastal floods and minimize damage to life and property (Working Group for Post-Hurricane Planning for the Louisiana Coast, 2006; Day et al., 2007). People living around the lagoon have turned the site into a refuse dump where they deposit most of their domestic waste. The rivers that join the lagoon are also polluted further increasing the problem. This has reduced the ecological health of the lagoon and all aquatic organisms found in them. The lagoon has deposits of heavy metals in its bed sediments, fishes and the water itself.

According to Tay et.al (2009), "Water and sediment in the Muni lagoon had trace metal concentrations with upper mean values as Cd (< 0.002 mg/l, 0.325 ± 0.01 mg/kg), Pb (0.033 ± 0.01 mg/l, 1.46 ± 0.18 mg/kg), Mn (0.434 ± 0.02 mg/l, 63.8 ± 1.50 mg/kg), Zn (0.077 ± 0.001 mg/l, 13.7 ± 0.18 mg/kg), Cu (0.013 ± 0.001 mg/l) and Fe (1.085 ± 0.26 mg/l, 3198.4 ± 3.51 mg/kg), respectively." These traces make the lagoon unhealthy and pose danger for all people who consume fishes from the lagoon. However, in their work, they picked only 3 samples whilst this study increase the number of samples to 9. Again, this study did not consider heavy metal concentration of fish species in the lagoon but this study looked at that. Atampugre (2010) did a comprehensive land cover change on the Muni lagoon catchment but did not necessarily discussed encroachment and its trend within the catchment which this study seeks to tackle. Current literature talks about the effects of urban growth on resources but do not necessarily look at how social and ecological systems can peacefully co-exist. With the literature that the researcher has come across, no study was found to have considered trends of climatic variation and its effects on the Muni lagoon. This study looked at how variation in rainfall and temperature may affect the area extent of the Muni lagoon. Moreover, there are lot of stakeholders performing different roles in conserving the Muni lagoon and its catchment, no work was found to have looked at their collaboration or cooperation working as a team to preserve this resource. This study considered the various stakeholders and how possibly they can work together in ensuring the continuous functioning of the Muni lagoon and its catchment.

Again, interaction with the local people of Winneba indicates that about two streams that fed the lagoon 20 years ago have now diminished as the stream courses are covered with tarred roads and other infrastructure. They further explained that the vegetation that served as the hydrographic centers for those streams have been destroyed as people turned those areas into settlements.

Monitoring and delving deep into how urban encroachment is affecting the lagoon and its catchment area in recent years and metal concentration present in the lagoon will give insight into the various actions and plans to be implemented to sustain the lagoon.

Purpose of the study

The rationale behind this study was to conduct hydro-morphodynamic investigation within the Muni Lagoon and its catchment to create awareness on how much urban growth is causing encroachment and affecting the catchment.

Objectives of the study

1. To model encroachment on the Muni catchment as a result of urban growth from 1990 to 2019
2. To examine the response of area coverage of the Muni Lagoon to temperature and rainfall variations from 1990 to 2019

3. To analyze the ecological health status of the Muni Lagoon by examining heavy metal content in its water and fish samples
4. To explore the multi- stakeholder approaches in conserving the catchment of the Muni Lagoon.

Hypothesis

1. H_a: There is statistically significant relationship between the extent of temperature and rainfall within the Muni Lagoon catchment

   H_o: There is no statistically significant relationship between the extent of temperature and rainfall within the Muni Lagoon catchment

Significance of the study

Conditions in climate keep varying from time to time and it is expected to have its attendant effects on phenomenon that occurs on the earth's surface. Aquatic organisms living in water bodies are supposed to live within a temperature range, however, temperature variations may cause either lowering or increase in temperatures which may pose challenges for survival hence a study into such a phenomena may pave way for necessary actions to be put in place to control the effects. Again, urban growth occurs as population increases and this calls for infrastructural development to provide shelter and amenities for people. In the Muni Lagoon catchment, people are encroaching and building closer to the lagoon catchment hence a study into how urbanization is affecting the catchment may give an idea on the need to set buffer zone and protect flora and fauna within the catchment. Urbanization again leads to increase in pollution which at the long run ends up in water bodies leading to an increase in heavy metal accumulation into rivers and lagoons. This study as it analyzes heavy metals will provide insight on how to control pollution to limit effect on fishes and other organisms which man consumes as a way of protecting humans from getting infected with diseases. Lastly, as this study explores multi- dimensional approaches to conserving the lagoon, it will bring together diverse ideas that may ensure the sustainability of the lagoon. This study will also contribute to the global effort of protecting wetlands that house biodiversity and provide numerous services for humans.

Scope and delimitation of the study

The study was confined to the catchment of the Muni Pomadze Lagoon along the Winneba coast of the central region. The study centred on the 11 communities that surround the Muni Lagoon. These are the people who benefit directly from the lagoon and their actions openly affect the lagoon and its catchment due to the rigorous interaction they have with the wetland and its resources. Experts' ideas of key informants from the Wildlife Division of Forestry, Municipal Assembly, University researchers, NGOs and local perspective were also sought. Climatic variation influence particularly temperature and rainfall was looked at since as urban growth is directly proportional to temperature increase and attendant influence on rainfall. Variations in temperature and rainfall, urban growth and its encroachment on the lagoon were assessed as well as analysis of heavy metal content present in the lagoon. Conservation of the lagoon from the stakeholders aforementioned was also explored.

Structure of the study

The project has five chapters; Chapter One presents a background, statement of the problem, objectives, justification and scope of the study. The Chapter Two covered review of literature related relevant to the topic under discussion. Chapter Three outlined the methodology used in the project such as the research design, population, sample size and techniques. Chapter Four reported the results and finding produced from the investigation done on the field as well as discussed significant issues gathered from the findings. Chapter Five ended the study with summary, conclusions of the project along with recommendations and areas for further research.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This chapter reviewed the relevant literature related to linking coastal wetlands to urban growth and its associated impacts. The review was done under the following themes; global distribution of wetlands, distribution of coastal wetlands, wetlands in Ghana, functions of wetlands and lagoons, drivers of urban growth in Africa, urban development and wetlands, urban growth and wetlands in Ghana, wetlands and climate change, temperature variations and its effects on lagoons, heavy metals, their sources and effects, and multi- stakeholder approaches in water resource management.

Global distribution of wetlands

Wetlands are vital for human survival. They include some of the world's most productive ecosystems and provide ecosystem services leading to countless benefits (MEA, 2005). Wetlands include permanently or seasonally inundated freshwater habitats ranging from lakes and rivers to marshes, along with coastal and marine areas such as estuaries, lagoons, mangroves and reefs. The global water cycle underpins primary production and nutrient recycling and provides fresh water and food for people. Wetlands are used for transport and hydropower. They provide raw materials and genetic resources, including medicines. They also help to mitigate floods, protect coastlines and store and sequester carbon. Many are important for culture, spiritual values, recreation and inspiration (Ramsar Convention on Wetlands, 2012).

According to Davidson, Fluet-Chouinard and Finlayson (2018), globally, 92.8% of continental wetland area is inland and only 7.2% is coastal. Regionally, the largest wetland areas are in Asia (31.8%), North America (27.1%) and Latin America and the Caribbean (Neotropics; 15.8%), with smaller areas in Europe (12.5%), Africa (9.9%) and Oceania (2.9%).

Two broad categories of wetland area assessment are covered by a review done by Davidson et al., (2018): ‘bottom-up’ and ‘top-down’. Bottom-up assessments provide wetland site-level descriptions and national inventories, with area extents. One bottom-up assessment approach has been through compilation of the national and regional directories of important wetlands. Although these provide precise area information for the wetlands covered, they can only provide minimum national, regional and global area figures, because they cover only a selection of major wetlands, albeit including most, if not all, large wetland areas. Finlayson and Spiers (1999) cited in Davidson et al. (2018) concluded that their estimates of global and regional wetland areas were major underestimates because of the lack of adequate inventory in many countries: at that time, only 7% of countries had adequate or good national inventory coverage, with 69% having only partial coverage and 24% having little or no national wetland inventory. Information from Ramsar Convention Contracting Parties’ triennial national reports cited in Davidson et al. (2018), suggests that the extent of national wetland inventory has improved since the assessment of Finlayson and Spiers (1999), from 29 countries with a national inventory in 2002 to 62 (47% of countries) in 2015.

Most of the published assessments of wetland area extent focus on ‘natural’ inland wetlands, with some also including human made inland wetlands such as reservoirs and inundated rice paddies (the latter particularly contributing a major area to the extent of Asian wetlands). For inland wetlands, the area of open waterbodies (i.e. river, lake and reservoir) is estimated with some agreement across remote sensing and atlas-based sources (Nakaegawa 2012 cited in Davidson et al., 2018). Because open water is detectable with optical radiometer sensors, changes in open water can be estimated from available optical remote sensing, from near realtime floods to change over a 30-year time series (Donchyts et al. 2016; Pekel et al. 2016 cited in Davidson et al., 2018). The area covered by seasonal wetlands is divergent between optical land cover maps and wetland-themed maps (Nakaegawa 2012 cited in Davidson et al., 2018). It is unclear to what extent coastal (intertidal) wetlands are included in the wetland areas from some sources. In addition, global inundation extent assessments do not include areas of permanently inundated shallow marine waters (as covered by the scope of the Ramsar Convention), but some of these areas are included in the site-based wetland directories and in some national wetland inventories. It is highly likely that some of the differences in wetland areas reported are a consequence of these differences in definition and types of wetlands covered.

There has been a significant increase over time in the area of global wetlands estimated since the late 1970s (linear correlation of maximum area estimates from each source: R ¼ 0.632, n ¼ 15, P ¼ 0.0115). On average, estimates of wetland area extent have increased between the late 1970s and mid-2010s by 7.2×10^6 km^2, a greater than threefold increase in area estimated.

Therefore, considering that this increasing trend over time of the estimated global extent of wetlands is not a genuine indication of any real temporal increase in global wetland area, especially because: (1) it is known that natural wetlands are continuing to be converted and lost at a rapid pace, with annual rates of loss of 1.21% $year^{-1}$ and 0.82% $year^{-1}$ and (2) the increasing area of human-made wetlands is minor in terms of the total increase in area reported (Davidson, 2014; Dixon et al., 2016 as cited in Davidson et al. 2018) . Rather, the recent increases in global wetland areas estimated are a reflection, inter alia, of refinements in remote sensing approaches: the limitations of optical sensor data (e.g. Landsat and MODIS), the increased spatial resolution of satellite sensors, the more recent use of multi satellite methods combining long wavelength SAR and passive microwave sources capable of detecting inundated areas under forest canopies and cloud cover, and the application of multiyear analysis approaches, which better detect the extent of inter-year variability in inundation than earlier 'time snapshot' approaches. It is also important to make a distinction in these area estimates between wetland area and area of water inundation. The largest inundation area estimated among high-resolution sources, a long-term inundated maximum extent (LTMax) of 17.255×10^6 km^2 (Fluet-Chouinard et al., 2015 as cited in Davidson et al., 2018), is likely to overestimate wetland area.

Many estimates of wetland extent do not distinguish between inland and coastal wetlands, or estimate inland wetlands only. Lehner and Doll (2004) cited in Davidson et al., (2018), provide area figures separately for inland wetlands and coastal wetlands (covering lagoons, estuaries, tidal wetlands, deltas and mangroves) in the source data of the Global Lakes & Wetlands Database (GLWD). Of their total maximum global wetland area of 9.167×10^6 km^2 (from their GLWD-3 dataset), inland wetlands cover an area of 8.507×10^6 km^2 (92.8%) and coastal wetlands account for a much smaller area, namely 0.660×10^6 km^2 (7.2%). A similar area (,0.500×10^6 km^2) for major estuaries only was reported by Agardy and Alder (2005) as cited in Davidson et al., (2018), although it is not clear whether this figure included mangroves, which Giri et al. (2011) as cited in Davidson et al., (2018), estimate as 0.138×10^6 km^2. It was reported that none of these coastal wetland estimates include coral reefs or other nearshore subtidal systems, so that overall coastal wetland area will be considerably higher than is currently reported.

Distribution of coastal lagoons

Except the Antarctica, Nichols and Boon (1994) puts that coastal lagoons occur all over the world and every continent. Together with barriers, flats and marshes, they occupy about 11% of the world coastline, the longest single stretch being the 2800km stretch of leaky lagoons landward of barrier islands on the east of the USA. Lagoons are most common on low- lying aggrading coastal plains with a history of submergence during the last 10,000 years. An abundant supply of sediment is required for barrier building to impound the lagoon, while an adequate exposure to wave action is necessary to transport sediments. According to Nichols and Boon (1994), microtidal coast (tide ranging less than 2 m) are the most favourable for barrier beach building by waves and consequent lagoon containment. In direct contrast, macrotidal environments (tidal rage greater than 4 m) exhibit few barrier- lagoon systems because of stronger tidal currents. Some of the best developed, largest barrier beach shores in New Zealand occur in Tasman and Golden Bays where tide ranges are up to 4m.

Nichols and Boon (1994) further described a distinctive association of lagoon-types based on climate. They explained that when looking at mid- latitude lagoons, they are characterized by catchments and basins having yearly excess of precipitation over evaporation though seasonal deficits may occur. The results is rigorous stream flow from catchments that typically have moderate specific sediment yields (a range of 10 to 100 ton/km2/year is suggested). Sedimentation in the lagoon is thus dominantly fluvial in origin rather than marine, though significant biogenic production can also occur.

Wetlands in Ghana

Since Convention on Wetlands of International Importance (Ramsar Convention, 1971) came into force, wetlands have been internationally recognized as ecosystems of considerable importance, comparable to our forests, rangelands and marine ecosystems. Kulser and Kentula (1992), explains classification of wetland as involving the grouping of wetlands by specified characteristics (vegetation, hydrology, soils, animal species present, function, value, etc.) to serve specific goals. Based on HGM dynamics of wetlands, Gwin, Kentula and Shaffer (1999) defined four classifications of naturally occurring wetlands. These are depression, lacustrine fringe, riverine, and slope. However, Brinson (1993) identifies a more detailed listed wetland classes that are distinguishable at the content scale as depression, tidal fringe, lacustrine, fringe, slope, mineral soil flats, organic soil flats, and riverine. The water found in wetlands can be freshwater, brackish, or saltwater. The main wetland types include swamps, marshes, bogs, and fens; and sub-types include mangrove, carr, pocosin and varzea and hence can be categorized into three main groups. Marine and Coastal Zone wetlands, Inland wetlands and Constructed or Human-made wetlands. (Ramsar Convention 1971). The Government of Ghana recognises the importance of wetlands as habitat for wildlife, in the maintenance of the water table, mitigation of flood conditions and water purification. Wetlands resources are also known to be of socio-economic importance and have been harvested for construction poles, fuel-wood, timber for furniture and craft work.

a) Marine and coastal zone wetlands

These are the types of wetlands that are found within the coastal zone of Ghana and are mainly saltwater ecosystems. They are primarily associated with flood plains of estuaries of large rivers and watercourses. The major coastal wetlands or salt-water ecosystems are: the Rocky Marine shores found at Senya Bereku and Cape three points etc, Estuarine Waters, which include the mouth of Volta, Pra, Butre and Ankobra etc. Again we also have mangrove and tidal forest encompassing the lower reaches of Volta, Oyibi, Kakum and Ankobra etc and lastly we have the Brackish or saline lagoons which include the open Korle, Amisa and closed Songor and the Muni. It extends to marine waters, the depth of which at low tide does not exceed six meters. This is exemplified by areas such as the sandy beaches and shallow waters along the Brenu Akyim seashore in the Central Region. Marine and Coastal Zone wetlands includes Marine waters— permanent shallow waters less than six metres deep at low tide; includes sea bays, straits), Subtidal aquatic beds; includes (kelp beds, Sea grasses, tropical marine meadows,) Coral reefs, Rocky marine shores; includes rocky offshore islands, sea cliffs. (Ministry of Lands and Forestry, 1999).

b) Inland wetlands

Inland waters are mainly freshwater ecosystems. They occur wherever groundwater, surface springs, streams or run-off cause saturated soils, frequent flooding or create temporary and/or permanently shallow water bodies. Inland or freshwater wetlands, especially freshwater marshes are the most widespread and important world-wide. In Ghana, this is the most extensive as it encompasses all the natural drainage systems. They are as follows; Freshwater marshes (Black, Red and White Volta), Freshwater swamp forest (Amansuri), Permanent river or stream (Densu, Afram, Oti and Ankobra) and Permanent freshwater lake (Bosomtwi). These are some of the numerous examples according to the (Ramsar Convention, 1971) Permanent rivers and streams; includes waterfalls, Seasonal and irregular rivers and streams, Inland deltas (permanent), Riverine floodplains; includes river flats, flooded, river basins, seasonally flooded grassland, savanna, and palm savanna, Permanent freshwater lakes and ponds includes large oxbow lakes, Seasonal/ intermittent freshwater lakes, floodplain lakes, etc. (Ministry of Lands and Forestry, 1999).

c) Constructed or human- made Wetlands

The Ramsar Convention also recognizes four categories of man-made or artificial wetlands. These are wetlands constructed for aquaculture, agriculture, salt exploitation, water storage and urban/industrial purposes. In Ghana, these are as follows: Irrigated land (Tono, Vea, Dawhenya, Anum Valley), Salt Pans (Elmina Salt Pans, Songor, Densu Delta), Reservoirs (Volta Lake, Kpong head pond, Brimsu reservoir), Urban/Industrial (Tema Sewerage Treatment Plant). All the above mentioned wetlands are classified as wetlands made by man for their various practices which seem to serve various needs for the human population. (Ministry of Lands and Forestry, 1999).

Drivers of urban growth in Africa

Report published by the UN in 2017 Drivers of Migration and Urbanization in Africa indicates that about 50% of the world population now lives in cities which is even expected to increase to 75% by 2050. One recent United Nations report offers the prediction that by 2034 50 percent of Africa's population is expected to be living as 'urban' dwellers. Not only this, at least for the past 50 years, Africa has experienced the world's most rapid rate of urban population growth and is likely to continue to do so for the next century (United Nations, 2012). Several urban scholars such as Parnell and Pieterse (2014) and Grant (2015) has been pointed out by, the scale and velocity of contemporary urbanization in Africa is markedly different to the historical urbanization experience of the global North. Grant (2015) asserted that, the rapid expansion which is occurring in African cities is a component of what is termed the 'second urban transition'. This transition is producing a situation that most of the world's urban population is now no longer resident in rich countries but instead is found in low and middle income economies, including sub-Saharan Africa. The urbanization processes taking place in the global South differ in many respects from the first urbanization wave as experienced in now advanced economies (Grant, 2015).

Most importantly, the primary wave of urbanization was observed via and aligned to industrialization strategies and the increase in of what could be defined as formal work opportunities. The 2nd urbanization wave is markedly special and for this reason poses an array of complicated troubles around sustainable socio- economic development. It is outstanding firstly by means of its scale and rapidity of increase of urban populations. Another difference is that the urbanization trends impacting upon urban Africa are happening and reflecting a country of disaster which is manifest in the boom of informality in urban life (Parnell & Pieterse, 2014). As Grant (2015: 135) reflects, the mass of urban dwellers in Africa "work outside of the formal economy, live in informal housing, and conduct business without using banks". It will be best if Africa need generates productive employment opportunities and livelihoods for the 7-10 million young people who are entering the labour force each year, with the hope that majority or most of them will be living in the cities as a consequence of the youthful nature of migration streams (Turok, 2012a, 2012b). For the majority of inhabitants of urban Africa, the informal city – as mirrored in informal settlements and the primacy of informal sector employment – is the real African city (Grant, 2015). The limited growth of industrial employment in sub-Saharan Africa starkly demonstrates the sharp contrasts that must be drawn between Africa's contemporary urban transition and that of the first urban transition as was experienced in the global North.

Urban development and wetlands

According to recent estimates, nearly 4 billion people now live in urban areas (United Nations, 2014). This growth presents enormous environmental challenges as increased demand for land and resources has a direct detrimental effect on wetlands. Whilst cities currently only occupy 2% of the Earth's surface, they use 75% of the world's natural resources and generate 70% of all the waste produced globally (ICLEI, 2010). Continuing population growth and urbanisation, are projected to add 2.5 billion people to the urban population by 2050 (United Nations, 2014). With an ever increasing global urban population, sustainable development challenges will be increasingly concentrated in cities, especially in the lower income countries where the pace of urbanisation is predicted to be fastest. Wetlands should be considered as solution providers within an urban and peri-urban context, which can mitigate risks from a changing climate, support food production for a growing population and generate income through tourism and recreation (Ramsar, 2013 cited in Wildfowl and Wetland Consulting Trust, 2018).

Human settlements have historically evolved around wetlands and watercourses. Increased urbanisation has put natural wetlands under threat from conversion to land for development or through degradation from pollution. Wetlands located in the urban and urban fringe are particularly sensitive to unsustainable use; they are usually not included within urban planning decisions and are often not the responsibility of a single agency, thus leading to poor governance. Urban wetlands need to be conserved, restored and managed to maintain the multiple services they provide. However, the fact that they are not usually included within urban planning decisions makes their conservation and wise use a very challenging issue. Wetland conservation needs to be mainstreamed into urban decision making (Wildfowl & Wetlands Trust Consulting, 2018).

The main threats to urban wetlands include according to the WWT Consulting (2018) include:

- Draining and infilling for housing or other developments
- Loss of biodiversity by conversion to open public parks and recreational lakes
- Solid waste and wastewater pollution
- Channelization of rivers and streams
- Hydrological disconnection of the wetlands from watercourses
- The use of hard infrastructure solutions rather than green infrastructure
- Invasive species resulting in the loss of native species

Urban developments, if designed with green infrastructure and environmental sensitivity at their heart, can deliver numerous financial, environmental and socio-cultural benefits. Targeted at places where it can have a positive environmental impact, and designed integrating space for both wildlife, people and prosperity, newly built developments can make a positive contribution to nature and promote health and wellbeing of citizens. The use of green infrastructure (such as such as Water Sensitive Urban Design approaches, e.g. Sustainable Drainage Systems) in new developments is recognised as a key approach to retrofitting wetlands into the urban environment; green infrastructure plays a key role in improving the quality of surface water and storing stormwater therefore reducing flooding. In the case of housing developments in particular, the implementation of green infrastructure is known to deliver benefits for wildlife, residents, the economy and developers (WWT Consulting, 2018). Some of the key “benefits for all” include:

- Benefits for wildlife: creation of habitat for biodiversity; habitat connectivity
- Benefits for residents: enjoyment of nature; sense of community; contributing to health and wellbeing
- Benefits for the economy: financially sustainable green infrastructure; employment; reduced health care costs
- Benefits for developers: higher market value; satisfied customers; improved environmental performance (Wildfowl and Wildlife Trusts Consulting, 2018)

Urban growth and wetlands in Ghana

In a study conducted by Amo, Bih, Agyeman, Gyamfi, and Mensah (2017) in Kumasi (Ghana), they posited that building structures have taken most portions of the wetlands in Kumasi. These are mainly residential buildings, religious buildings, fuel service stations, industrial plants, ware houses and shops. Betey (2012) cited in Amo et al., (2017), emphasize that, various types of houses such as compound houses, single family self- contained structures, single room structures and wooden structures have been built within 20m from water channels. Abdul-Razak (2012) cited in Amo et al., (2017), also added that, the main reason why most people are building on wetland areas in the urban centres is that of their relatively cheap cost yet the long term cost of maintenance cannot be ascertained. Construction of these facilities may involve similar range of activities. This may include site preparation, setting out, excavation, substructure construction, superstructure construction, mechanical and electrical installation and finishes. The activities involve in the construction of these facilities may have negative consequences on the wetlands which must be protected in order to maintain the sustainability of our natural resources.

On the other hand, urbanisation coupled with high rate of migration to the urban centres in search of urban benefits has increase demand for housing and accommodation. Unfortunately, lands for constructional purposes are very scarce in the urban centres. Therefore, outside the buffer range of the wetlands are used to substitute the scarcity of land for infrastructural development (Amo et al., 2017). According to Sithole and Goredema (2013) cited in Amo et al., (2017), rapid urbanization and urban growth have led to the construction of housing units and other buildings on wetlands to cater for the needs of the growing population. Sithole and Goredema (2013) cited in Amo et al., (2017) reported that, residents have become vulnerable to water-borne diseases, such as cholera, typhoid, dysentery and diarrhoea among others due to building on wetlands. As a result, most residence of these areas may spend huge sums of money to maintain their health. Consequently, cost on importation medical suppliers by the nation may be high, looking at the high inflation rate at 16.90% and the current economic situation of the country. Also, buildings on wetlands may experience some level of structural defects due to the presence of high amount of ground water.

Amo et al., (2017) mentioned some specific effects urban wetland destruction have on humans. They include;

Risk of structural collapse: The various defects that may develop in the building may render the building liable to total collapse. Prolong development of dampness, cracks and other defects may result in the general weakness of the structure which may render the building or the structure to total collapse. According to Sithole and Goredema (2013) cited in Amo et al., (2017), there is an increase in the number of people living in wetlands and the inhabitants of wetlands encounter a number of problems that include structural failure of their housing units

Also, destruction of aquatic and terrestrial lives: The aquatic and terrestrial lives of the wetlands may be destroyed through pollution caused by construction activities. Attuquayefio and Fobil (2005) cited in Amo et al., (2017), about 1% of the world's recorded species have been lost, of which human activities contributed about 75%. When dangerous and poisonous substances from construction activities get to the wetlands, they have the tendency of harming the organisms of the wetlands. These substances destroy the conditions that support life and existence of aquatic and terrestrial species thereby causing destruction to them.

Again, changes in the atmospheric pressure: The destruction of the wetlands also causes changes in the atmospheric pressure. The vegetation of the wetlands helps to regulate the amount of air pressure within the environment. The European Commission (2009) cited in Amo et al., (2017) account that, terrestrial and marine ecosystems play an important role in regulating climate by absorbing roughly half of manmade carbon emissions. The vegetation of the cities and urban centres are normally minimal and limited to the wetlands since most of the areas within the urban centres are either tarred or bare. Therefore, when the vegetation of the wetlands is destroyed, the regulation of the atmosphere will be reduced thereby affecting the atmospheric pressure. According to Didyk et al., (2012) cited in Amo et al., (2017), numerous studies in medical meteorology indicate that abrupt daily variations in the atmospheric pressure have adverse effects on health and different kind of human activity. Also, wetlands remove and store greenhouse gases from the earth's atmosphere, therefore the destruction of wetlands may result in global warming (Sithole & Goredema, 2013 cited in Amo et al., 2017).

Reduction in the amount of oxygen in the atmosphere: The destruction of the wetlands can also cause the reduction in the amount of oxygen in the atmosphere. The

European Commission (2009) cited in Amo et al (2017), emphasized that, the continuing loss of biodiversity and degradation of ecosystems weakens their ability to provide essential services. Vegetation helps to regulate the oxygen in the environment through its gaseous exchange. In the urban areas amount of pollution is very high because of fumes from vehicles and other industrial machines. When the vegetation of the wetlands are destroyed by the construction activities, the chemical processes of the green plants are also reduced thereby affecting their gaseous exchange, that is green plants taking in or using carbon dioxide from human being other animals to process their food and in the end giving out oxygen as a result of photosynthesis.

Wetlands and climate change

A wetland according to Jin, Cant and Todd (2009) is defined as areas that have permanently or temporarily shallow lentic water, or that have soil that is saturated at or near the surface. They include lakes, estuaries, mudflats, shores and bays. According to these authors, wetlands depend on, are shaped by, and affect climate. There is growing scientific evidences that human-induced climate change, primarily through increases in greenhouse gas concentrations resulting from burning fossil fuels and deforesting large areas of land, is occurring (Solomon, Qin, Manning, Marquis, Averyt, Tignor, Miller, & Chen, 2007); earth's climate has varied naturally throughout its history, with cycles of warming and cooling (Jin et al., 2009).

A steady increase in greenhouse gas concentrations in the atmosphere over the last 100 years from anthropogenic sources has enhanced the greenhouse effect, and has produced 'global warming' of the order of approximately 0.85°C since 1880. This warming, in turn, has affected global weather patterns, resulting in changes to other climatic elements such as rainfall, snow cover, sea ice extent, evaporation and wind patterns across the globe. Warming of the climate system is observed and since the

1950s many of the observed changes are unprecedented. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 ((Robertson, Bowie, Death, & Collins, 2016).

Climate change has a significant impact on physical and biological systems globally (Parmesan, 2006). Climate and wetlands are interconnected in complex ways, and any change in either can induce a change in the other. The responses of wetlands to climate change are a result of a balance between changes in water regime, temperature, nutrient cycling, physiological acclimation and community reorganisation (Oechel et al., 2000 cited in Jin et. al., 2009), making the latter aver that climate change is the only one way in which the environment and human activities are affecting wetlands. Internationally there has been significant investments in climate change research to aid management (e.g. Heller et al. 2009; Bates et al. 2011; Jeppesen, et al. 2011; Palmer et al. 2014 cited in Jin et. al., 2009) but less attention is paid to climate change impact on freshwater species and their habitats (Solomon et al., 2007); while there have been numerous studies investigating land use change impacts on WES (Brauman et al. 2014; Gao et al. 2016 cited in Chang & Bonnette, 2016) only a few studies examined climate change impacts on WES (e.g., Nelson et al. 2013, Hoyer and Chang 2014, Lorencova et al. 2016 cited inChang & Bonnette, 2016). Impacts from climate change are inevitable in the decades ahead, and wetlands are among the ecosystems most at risk (Jin et. al., 2009). Climate change impact on wetlands are categorized and discussed under the following themes: ecosystem services and biota, varying water availability, droughts and floods, and water quality.

Ecosystem services provided by wetlands

Wetlands play two important roles in ecosystem feedbacks to climate: as sinks and sources of greenhouse gases, and as regulators of climate. They are different to other biomes in that they have the ability to sequester large amounts of carbon in their waterlogged soils. In fact, they are net sinks for carbon dioxide and provide the largest below ground stores of carbon (Jin et. al., 2009).

Any waterbodies such as rivers, springs, wetlands, lakes, reservoirs, and swamps offer space for ecosystems and contain specific ecosystem structures and functions (Chang & Bonnette, 2016). Of all ecosystems, freshwater aquatic ecosystems appear to have the highest proportion of species at risk of extinction by climate change (Millennium Ecosystem Assessment, 2005b), because of their higher sensitivity to climate change and limited capacity for adaptation (Carpenter et al. 1992 cited in Jin et al., 2009; Millennium Ecosystem Assessment, 2005b). While the effects of climate change may not be seen yet on most fish populations, stream temperature increases, decreased dissolved oxygen, changing sediment and nutrient loads, and changes to hydrographs could lead to decreased productivity of native fish populations and eventually extinction of fish species around the world (Ficke et al. 2007 cited in Chang & Bonnette, 2016). In southwestern Balkan mountain rivers in southern Europe, with declines in summer flow and rising stream temperatures, the western Balkan trout population and other biota are projected to decline substantially in the latter half of the 21st century (Papadaki et al. 2016 cited in Chang & Bonnette, 2016). Similarly, as a result of decreased flow (20%–29%) and increased water temperature (4–4.2°C), habitat suitability for large brown trout is also projected to decline in the near future (2011–2040) in the Cabriel river in Iberian Peninsula, climate change is projected to decrease most of California's salmon species in the 21st century (Katz et al. 2013 cited in Chang & Bonnette, 2016).

Together with overfishing, ocean warming and acidifications will have negative consequences on shellfish fisheries, aquaculture and corals, leading to shifts in tourism flows and thus revenues associated with the industry (Weatherdon et al. 2016 cited in Chang & Bonnette, 2016). As air temperatures rise, so will wetland water temperatures; increasing water temperature reduces the capacity of water bodies to store dissolved oxygen, increasing the likelihood of anoxia (Jin et. al., 2009). Wetland ecosystems are fundamentally linked to hydrology, which creates the physico-chemical conditions that make them different from well-drained terrestrial or fully aquatic deepwater systems (Mitsch and Gosselink 2000). Thus wetlands are naturally sensitive to changes in hydrology (Jin et. al., 2009). The ecological consequences of climate change on wetlands will depend largely on changes in hydrological regime and water quality (Jin et. al., 2009). The most pronounced effects will occur through altered hydrological regimes and more frequent or intense extreme weather events as heatwaves, droughts, storms and floods (Bates, Kundzewicz, Wu & Palutikof, 2008)

Varying water availability, floods and drought

The dominant sources of water to wetlands are precipitation, surface runoff, groundwater discharge, and high or overbank stream flows and evaporation, transpiration, seepage to groundwater, and overflow result in loss of water in wetlands (Jin et al., 2009). The balance of water inputs and outputs determines the hydrology of wetlands. The vulnerability of wetlands to a drying climate depends, in large part, on the sources of their water supply (Poff, Brinson & Day, 2002). Wetlands that depend upon precipitation and surface runoff are more sensitive to drying than those fed by groundwater (Winter, 2000). In general, the shallower the water depth and the more dependent the water source is on direct precipitation, the more likely these wetlands will be vulnerable to climate change; shallow, intermittent wetlands in hot dry areas will disappear (Jin et al., 2009). Changes in air temperatures and atmospheric circulation will have a range of implications for the water cycle, altering the extent of snow and ice cover, and the hydrological regime of rivers and groundwater (Solomon et al., 2007).

Entering 2016, California completed its fourth consecutive year of below-average runoff and snowpack, making it the eighth year (out of the last nine) with below-average runoff levels (Chang & Bonnette, 2016). Even though mean annual water availability may remain the same under a changing climate, the amplified seasonality of water availability and increased frequency of extreme hydrologic events will have substantial effect on WES. For example, in high alpine watersheds, rising air temperatures will bring more rain than snow in winter and result in less snow accumulation and earlier snow melt (Barnett, Adam & Lettenmaier, 2005), thus limiting summer water supply when humans and ecosystems need water most (Chang & Bonnette, 2016).

Drought is a recurring event and climate change and variability are the biggest factors affecting water availability and reliability (DSE, 2008 cited in Jin et al, 2009). Drought frequency is projected to increase under climate change scenarios (Jung and Chang 2011; Chang and Bonnette 2016). In their study on climate change in Victoria, Jin et al., (2009) asserted that climate change will increase the frequency and severity of drought in Victoria. Chang and Bonnette (2016) has it that by 2080, about 20–38% of the population of the Mediterranean regions will be living in areas of increased water stress because they have high vulnerability to climate change. Decreases in streamflow will result in further reductions in groundwater recharge in the Candelaro catchment, threatening sustainable supply of water (D'Agostino Trisorio, Lamaddalena, & Ragab, 2010). Again, in a study by Bangash et al. (2013) and Terrado et al. (2014) cited in Chang and Bonnette (2016) on the Llobregat basin in Catalonia, Spain, it is revealed that water provisioning in the basin is highly sensitive to climate change, and water supply and delivery are likely to decline significantly; a subsequent study in the same basin shows that annual water volume in the basin decreased by 80% from normal in dry years. In the east Mediterranean island states, 3°C warming is projected to decrease freshwater resources by 10-30% in Crete (Koutroulis, Grillakis, Daliakopoulos, Tsanis, & Jacob, 2016).

In southern Australia, climate change will reduce not only streamflow but also recharge, although specific impacts of climate change at a local scale will vary depending on topographic and soil conditions (Dawes et al. 2012 cited in Chang & Bonnette, 2016). In southwest Western Australia, a 13.6% decline in mean annual rainfall is projected to result in 36% decline in annual streamflow in the mid-21st century. Annual runoff is projected to decline by 74% with a 23.6 reduction in precipitation in the late 21st century (Chang & Bonnette, 2016). In Mountain Rivers of the southwestern Balkans in Europe, due to decreases in summer precipitation and increases in air temperature, minimum flows are projected to decline in the mid-and late-21st century, particularly under the high emission scenario, increasing the risk of droughts (Papadaki et al. 2016 cited in Chang & Bonnette, 2016).

Additionally, climate change may shift the distribution of rainfall events with more extreme weather events, which may lead to more frequent floods and droughts (Chang & Bonnette, 2016). According to the IPCC 5th assessment report, flood probability is projected to rise in mid-latitudes where the majority of the world population resides (Chang & Bonnette, 2016). Such extreme weather events may exceed the drainage basin's capacity to regulate floods, thus damaging communities that are prone to floods; Water in the Llobregat basin in Catalonia, Spain increased 160% in wet years, corroborating the sensitivity of the region to severe climate shifts (Terrado, Acuna, Ennaanay, Tallis, & Sabater, 2014). With expected increases in the frequency of extreme events under a warming atmosphere, the probability of floods is likely to increase worldwide (Milly, Wetherald, Dunne & Delworth, 2002) as drainage basin capacity to regulate floods will decline. Alfieri, Feyen, Dottori and Bianchi (2015) found that flood risk is projected to increase by an average 220% by the end of the 21st century under a 4°C warming scenario.

Water quality

Higher water temperature and increased variations in hydrology under the projected climate change are likely to affect water quality (Poff et al. 2002). Increasing nutrient loading and sediment input from fire, erosion and flooding will increase water turbidity. Groundwater-fed wetlands may become more acidic in a drier climate (Webster et al. 1990 cited in Jin et al., 2009), whereas those fed by surface water may become more alkaline (Schindler, 2001). If wetlands with acid sulfate sediments become dry and expose the sediments to the air, acidification of wetlands results. Other risks associated with acid sulphate soils include mobilisation of metals, deoxygenation of the water column and production of toxic gases. Decreases in water levels can also increase the concentration of salts and pollutants, even in wetlands with normally low ionic or pollutant concentrations. On the other hand, a decrease in groundwater recharge may reduce the discharge of saline groundwater, so that one of the causes of secondary salinization might diminish (Jin et al., 2009). Further, saltwater intrusion as a result of rising sea levels, increases in coastal storm surges, decreases in freshwater inputs, and increased drought frequency and intensity are very likely to expand the areas of salinization of coastal freshwater aquifers and coastal wetlands (Pittock 2003). Coastal wetlands may be made worse by dieback of shoreline plants caused by increased salinity (Pittock 2003). In areas where the climate becomes hotter and drier, human activities to counteract the increased aridity (e.g., more irrigation, diversions and impoundments) might exacerbate secondary salinization (Williams 2001; Nielsen & Brock 2009). Increases in the variability of wetland levels will also lead to highly variable changes in water quality. It also increases the decomposition rate of organic material, which in turn increases the biological oxygen demand, further decreasing the concentration of dissolved oxygen.

Temperature variations and its effects on lagoons

Intergovernmental Panel on Climate Change in 2007 reported that in the last 100 years, global air temperature has increased by 0.76°C and is expected to increase by an additional 1.1- 6.4°C by 2100. Temperature increases will vary regionally and will be modulated by natural climate variation (Smith, Cusack, Colman, Folland, Harris & Murphy, 2007; Keenlyside, Latif, Jungclaus, Kornblueh & Roeckner, 2008). IPCC (2007) signaled greatest warning with the high latitudes during winter since temperature changes will affect them much.

Changes in air temperature greatly influence the water temperature of slow-moving, shallow water bodies such as coastal lagoons (Turner, 2003). The temperature of the world's oceans have increased, on average, by 0.3°C (IPCC, 2007) and is likely to continue to increase through the next century, because air temperatures increase more quickly over land than oceans. Coastal waters are therefore likely to increase more rapidly (Nixon, Granger & Buckley, 2003). Jiang, Huang and Han (2014) put forth that type of temperature change is consistent with the process of land use change and urbanization in a study they conducted in Beijing. This implies that increase in urban growth around wetlands may have effect on their surface temperatures.

This rate of increase is approximately four times greater than that of the ocean. Although much is not published on the long term data for water temperature in coastal lagoons, the shallow nature and low flushing rates of coastal lagoons indicate that water temperatures in lagoons will increase even more rapidly than open waters in open estuaries.

Water temperature in turn influences dissolved oxygen concentrations, as well as physiology of lagoon organisms, species' ranges and patterns of migration (Turner, 2003). Many marine species live near their threshold of thermal tolerance (Tomanek & Somero, 1999) at which even small changes in temperature can have large impacts on their viability. In addition, these ecosystems are more susceptible to increases in colonization of invasive species that may thrive in warmer waters (Stachowicz, Terwin, Whitlatch & Osman, 2002). As lagoon temperature increases, dissolved oxygen concentrations are likely to decrease especially as seasonal stratification of the water column isolates oxygen- depleted deep waters from oxygen- rich surface waters.

Reduced dissolved oxygen adversely affects aerobic biota with benthic communities expected to be the most severely stressed. In lagoons with high flushing rates, the influx ocean water will interrupt stratification, causing the water column to mix. In restricted lagoon with low flushing rates and high nutrients input, temperature increases will increase the probability and severity of hypoxic events (D'Avanzo & Kremer, 1994). Chronic hypoxia in coastal waters has been linked to long- term changes in benthic community structure characterized by a persistent shift in species compostion to more hypoxia- tolerant species and an overall decrease in species diversity (Conley, Carstensen, Aertebjerg, Christensen, Dalsgaard, Hansen & Josefson, 2007).

The timing (phenology) of lagoon processes will also be affected by temperature increases. For example changes in air temperature have affected the timing and route of migrating birds that traditionally stop over at coastal lagoons (Gatter, 1992). Developmental and reproductive timing in shellfish as evidenced by early gonad maturation and spawning in bay scallops is associated with higher temperatures (Sastry, 1963 cited in Barber & Blake, 2006). Changes in plankton phenology have also been observed, with zooplankton becoming active earlier in the year following relatively warm winters (Edwards & Richardson, 2004). Increased grazing of phytoplankton abundance associated with warmer temperatures (Oviatt, 2004). Warmer temperatures are also thought to contribute to observed declines in seagrass abundance (Blintz, Nixon, Buckley, & Granger, 2003)

Heavy metals

Over recent decades a marked decline in the health of lagoon, and wetland habitat has been reported over a global scale (Callaway, Delaune, & Patrick, 1998; Bellucci, Frignani, Paolucci, & Ravanelli, 2002; Accornero, Gnerre, & Manfra, 2008). These changes are typically associated with anthropogenic activities and often result in decreased biodiversity, alteration of ecosystem function and an overall loss of habitat (Callaway *et al* 1998). Primary drivers for this decline include the modification of hydrological processes (Kim, Engel, Lim, Larson, & Duncan, 2007), changing land use practices (Kim *et al* 2007, Accornero *et al* 2008), deforestation (Fuller, Simone, & Driscoll, 1988), intensified agriculture (Bramley & Roth 2002) and pollution from household and industrial waste (Callaway et al., 1998, Bellucci et al., 2002)

Heavy metals are chemical elements with a specific gravity that is at least 5 times the specific gravity of water. Heavy metals are not biodegradable and thus are harmful to plants, aquatic animals and human health at certain levels of exposure (Mustafa & Nilgun, 2006). Heavy metals are usually present in trace amounts in natural waters but many of them are toxic even at very low concentrations (Herawati, Suzuki, Hayashi, Rivai, & Koyoma, 2000). Metals such as arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, zinc and selenium are highly toxic even in minor quantity.

Heavy metals become toxic when they are not metabolised by the body and accumulate in the soft tissues. They may enter the human body through food, water, air or absorption through the skin when they come in contact with humans in agriculture, manufacturing, pharmaceutical, industrial or residential settings.

Sources of heavy metals

Basically, literature reveals that there are two main sources of heavy metals in the environment, being it natural or anthropogenic. The natural processes include such emissions like volcanic eruptions, sea-salt sprays, forest fires, rock weathering, biogenic sources and wind-borne soil particles. Natural weathering processes can lead to the release of metals from their endemic spheres to different environment compartments. Heavy metals can be found in the form of hydroxides, oxides, sulphides, sulphates, phosphates, silicates and organic compounds. The most common heavy metals are lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), zinc (Zn) and copper (Cu). Although the aforementioned heavy metals can be found in traces, they still cause serious health problems to human and other mammals (Herawati et al., 2000)

The anthropogenic processes are from industries, agriculture, wastewater, mining and metallurgical processes, and runoffs also lead to the release of pollutants to different environmental compartments. Anthropogenic processes of heavy metals have been noted to go beyond the natural fluxes for some metals. Metals naturally emitted in wind-blown dusts are mostly from industrial areas. Some important anthropogenic sources which significantly contribute to the heavy metal contamination in the environment include automobile exhaust which releases lead; smelting which releases arsenic, copper and zinc; insecticides which release arsenic and burning of fossil fuels which release nickel, vanadium, mercury, selenium and tin (He, Yang, & Stoffella, 2005)

Effects of heavy metals on water

Although there are many sources of water contamination, industrialisation and urbanisation are two of the culprits for the increased level of heavy metal water contamination. Heavy metals are transported by runoff from industries, municipalities and urban areas. Most of these metals end up accumulating in the soil and sediments of water bodies (Musilova, Arvay, Vollmannova, Toth, & Tomas, 2016)

Heavy metals can be found in traces in water sources and still be very toxic and impose serious health problems to humans and other ecosystems. This is because the toxicity level of a metal depends on factors such as the organisms which are exposed to it, its nature, its biological role and the period at which the organisms are exposed to the metal. Food chains and food webs symbolize the relationships amongst organisms. Therefore, the contamination of water by heavy metals actually affects all organisms. Humans, an example of organisms feeding at the highest level, are more prone to serious health problems because the concentrations of heavy metals increase in the food chain (Lee, Bigham, & Faure, 2002).

Cadmium

Cadmium occurs naturally in soils as a result of the weathering of the parent rock (Environment Agency, 2009). Sedimentary rocks have the greatest range of cadmium concentrations with the highest values found in sedimentary phosphate deposits and black slates (Environment Agency, 2009). Large concentrations of Cd in the soil are associated with parent material (black slates) and most are manmade (burning of fossil fuels, application of fertilizers, sewage sludge, plastic waste and e-waste) which is responsible for soil contamination and also contaminates pasture (Reis, Pardo, Camargos & Oba, 2010). Anthropogenic sources of cadmium are much more significant than natural emissions and account for its ubiquitous presence in soil (ATSDR, 2008; Environment Agency, 2009). Atmospheric deposition is also an important source of cadmium pollution (ATSDR, 2008; Environment Agency, 2009). The major sources of atmospheric emissions are non-ferrous metal production, fossil fuel combustion, waste incineration, and iron and steel production (ATSDR, 2008). A representative deposition rate to agricultural land across the European Union has been estimated to be 3g of cadmium per hectare per year (Environment Agency, 2009). The primary commercial source of cadmium is as a byproduct from the processing of zinc ores including sphalerite and smithsonite (Environment Agency, 2009). Cadmium metal, its alloys and compounds have been used in a variety of different industrial and consumer products, although most uses are now declining due to concerns about its toxicity (ATSDR, 2008; Environment Agency, 2009).

In aquatic ecosystems, cadmium can bioaccumulate in mussels, oysters, shrimps, lobsters and fish. The susceptibility to cadmium can vary greatly between aquatic organisms. Salt-water organisms are known to be more resistant to cadmium poisoning than freshwater organisms. Animals eating or drinking cadmium sometimes get high blood-pressures, liver disease and nerve or brain damage (Goyer, 1991). Cadmium is also present as an impurity in several products, including phosphate fertilizers, detergents and refined petroleum products (Weggler, McLaughlin, & Graham, 2004). The application of agricultural inputs such as fertilizers, pesticides, and biosolids (sewage sludge), the disposal of industrial wastes or the deposition of atmospheric contaminants increases the total concentration of Cadmium (Campbell, 2006). In low doses, cadmium can produce coughing, headaches, and vomiting according to EPA (1999). When cadmium accumulates in soils, it can contaminate crops that are grown on such soil. In the 1940s in Japan, an epidemic known as Itai- itai disease occurred when people ate from cadmium contaminated rice that grown on contaminated soil along riverbanks downstream of a mine (Nogawa, Kobayashi, Okubo, & Suwazono, 2004)

Lead

Lead is a bluish-white lustrous metal and a relatively poor conductor of electricity. Lead occurs naturally in the environment. However, most lead concentrations that are found in the environment are a result of human activities (ATSDR, 2008). The burning of leaded fuels in automobiles is an example of such activities. Lead accounts for most of the cases of pediatric heavy metal poisoning (Roberts, 1999). Every year, industry produces about 2.5 million tons of lead throughout the world. Most of this lead is used for batteries. The remainder is used for cable coverings, plumbing and ammunition. Other uses are paint pigments and in PVC plastics, x-ray shielding, crystal glass production, and pesticides (ATSDR, 2008). The main sources of lead entering an ecosystem are atmospheric lead (primarily from automobile emissions), paint chips, used ammunition, fertilizers and pesticides and lead acid batteries or other industrial products. The transport and distribution of lead from major emission sources, both fixed and mobile, are mainly through air (UNEP, 2005).

The central nervous of animals are affected by lead and this inhibits their ability to synthesis red blood cells. Lead has been known to be toxic since the 2nd century BC in Greece according to Asio, (2007). Lead is one of the metals that have the most damaging effects on human health (Greenberg, Clesceri, & Eaton, 1992). It can enter the human body through uptake of food, water and air. Children below 6 years of age and pregnant women are most susceptible to the adverse health effects of lead. Children absorb 4–5 times as much lead as adults, whilst its biological half-life is also considerably longer in children than in adults, (Environment Agency, 2009). Lead is highly toxic to fish (Rompala, Rutosky, & Putnam, 1984 cited in Obodai et al., 2011). The biological effects of high concentrations of lead include delayed embryonic development, suppressed reproduction and inhibition of growth. It also causes increased mucus formation, neurological problems. It may also cause enzyme inhibition and kidney malfunction ((Rompala, Rutosky, & Putnam, 1984; Leland, & Kuwabara, 1985 cited in Obodai et al., 2011). Lead poisoning is one of the most prevalent public health problems in many parts of the world. It was the first metal to be linked with failures in reproduction (Asio, 2007).

The main sources of lead entering an ecosystem are atmospheric lead (primarily from automobile emissions), paint chips, used ammunition, fertilizers and pesticides and lead acid batteries or other industrial products (UNEP, 1991). Salem, Eweida and Azza (2000), stated that lead is found in trace amounts in various foods, notably fish, which are heavily subject to industrial pollution. Lead when consumed accumulates in the human bones. Most of the lead taken into the human body is removed through urine; however, there is still risk of buildup, particularly in children (Salem *et al*., 2000)

Zinc

Zinc is a fairly reactive metal that will combine with oxygen and other non-metals, and will react with dilute acids to release hydrogen. Common anthropogenic sources of zinc are usually smelting, mining, metallurgy, electro-galvanising, pesticides, various alloys (Housecroft & Sharpe, 2008). Zinc is an essential mineral that is naturally present in some foods and is also available as dietary supplement. Zinc toxicity can occur in both acute and chronic forms. Acute adverse effects of high zinc intake include nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, and headaches (Food and Nutrition Board, 2001 cited in Eshun, 2011). Intakes of 150–450 mg of zinc per day have been associated with such chronic effects as low copper status, altered iron function, reduced immune function, and reduced levels of high-density lipoproteins (Hooper, Visconti, Garry, & Johnson, 1980). Forstner and Prosi (1979) cited in Eshun (2011) wrote that the well-known anthropogenic sources of zinc are usually smelting, mining, metallurgy, electro-galvanising, pesticides, various alloys. Zinc oxide is widely used as a white pigment in paints, and also in the manufacture of rubber and other plastics (Emsley, 2001). With increasing building closer to the lagoon, then it is likely some of these products might have gotten into contact with the lagoon releasing zinc into it. Natural source through weathering of mineral and soils can introduce zinc into water bodies (Merian, 1991).

Manganese

Manganese is a hard metal and is very brittle. Manganese is reactive when pure, and as a powder it will burn in oxygen (Stokinger, 1981 cited in Eshun, 2011). It is an essential trace element but can bring forth a variety of serious toxic responses upon prolonged exposure to elevated concentrations. Normal nutritional requirements of Mn are satisfied through the diet, which is the normal source of the element, with minor contributions from water and air (US EPA, 1984 cited in Eshun, 2011). Toxic exposures occur largely due to particulate material in the air from mining and manufacturing activities (Francis & Forsyth, 2005). This heavy metal is frequently associated with iron deposits (Hoekman, 2008). Chronic Manganese poisoning may result from prolonged inhalation of dust and fume. The central nervous system is the chief site of damage from the disease, which may result in permanent disability and can also cause impotency in men (Francis & Forsyth, 2005). Manganese substances can cause lung, liver and vascular disturbances, declines in blood pressure, failure in development of animal foetuses and brain damage. In the developing nations, the pollution of the environment by trace metals through industrial emission, effluent discharges, solid waste disposal, usage of agro-chemicals and sewage sludge in agricultural practices as well as automobile activities is evident (Oladeji Irinkoyenikan, Gbadamosi, Ibironke, Akanbi, & Taiwo, 2016). Symptoms of manganese poisoning are hallucinations, forgetfulness and nerve damage. A syndrome that is caused by manganese has symptoms such as schizophrenia, dullness, weak muscles, headaches and insomnia (ATSDR, 2000). Accumulation of manganese occurs in the subsoil rather than on soil surface. Anthropogenic sources of manganese include mining and smelting, engineering, traffic and agriculture. It is also used in the manufacture of steel, glass, dry batteries and chemicals (Yang & Sanudo–Wilhelmy, 1998).

Iron

Iron, is the most abundant element in the Earth's crust (Aisen, Enns, & Wessling-Resnick, 2001). Iron can exhibit two oxidation states; ferrous (Fe^{2+}), and ferric (Fe^{3+}). Iron is the fourth most abundant element and second most abundant metal in the Earth's crust after aluminium (Rose, Hawkes, & Webb, 1979). The anthropogenic sources of iron have been reported to include the iron and steel industry, sewage and dust from iron mining (Reimann, & de Caritat, 1998). Iron sulphate is also used as a fertilizer and herbicide (Reimann, Siewers, Tarvainen, Bityukova, Eriksson & Gilucis, 2003). Despite its toxicity, iron is essential to several life processes including the synthesis of DNA, the respiratory electron transport chain, as well as oxygen storage and transport. Cellular iron deficiency arrests cell growth and leads to cell death (Hentze, Muckenthaler, & Andrews 2004). Iron may cause conjunctivitis, choroiditis, and retinitis if it contacts and remains in the tissues (Braun & Killmann, 1999). Chronic inhalation of excessive concentrations of iron oxide fumes or dusts may result in development of a benign pneumoconiosis, called siderosis, which is observable as an x-ray change (Archibald, 1983). No physical impairment of lung function has been associated with siderosis. Inhalation of excessive concentrations of iron oxide may enhance the risk of lung cancer development in workers exposed to pulmonary carcigones (Hentze et al., 2004).

Table 1: Some metals considered harmful anthropogenic pollutants to aquatic ecosystems

Metal	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Manganese (Mn)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
Source	Herbicides/pesticides, car batteries, wood preservative	Batteries, stabilizes for plastics, electroplating	Wood preservative, electroplating, dye, tanning agent	Electronics and wiring, plumbing and roofing	Batteries, fertilizer, steel manufacturing and as a disinfectant	Plating to avoid corrasion, magnets, coins and batteries	Batteries, bullets, weights, paints, water piping and fuel	Plating, galvanizing and batteries
Effect on aquatic organisms	Inhibits growth, photosynthesis and reproductions	DNA damage, infertility, damage to immune and nervous systems	DNA damage, inhibits photosynthesis and carcinogenic	DNA damage, loose ability to regulate salt transport and damages gills	Tumour development, disturbs division of water in plants	DNA damage and mutation	Affects nervous system and brain function	Interferes with plants uptake of other metals
Threshold level in sediment	5.9mg kg^{-1}	0.6mg kg^{-1}	37.3 mg kg^{-1}	35.7mg kg^{-1}	460 mg kg^{-1}	18mg kg^{-1}	35mg kg-1	123mg kg^{-1}

Source: Burton, 2002

Ramsar convention on wetlands

According to the Ramsar Convention (2007) cited in Blumenfeld, Christophersen and Coates (2009), Ramsar's mission is "the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world." In its first "Wise Use" handbook 35, Ramsar gives its definition of wise use of wetlands: "Wise use of wetlands is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development. "By advocating this approach, Ramsar therefore necessitates that all Parties use the ecosystem approach when managing wetlands to account for the linkages and interdependence between wetlands and forests. This policy integration of wetlands, water, and forests is evident in many of Ramsar's Wise Use handbooks. Handbook 2, for example, mentions that "wetlands have been identified as one of the key life support systems on this planet in concert with agricultural lands and forests," and uses this rationale to advocate coordinated government programmes to minimize the adverse effects that policies created for a related sector may inadvertently have on wetlands. It is with this in mind that Ramsar advocates the development of "a unique or 'stand-alone' wetland policy statement and/or strategy," but it is important that such strategies are carefully integrated with interrelated sectors such as agriculture and forestry.

Handbook 3 focuses on cross-sectoral policies and warns Parties that "wetlands are directly or indirectly affected by a large number of sectoral activities, ranging, inter alia, from marine transportation and port and harbour construction through fisheries and forestry to domestic and foreign trade and investment." It then goes on to point out the collateral damage that often befalls wetlands as a result of the policy gaps caused by sector-specific legislation that has no mandate for wetland conservation or wise use. To correct this gap, Ramsar states the need for integration of regulations and guidelines regarding land uses on river systems and associated wetlands (Handbook 7). An example of damage caused by neglecting this gap is highlighted by the case of mangroves, which are often administered by forestry authorities without cross-sectoral coordination—thereby overlooking their important functions in coastal flood protection and the provision of fish spawning and nursery areas, resulting in major market failures with economically disastrous consequences.

Ramsar takes the economic considerations surrounding water, wetlands and forest interactions into consideration by stating that it must engage with business sectors to ensure that activities undertaken are not acting contrary to the objectives of the Convention (Handbook 4). The recommendations go on to encourage the application of Ramsar wise use practices through professional associations to promote these practices within key business sectors (such as water and sanitation, irrigation and water supply, agriculture, mining, forestry, fishing, environmental managers, tourism, waste disposal, and energy). The remaining Wise Use handbooks account for the important water, wetland and forest relationship by advocating the need to incorporate appropriate management of terrestrial ecosystems into water resource management (Handbook 8); the importance of recognizing the intricacies of upstream-downstream relations and the specific impact of deforestation on those relations (Handbook 10); and the need for "integrated river basin management" (IRBM) as a holistic approach integrating wetland conservation and wise use into river basin management (Handbook 16).

Multi- stakeholder approaches in water resource management

It is generally accepted that sustainable development requires a process and ultimately consensus-building among all stakeholders inclusive of all role-players, government institutions, stakeholders, clients, non-governmental organizations and community based organizations as partners who together define the problems, design possible solutions, collaborate to implement them, obtain specific products, and monitor and evaluate the outcome. Through such activities stakeholders can build relationships and knowledge that will enable them to develop sustainable solutions to new challenges (Hemmati, 2002 cited in Müller & Enrigh, 2009). In fact, the multi-stakeholder approach reflects some of the most frequently and fervently debated issues in discussions on governance, democracy, equity and justice in recent years.

The Global Water Partnership (GWP), defined IWRM as 'a process which promotes the co-ordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems', emphasizing that water should be managed in a 'basin-wide context', with principles of good governance and public participation (Jønch-Clausen, 2004 cited in De Cosmi & Reed, 2009). Sound IWRM needs the involvement of different stakeholders, from the community to governments, but it is not clear how this involvement should occur.

Because citizens expect to have a greater say today in the decisions that impact upon their communities, the participation of non-state actors has become an essential component of success, and people's participation in good governance for sustainable development – from policy design to decision-making and implementation – is leading to better long-term outcomes (Küpçü 2005 cited in Müller & Enrigh, 2009). Salamon

(2002) cited in Müller and Enrigh (2009) also expressed the view that there is a clear recognition that the task of public problem solving has become a team sport that has spilled well beyond the borders of government agencies and now engages a far more extensive network of social actors – public as well as private, for-profit as well as non-profit – whose participation must often be coaxed from them and not commandeered and controlled.

Bovaird (2004) cited in Müller and Enrigh (2009) suggested principles partnership of good governance in stakeholder's participation. The working of collaborative structures must, apart from solving the 'wicked' problems with which they are faced, also be based on principles of good governance (Bovaird, 2004). The following criteria have been selected by Bovaird (2004:210-211) from approaches to good governance which have been advocated by major international and multi-national agencies in recent years:

- citizen engagement: participation of citizens and other stakeholders in decision-making;
- transparency: open-book working in respect of all partners (including user and citizen representatives where appropriate) as a critical element of building trust;
- accountability: partners are prepared to account to each other for their actions and performance on all issues which arise – and must be prepared to account to other stakeholders for the overall performance of the partnership;
- equalities and social inclusion: accepted as core values in the working of the partnership – partners must actively seek innovative ways of improving performance against these principles;

- ethical and honest behaviour: accepted as core values in the working of the partnership – partners must actively seek innovative ways of improving performance against these principles;
- equity (fair procedures and due processes): accepted as core values in the working of the partnership – partners must continuously seek innovative ways of improving performance against this principle;
- willingness and ability to collaborate: critical success factor for all partners;
- ability to compete: critical success factor for the partnership as a whole (incorporating both cost consciousness and customer focus);
- leadership: necessary at all levels of the partnership as a whole, in each of its constituent organizations and in the communities which it serves; and
- Sustainability: partners must continuously seek improved ways of increasing the sustainability of policies and activities.

Theoretical perspectives

The driver-pressure-state-impact-response (DPSIR) framework was used as a theoretical basis for this study. The DPSIR is an analytical framework which can ssbe used to organize, report and illustrate the effects of human activities on the environment. This framework was developed by the European Environmental Agency in the 1990s and has since been applied in environmental research projects to support planning decisions (Kristensen, 2004). Ideas from former works such as Stress-Response (SR) framework, Pressure-State-Response (PSR) framework and the Drivers State-Response (DSR) framework formed the basis on which the DPSIR was developed. The SR framework, developed in the late 1970s, indicates the impact of the main pollutants (anthropogenic stresses) on biotic systems (Klotz, 2007). The PSR framework, launched by the Organization for Economic Cooperation and Development (OECD) in 1993, highlights the cause-effect relationships between humans and the environment, with regard to human activities, state of the environment and of natural resources and economic and environmental agents (OECD, 1993). Another development is the DSR framework, initiated by the United Nations Division for Sustainable Development, which expands the concept of ‘pressure’ to incorporate social, economic, institutional and natural system pressures (Bowen & Riley, 2003). As per the DPSIR system there is a chain of causal connections beginning with 'driving forces' (economic sectors, human activities) through 'pressures' (outflows, waste) to 'states' (physical, chemical and biological) and 'effects' on environments, human wellbeing and capacities, in the end prompting political 'reactions' (prioritization, target setting, indicators) (Kristensen, 2004).

A ‘driving force’ is a need. Examples of essential driving forces for an individual are the requirement for shelter, sustenance and water, while instances of secondary driving forces are the requirement for mobility, stimulation and culture. The driver force arises from the population such as number, age structure, education levels and political stability. It could also be from transport such as the persons and goods to be carried by road, water, air and off-road. Kristensten (2004) also mentioned energy use, power plants, industries, the presence of refineries or mining, agricultural activities such as number of animals, types of crops, stables and fertilizers. He added landfills, sewage, non- industrial sectors and land use. Pressures consist of the driving forces’ consequences on the environment such as the exploitation of resources (land, water, minerals, fuels, etc.), pollution and the production of waste or noise (Wood & van Halsema, 2008). Driving forces lead to human activities such as transportation or food production, that is, result in meeting a need. The activities put 'pressures' on the environment, due to production or consumption processes categorized into three main types: (i) excessive use of environmental resources, (ii) changes in land use, and (iii) emissions (of chemicals, waste, radiation, noise) to air, water and soil.

The ‘state’ of the environment is affected as a result of pressure; that is, the quality of the different environmental sectors (air, water, soil, etc.) in relation to the functions that these compartments fulfil. The physical, chemical and biological conditions combine to determine the state of the environment. The support of human and non-human life as well as the depletion of resources can serve as pertinent examples (Kristensen, 2004). The state of air quality from the local to urban through to national level may be affected as a result of the pressures. The water quality of rivers, lakes, seas, coastal zones and groundwater is affected. Soil quality, ecosystems and human health is affected. Impact may be expressed in terms of the level of environmental harm (Giupponi, 2002; Kristensen, 2004; Wood & van Halsema, 2008). The adjustments in the physical, chemical or natural condition of the environment decide the nature of ecosystems and the welfare of individuals. At the end of the day changes in the state may have ecnvironmental or financial 'impacts' on the working of ecosystems, their life supporting capacities, and eventually on human wellbeing and on the economic and social execution of society. A 'reaction' by society or decision is the result of an undesired effect and can influence any piece of the chain between driving forces and effects. The reactions show the social endeavors to tackle the issues recognized by the assessed impacts, for example proposed actions, and planning (Giupponi, 2002; Kristensen, 2004; Wood and van Halsema, 2008).

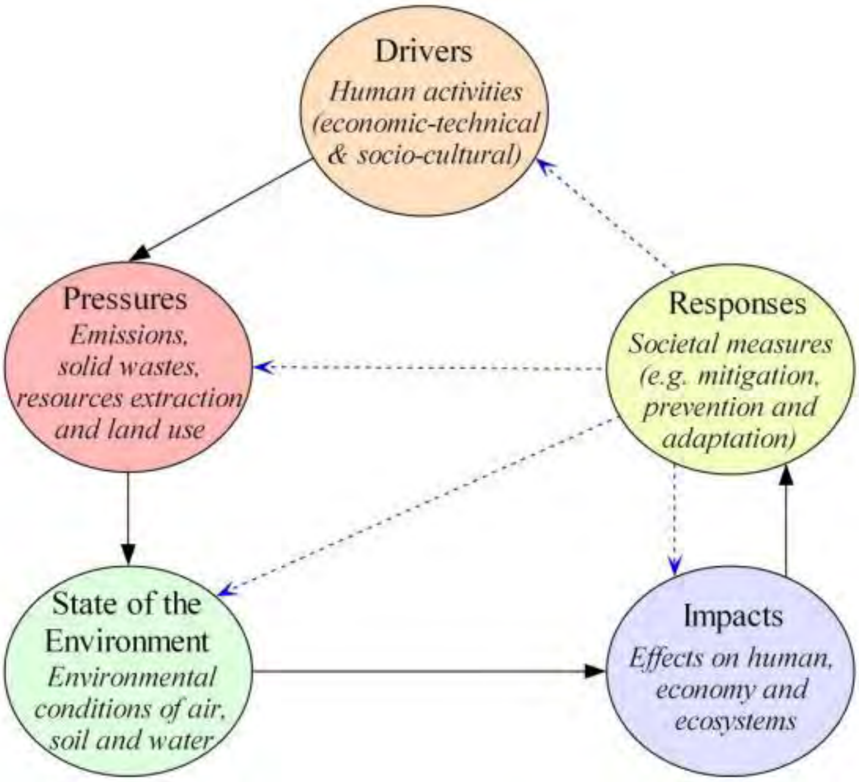


Figure 1: The European DPSIR framework
Source: Gabrielsen & Bosch (2003) cited in Xingqiang, (2012).

The framework however is not without critiques. Some typical criticisms of the framework include: (i) it employs static indicators that fail to consider the dynamics of the systems under study; (ii) it cannot clearly illustrate specific causal relationships of environmental problems; and (iii) it suggests linear causal chains to represent complex environmental problems (Rekolainen, Kämäri, & Hiltunen, 2003). Timmerman, Beinat, Termeer and Cofino (2011) claim that the DPSIR framework can be considered useful for improving communication and in breaking down water policy objectives into information needs. Moreover, Carr, Wingard, Yorty, Thompson, Jensen and Roberson (2007) point out that “DPSIR is not a model, but a means of categorizing and disseminating information related to particular environmental challenges”.

Application of the DPSIR in coastal lagoon management

In its application, the DPSIR can be used in assessing both land and water related ecosystems. The framework looks at how development and the growth of cities and towns affects the environment and the community at large. Bidone and Lacerda (2003) indicated that it has been used in appraising coastal development and sustainability, in water planning as a way for sustaining groundwater, inland waters, estuaries and coastal waters as well as reducing biodiversity risks (Borja, Galparsoro, Solaun, Muxika, Tello, Uriarte & Valencia, 2006; Maxim, Spangberg, & O'Connor, 2009). Smeets and Wetterings (1999) put forward features that has contributed to the numerous use of the framework; that is, it structures the indicators with reference to the political objectives related to addressing environmental problems and again, focuses on supposed causal relationships in a clear way that appeals to policy actors. The framework rather looks at environmental issues by looking at the interaction between human activities and the environment. To add more, it provides an avenue to put together different mechanisms that considers both environmental and socio- economic effects resulting from changes in the nature of coastal systems (Pacheco, Vila-Concejoa, Ferreira & Dias, 2007).

Environmental, social and economic sustainability theory

With the rise of population concentrating in urban areas, the United Nations has predicted numerous attendant problems such as conflict in societies, environmental deterioration as well as difficulty in meeting basic human needs. Basiago (1999) suggested paying attention to urban sustainability that reflects in economic, social and environmental practices of societies which will go a long way to reduce adverse urban trends. The advent of 'sustainability' in development science has led planners to apply evolving notions of 'sustainability' to the contemporary debate over how cities and regions should be revitalized, redeveloped, and reformed.

Kahn (1995) cited in Basiago (1999) put forward there are three conceptual pillars on which the paradigm of sustainable development rest described in Agenda 21. These pillars are 'economic sustainability', 'social sustainability', and 'environmental sustainability' illustrated in figure 2. Economic sustainability, by way of growth, development, and productivity, has guided conventional development science in the past. Market allocation of resources, sustained levels of growth and consumption, an assumption that natural resources are unlimited and a belief that economic growth will 'trickle down' to the poor have been its hallmarks. Development should concern itself with monetary capital taking into consideration natural, social and human capital. Restraint upon economic growth and consumption which deplete these is favoured (Kahn, 1995). In relation to social sustainability*,* issues such as equity, empowerment, accessibility, participation, sharing, cultural identity, and institutional stability are given the needed attention. Social sustainability attempts environmental conservation by seeking economic growth and the alleviation of poverty. Some commentators have suggested that poor countries must accept environmental degradation as a short term consequence of economic development. Others have argued that an enabling environment that optimizes resource allocation can obviate the need for such a trade-off (Kahn, 1995 cited in Basiago, 1999). On the part of e*nvironmental sustainability,* it involves ecosystem integrity, carrying capacity and biodiversity. Maintaining natural capital as a source of economic input and sink for waste is what is required in environmental sustainability. Kahn (1995) cited in Basiago (1999) advised that since resources regeneration are not that quick, resources should be exploited with this notion in mind. He added that, the rate at which waste are produced must not exceed what the environment can absorb. Kahn (1999) put forward a theoretical framework which posits that economic, social and environmental 'sustainability' must be 'integrated' and 'interlinked'. They must be coordinated in a comprehensive manner.

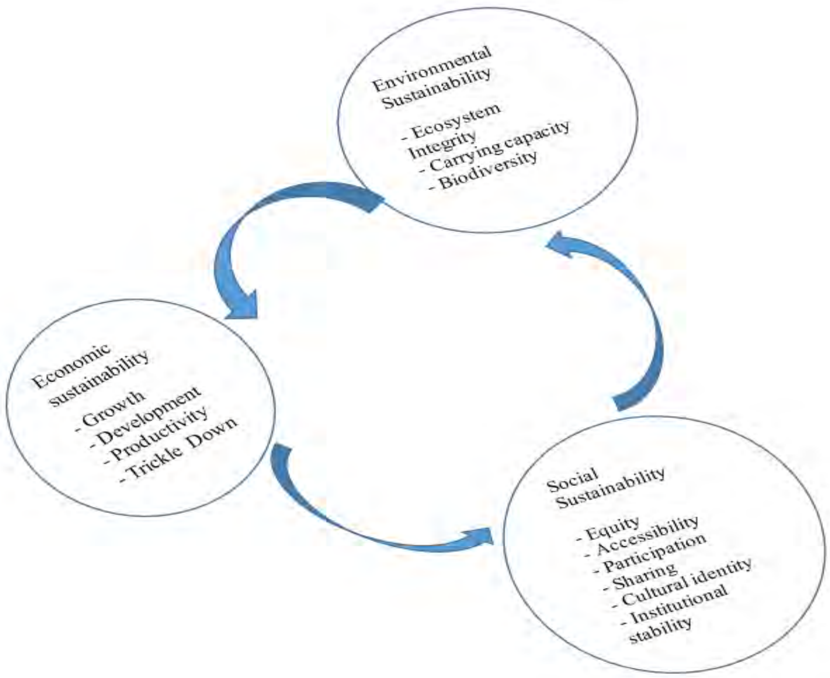


Figure 2: The paradigm of sustainable development in Agenda 21
Source: Adapted from Kahn (1995) cited in Basiago (1999)

Basiago (1999) defined 'economic sustainability' as the production system provides for the current generation whiles still making provision for the generations yet to come. He added that initially economist had the notion that supply of resources was unlimited and ability of technology to replenish natural resource hence did little to look at the ability of the market to efficiently allocate resources. In implementing the economic sustainability theory in a practical fashion is to adopt an urban design that satisfies the needs of the people especially the urban poor and still keeping the genuineness of the urban environment Basiago (1999).

The basic premise of 'Social sustainability' implies tackling and mitigating poverty in our societies. In a more fundamental sense, however, 'social sustainability' establishes the nexus between social conditions such as poverty and environmental decay (Ruttan, 1991 cited in Basiago, 1999). There is a divergence of opinion in development theory whether 'environmental sustainability' is a prerequisite of economic growth and poverty alleviation, or economic growth and poverty alleviation are needed before 'environmental sustainability' can even be addressed. There is some evidence that 'environmental sustainability' may be a necessary pre-condition of sustained economic growth (Basiago, 1999).

'Ecological sustainability' requires keeping up characteristic capital as both a supplier of financial information sources called 'sources' and an intake called 'sinks' of economic yields called 'waste'(Daly, 1973; 1974; World Bank, 1986; Pearce & Redclift, 1988; Pearce et al., 1990a; 1990b; Serageldin, 1993 cited in Basiago, 1999). At the 'source site', harvest rates of assets must be kept inside recovery rates. At the 'sink site', waste emissions from industrial production must be controlled so as to not exceed the capacity of the environment to assimilate them without impairment (Goodland, 1995 cited in Basiago, 1999). Considering the three pillars of 'sustainable development' or 'sustainability', it will never be a mistake to define it strictly in terms of 'environmental sustainability'. In practical terms, the theory of 'environmental sustainability' suggests a planning process that allows human society to 'live within the limitations of the biophysical environment' (Goodland, 1995 cited in Basiago, 1999).

Conceptual framework

A good understanding of the processes controlling environmental behaviour is considered essential when planning for long- term sustainable management for natural resources. To ensure sustainability of our environment, Basiago (1999) stressed on the need to take critical look at ensuring ecosystem integrity. This should be on the hearts of environmentalist to ensure the integrity of our ecosystem. By ensuring integrity, we will respect the environment within which we live knowing very that it is our major means of survival hence the need to treat it with outmost caution. Again, Basiago (1999) mentioned carrying capacity which is loosely used for this study captured in this framework to mean the extent to which a resource can be stressed to or provide support without degrading. In practice, carrying capacity cannot be necessarily quantified but may be described depending on changes occurring to a particular resource. The environment has its own strength and the maximum capacity to which it can be stressed up to. Exceeding this threshold puts undue pressure on the environment which can lead to break down in its functioning. For example, over and indiscriminate fishing in a lagoon can lead to some species going extinct which will affect the ability of the lagoon to produce fish to feed the population implying it has exceeded it carrying capacity. Increase in population is also another means in which the environment is stressed to exceed its carrying capacity. With increasing population and the need for survival, the environment is over- exploited affecting its overall ability to function effectively.

Mention must also be made of biodiversity. Each and every organism within the environment should be protected since they all play a role to keep the ecosystem functioning. Respecting the different species and protecting them will goes a long way to make the environmental sustainability dream a reality.

To achieve the idea of seeing that the aforementioned variables are kept in shape, there is the need to seriously consider urbanization, climatic variation and also institutional coordination. Urban growth comes with its own attendant problems evidenced in encroachment into watershed and pollution among others. Through infrastructural development and agricultural activities, there is encroachment into areas that should have been preserved to maintain the sanity of natural resources. Agricultural activities are being carried out close to water bodies where chemicals are released into the water affecting the health of the aquatic organisms in the water. As people stay closer to say lagoons, they produce numerous waste where most of them end up in the lagoon.

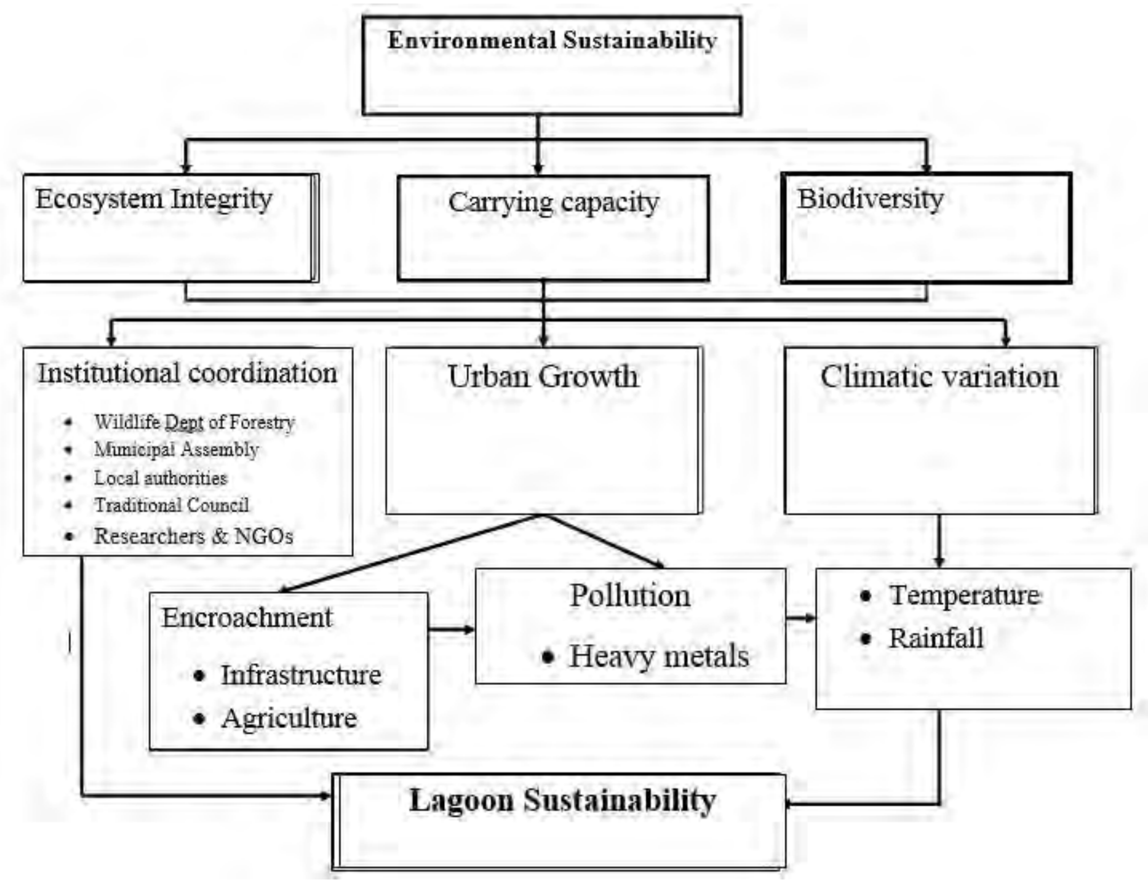


Figure 3: Tenets of coastal lagoons sustainability model
Source: Adapted from Basiago (1999) and the The European DPSIR framework (after Gabrielsen & Bosch, 2003)

Domestic, agricultural and industrial waste leads to nutrient building in water bodies such as lagoon which increases the metal content in the water. Organisms are not able to metabolize these heavy metals hence they stay in their tissues putting humans who consume them at risk of the effects of heavy metals. When all these are checked, our water bodies specifically lagoons can be sustained. The part where we mostly ignore is that of coordination between stakeholders where institutions are expected to work in close collaboration with each other. In the case of the Muni Lagoon, the Wildlife Commission is expected to work in close collaboration with local authorities who serve as representatives of the people. Again, they must work with the traditional authorities who are the custodians of lands within the catchment. All these stakeholders must also work with the Municipal since we are dealing with planning. Researchers and NGOs who have keen interest must also be brought on board. What is being said it that, there should be institutional and stakeholder coordination to achieve the dream of sustaining our lagoon.

CHAPTER THREE

RESEARCH METHODOLOGY

Introduction

This chapter presents the methods employed in carrying out this study. It discussed the research design, study area, site selection, data types and sources, sampling technique, water and fish sampling, laboratory procedures and data analysis and discussion.

Study area

Location

The Muni-Pomadze wetland, a closed estuarine coastal lagoon, is found in Winneba in the Central Region of Ghana. It is about 56km west southwest of Accra on the south coast of Ghana. The Muni Lagoon (05º22' N 0º40' W) is situated on the south-western part of Winneba in the Central Region of Ghana. It is a closed lagoon which occasionally opens to the sea, especially during the wet season. The lagoon is usually 3km^2 in extent (Ntiamoa-Baidu & Hollis 1988 cited in Gordon et al., 2000) but could expand over 6 km^2 of surrounding floodplain in the wet season. The Muni-Pomadze Ramsar Site encompasses an area of about 94.61km^2 (9,461 ha) (Wuver & Attuquefio, 2006) comprising the water shed of the Muni Lagoon. This area is peri-urban implying a rapid expansion of human activities. The wetland is bounded in the north by the Yenku A and B Forest Reserves, in the south by the Atlantic Ocean (Gulf of Guinea). River Pratu and River Ntakofa feed the Lagoon with fresh water. The lagoon is separated from the sea by a sand bar during the dry season which gets breached intermittently during the wet season. The lagoon which is characterized by shallow, saline, semiclosed, coastal line, with a surface area of 300ha has iconic flood-plains and the adjacent sandy beaches which constitute the southern part of the site (Ntiamoa-Badu, 1991 cited in Gordon et al., 2000) serving as nesting sites for marine turtles. These locational characteristics make the wetland an attractive site for all sorts of human activities.

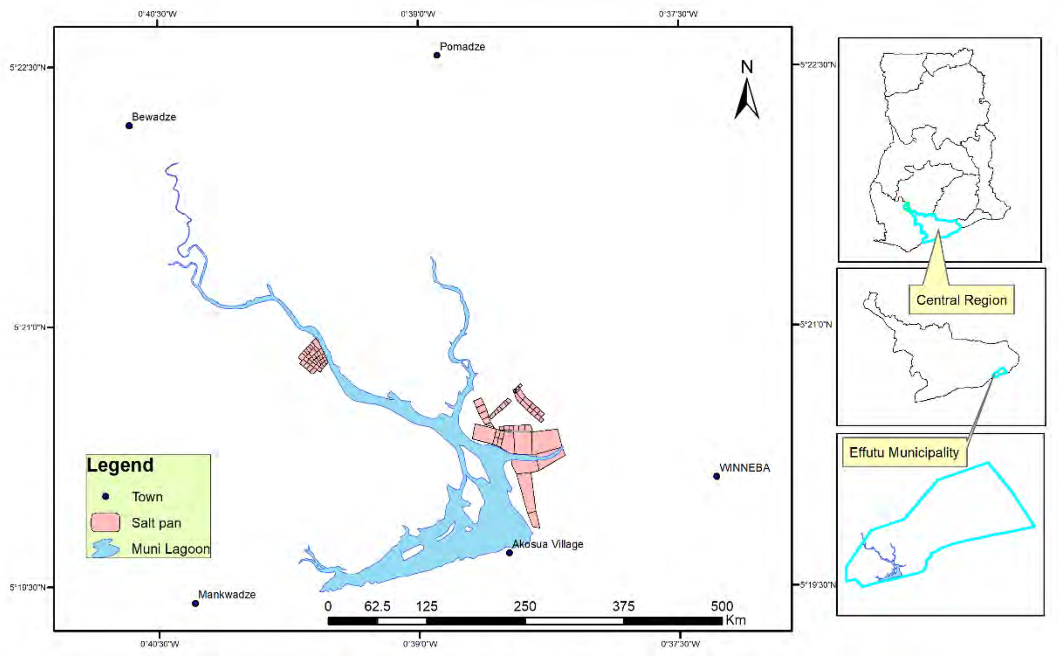


Figure 4: Map of the Muni Pomadze Lagoon watershed in national and regional context
Source: Author’s construct (2020)

Demography and socio-economics

The nine major settlements within the Muni Pomadze Ramsar Site (MPRS) constituted a population of 32,000 people in 1984. This went up to about 47,327 by the year 2000 (Ghana Statistical Service, 2005). The population growth rate is less than 1% annually (Gordon et al., 2000). Data from the 2010 Population and Housing Census indicates that the Municipality has a population of 68,597 which represents 3.1 percent of the population of the Central region. The dominant ethnic groups are the Fanti, Ewe and migrant Fulani herdsmen. The management of the site is vested jointly in two local or traditional authorities. The Effutu have responsibility for issues concerning the Muni

Lagoon, while the Gomoa manage the wetlands. Chief Fishermen are responsible for fishing-related issues in their respective traditional communities. The major economic activities in the municipality are fishing, wholesale/retail trade, services, manufacturing, salt mining (white gold), crop farming and agro-processing. Fishing, farming, and related work are the leading economic activities in the municipality. (e.g. maize and cassava), but there are other minor activities like hunting (Effutu people), cattle grazing, sand, clay and gravel mining, salt winning and charcoal production. The MPRS is home to the annual "Aboakyir" festival, during which "Asafo" companies compete to capture a live bushbuck (Wuver & Attuquayefio, 2006). These are followed by services with salt mining along the coast of Winneba and Warabeba. The fishing industry is very prominent in the coastal communities of Winneba, Akosua Village and Warabeba within the municipality (GSS, 2014).

Geomorphology and Vegetation of Muni Lagoon Catchment

The Muni Lagoon catchment is a gentle undulating plain rimmed in the north and the north-east by the Yenku Hills (max. height 290 m) and in the south-west by the Egyasimanku Hills (max. height 205 m). The lagoon lies behind a sand bar, which is formed by the strong longshore littoral drift of sand in the west to east direction. Muni lagoon is a closed lagoon but during rainy seasons, the people around the lagoon breach the sand bar to control flooding (Gordon et al., 2000).

The vegetation found in the area is consistent with the flora of coastal savannah regions of Ghana. This vegetation type is typically a fire climax, which in the case of the lower lying areas of the Muni-Pomadze catchment, is compounded by edaphic factors such as saline soils and sub-soils. Oteng-Yeboah (1994) cited in Gordon et al., 2000 divides the natural flora into four main types, based on ground situations. These types are (i) flood plain (including mangrove and wetland vegetation), (ii) sand bar (dune) vegetation, (iii) riverine vegetation and (iv) the vegetation of elevated and undulating ground. The floodplain vegetation is typical of the flora found around the lagoons of Ghana.

Grassland covered most of the area, prominent grass species included *Setaria pallide-fusca*, *Sporobolus pyramidalis*, *Panicum maximum* and *Andropogon canescens*. The final vegetation forms in the elevated areas were the two blocks of forest reserve, parts of which had been planted with exotic Eucalyptus. The undergrowth in these areas was made up of several rudeal species (Oteng-Yeboah 1994 cited in Gordon et al., 2000)

Climate and hydrology

This area is characterized by low annual rainfall. The rainfall pattern is bimodal with the main wet season occurring from April to June followed by the minor wet season from early September to October. Approximately three quarters of the total annual rainfall (850 mm) falls during the months of the wet season. Pan evaporation rates are generally high that occur in the area. The rates peak in February and May as well as in October and November. The mean annual temperature is around 27 ◦C. Temperatures are highest during the long dry season, November– March and lowest during the short dry season in August. The relative humidity as measured at 1500 hrs averages 75–80% for most of the year. In the dry season, relative humidity may drop to below 65%. At night, the relative humidity can reach 100% saturation. Due to the impermeable nature of the rocks, most of the rainfall in the catchment either evaporates or flows as sheet surface runoff to the three streams that drain the catchment, these then empty into the lagoon (Tumbulto & Bannerman 1995 cited in Gordon et al., 2000). Ayensu River which is located to the east of Winneba has the same hydrological regime as the Muni catchment (Tumbulto & Bannerman 1995 cited in Gordon et al., 2000). With a total catchment area of about 100 km^2, the estimated volume of water available, assuming an average rainfall year is of the order of 80 million m^3 (Tumbulto and Bannerman 1995 cited in Gordon et al., 2000). Due to evaporation, all of this water is not available for recharge of the lagoon, in fact it is only in May and June that the input from rainfall exceeds the monthly potential evaporation. The maximum volume/water level (estimated at 12 million m^3) is expected to be in June or early July while the minimum volume (estimated at 3 million m^3) is expected in the April, just before the start of the next rainy season. The extent of the open water varies according to the season, from about 100 ha in the dry season to over 1000 ha in the wet season; with maximum water depth of 2 m, grading out to shallow margins and mud banks (Gordon 1994, 1995 cited in Gordon et al., 2000).

The lagoon morphometry was determined in January 1995 and indicated that the lagoon has an area of shallow water at the lower end of the northern arm, which effectively divides the lagoon into two basins. Reports from the local fishermen indicated that the lagoon and surroundings get flooded about every 10 years, the period of flooding coinciding with periods of very intense rainfall. When the flooding occurs, a canal is dug through the sand bar releasing the floodwater into the sea to prevent inundation of houses as happened in July 1994 (Gordon 1994 cited in Gordon et al., 2000). Tumbulto and Bannerman (1995) cited in Gordon et al. (2000) estimate that at times of breach of the sand bar, an additional 4 million m^3 of sea water enters the lagoon at high tide. In addition to these major inputs of water, there are two minor inputs of water to the lagoon, both from seepage. At high tides, especially during the dry season when the lagoon level is low, there is seepage from the sea through the sand bar into the lagoon (Tumbulto and Bannerman 1995 cited in Gordon et al., 2000). The rate of seepage is limited by a seal of black anoxic organic layer in the sediment, which also has high clay content. The second input from seepage stems from a rain fed perched brackish water table in the sandbar. This comes to the ground near the western extreme of the lagoon, in a small grove of mangroves. The discharge from this source which, runs into the lagoon, is of the order of 1 l/min. In the past the perched water table was fresher and was tapped by the inhabitants of Akosua Beach village who operated two shallow wells which are no longer in use.

Land-use patterns within the Muni-Pomadze site

Five main categories of land use/land cover exist in the Muni-Pomadze Ramsar site, these are; (i) Built-up areas (12.6%), (ii) Agricultural lands (32.5%), (iii) Natural vegetation (53.1%), (iv) Water bodies/floodplain(1.5%) and (v) Salt pans and salt flats (0.3%) (Amatekpor 1994 Gordon et al., 2000). The areas and the proportion of the catchment covered by each of these land use types are given in. There are few settlements in the area, which however are expanding rapidly in the vicinity of the wetland. In the Winneba Township, many new houses are being built on the eastern parts of the wetland, up to areas that had been used for the winning of salt in the 1970s.

Farming in the catchment occurs mainly in the area north of the main Accra to Cape Coast trunk road, where the soils are agriculturally better. Slash and burn, shifting cultivation and mixed cropping systems are common. In the past, land was prepared with hand held implements, this coupled with some degree of land rotation and the mixed cropping are traditional methods of soil conservation. Fallow periods are now getting shorter, and the use of agricultural machinery for tillage, sometimes in the hands of untrained operators is causing accelerated erosion. Only the few commercial farmers in the area use agro-chemicals such as fertilizers and pesticides. Fuelwood is the major source of energy for cooking, the wood is collected, mainly by women, from the areas surrounding the settlements even in areas that are under modern or traditional protection such as the forest reserves or the traditional hunting areas. Amatekpor (1994) cited in Gordon et al., 2000 observed that the rate of fuel wood regeneration is slower than the rate of exploitation.

Site selection

The Muni Pomadze Ramsar Site was purposively chosen for the study. This lagoon is chosen because it is one of the few internationally recognized wetlands in Ghana that houses diverse species (Ramsar Convention, 2012). It is an area specifically conserved to continually support ecosystem services hence need careful study to sustain it. Besides the area is recently faced with the challenge of a community that is growing rapidly outwards towards the watershed of the wetland hence the need to delve deep and report on current happenings.

Research design

The study employed the mixed approach. The research design employed was the causal- exploratory. Quantitative approach was used to find pattern on the extent of urban growth (encroachment) on the lagoon catchment. Again temperature and rainfall variation statistically analyzed to report whether they were increasing or declining within the catchment. The presence and level of concentration of heavy metals were quantified which aimed at establishing relationships between variables and predicting outcomes to ensure objectivity, generalizability and reliability (Van der Merwe, 1996; Weinreich, 2009). Again, qualitative approach was also used in the sense that multi-dimensional approaches of conserving the lagoon were explored by delving deep into culture and having direct interaction with people (Weinreich, 2009) to promote understanding and insight as to how to conserve the lagoon without necessarily quantifying such information. The mixed method was used because each or both may be appropriate depending on the research problem one is interested in. This is supported by Silverman (2005) who argued that “in choosing a method, everything depends upon what we are trying to find out. No method of research, quantitative or qualitative, is intrinsically better than any other. According to Sale, Lohfeld and Brazil (2002), combining the two approaches brings out numerous perspectives to studying a phenomenon that provides better understanding and improvement in human condition as well as complementing the strength of one approach to augment the other.

Neuman (2003) recommended the use of the mixed methods when he contended that combining different approaches in a study is the method to be adopted because it is better to look at situation from different angles than to look at it from a single perspective. Causal design here as an analysis of how change in temperature and urban encroachment affect the Muni Lagoon. The purpose of causal design is to examine the possible cause and effect relationship between variables that exists without manipulating the phenomena under study to gain much information about it (Rockinson-Szapkiw, 2012). Malhotra (2004) argues that the objective of exploratory research is to search through a situation to provide insights and understanding. This design is appropriate when the researcher knows little about the issues under discussion where in this situation, achieving institutional coordination in conserving the lagoon is not so much known. Exploratory design also fits all the two paradigms of research that is the qualitative and quantitative (Burns & Bush, 2006). The chosen designs were appropriate as they helped to achieve the cause effect relationship between anthropogenic activities and that of the Muni lagoon and its catchment. The exploratory provided in- depth information on the approaches necessary in sustaining the catchment as revealed by the various stakeholders.

Data sources

Two types of data was needed for this study. Availability of data and cost was considered in acquiring the data for this research. The primary source of data was acquired from the field and the Ghana Meteorological Agency (GMet). Though data from GMet may be a secondary source of data, for the sake of this study, it was treated as a primary data. The secondary data was from existing data and literature. Data from the field was based on field water and fish sampling, observation and interviews.

The primary data was from samples of water and sediments from the lagoon which was subjected to laboratory analysis. The GMet provided temperature and rainfall data of the study area from 1990 to 2019 for analysis to establish the rate of variation in temperature and rainfall trend within 30 year period. Other secondary data source were satellite images to analyze the rate of urbanization effect (encroachment) and other land use patterns and change occurring within the catchment of the lagoon. The satellites images were 10% cloud cover images so as to give a real reflection of objects and phenomenon on the images as they occur on the earth surface. Enhanced Landsat Thematic Mapper plus (ETM +) imagine of dry season for 2000 and 2019 Landsat 8 image were used. Data for the 1990 image was Landsat Thematic Mapper (TM). These images were taken in the dry season due to absence of cloud cover more specifically in December for 2019 and January for 1990 and 2000 based on availability and clearness of image. These images were acquired from USGS website (earthexplorer.usgs.gov.gh.)

Remote sensing: Image processing and classification

Images for the study was georeferenced which generated thematic images for both years. Stacking of bands was done followed by subsetting to generate the study area from the stacked images using ERDAS Imagine software. A 2km buffer shapefile with the lagoon as reference point was created for subsetting. This allowed for unsupervised classification of 250 classes to be done. Supervised classification then followed to generate clusters of various land covers of the area. This helped in providing an idea of how urbanization (built up) has affected and encroached the catchment of the lagoon. This was supplemented by number of field visits to verify land covers that has been generated.

Land cover classes

The analysis was done using remotely sensed images for 1990, 2000 and 2019. Five land use classes were generated form the analysis. These were areas that have built up or any form of anthropogenic activities such as agriculture; areas with open forest cover; areas with grass cover (grass land); waterbody specifically the Muni Lagoon; and areas such as bare land, salt pan and beach sand. Due to the time the image was picked which was the dry season, the reflectance for most of the dry surface was similar making it very difficult to differentiate between bare land, the abandoned salt pan and beach sand hence they were classified as one and given the land use unit name as Salt Pan/Beach Sand/Bare Land. The land cover classification system used followed the USGS (2010) explained in table 3.

Table 2: Land cover descriptions

Land cover classes	Description
Barren Land	Barren Land is land of limited ability to support life and in which less than one third of the area has vegetation or other cover. It is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the Shrub and Brush category of Rangeland. Categories of Barren Land are: Dry Salt Flats, Sandy Areas; Transitional Areas; and Mixed Barren Land
Built- up	Built-up land is comprised of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns and villages, and institutions that may, in some instances, be isolated from urban areas.
Open Forest	Open forest has a tree-crown aerial density (crown closure percentage) of less 10 percent but more than 5 percent.
Water	Water as includes all areas within the landmass that persistently are water covered. The delineation of water areas depends on the scale of the presentation and resolution of the remote sensor data used; Categories include stream, lakes, reservoir, lagoon and estuaries.
Grassland	Grassland is comprised of areas where the potential natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs and where natural herbivores were an important influence in its pre-civilization state. Some rangelands may have been or may be seeded in introduced or domesticated plant species. Categories include herbaceous range, shrub and brush rangeland and mixed rangeland.

Water collection

The stratified sampling technique was used to divide the lagoon into three strata (sites) namely the Muni Upper Site (MUS), the Muni Middle Site (MMS) and the Muni Lower Site (MLS). At each site, three sampling points were established. This was necessary to help in picking water samples across the full extent of the lagoon which is necessary in generalizing the concentration of heavy metals within the lagoon.

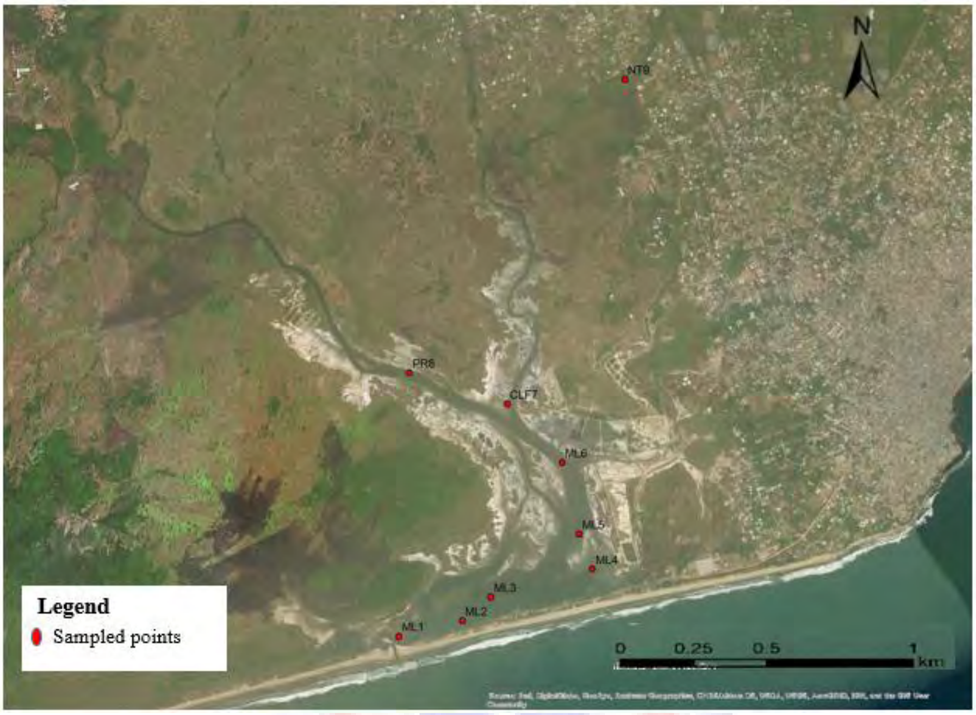


Figure 5: Muni Lagoon sampling points
Source: Field data (2019)

Samples of water were collected in both wet and dry season. Wet season samples were collected in July, 2019 whilst dry season samples were collected in January, 2020. Samples were collected on the lagoon with the aid of a canoe using polyethylene bottles as well as on the rivers feeding the lagoon (Pratu and Ntakofa). All polyethylene bottles (500 mL polyethylene bottles) for sampling were immersed in a 10% HNO_3 solution for 48 hours and thoroughly rinsed with double-distilled water before use (Mahapatra, Tripathi, Raghunath, & Sadasivan 2001; Bohrer, Becker, Cícero do Nascimento, Dessury, & Machado de Carvalho, 2007; Momen, Zachariadis, Anthemidis, & Stratis, 2006).

In collection of the water samples, sampling bottles were immersed into the lagoon to be completely filled with water at a depth of 5- 10 cm at the established sites after which bottles were tight closed and labeled accordingly. Control water sample was taken from the Ayensu estuary at the Winneba coast closer to the Royal beach in the wet season. Garmin 12XL GPS was used to pick coordinates of exact locations where field samplings were made. However, during the dry season, the Ayensu was dried at the point where it was collected in the wet season (the estuary) hence the researcher went to up to about 10km from estuary to get the dry season sample for lab analysis. Collected wet season water samples were sent to the UEW chemistry lab for digestion after which they were sent to the chemistry lab at University of Cape Coast for heavy metals of Pb, Cd, Fe, Zn and Mn to be tested. However, during the dry season, the samples were sent to the Ecolab at the University of Ghana for heavy metal analysis for convenience sake.

Digestion of water samples

50ml of each of the water samples was measured and transferred into an acid washed boiling tube. 2ml of HNO_3 followed by 5ml of HCL was added to each of the measured water samples (both acids were AnalaR grades). The sample solutions were covered then placed on the hot plate digestor for 30 minutes between a temperature of 95°C and 100°C until the volume reduced to 15-20ml. The samples were then brought out and allowed to cool for some time after which they were filtered using whatman No 40 filter paper into a volumetric flask each. The filtrates were then toped up to the 50ml mark of the flasks using distilled water. The resulting solutions were shaken well to ensure uniformity and were then transferred into their Pet bottles for analysis.

The wet season samples were analyzed in the laboratory using APHA 3111 Flame Atomic Absorption Spectrophotometer (FAAS) whilst the dry season samples were analyzed using the Perkin- Elmer PinAAcle 900T Flame Atomic Absorption Spectrophotometer.

Water analysis at laboratory

Heavy metal content in the water samples were measured with the Analyst 400 Perkin-Elmer Atomic Absorption Spectrophotometer according to the method prescribed by Serfor-Armah, *et al;* (2006) cited in Eshun (2011). The water sample was first filtered with Whatman No. 0.45 filter paper, after which 50ml of the filtrate was acidified with 50% nitric acid to give a pH of 1. The AAS was calibrated with standard solutions and de-ionized water before heavy metal concentrations in water samples were measured.

Fish collection

Fishes were collected from the lagoon using cast net for heavy metals analysis. The researcher sought the services of an expert who can cast a net. Canoe was used to traverse the lagoon where fish samples were caught from three sampling points that is, the lower, middle and upper portion of the lagoon. The main fish caught was the black chin tilapia *Sarotherodon melanotheron* which the people indicated were all males using their colour. The fishes were kept refrigerated until the day of analysis where they were sent to the Ecolab at the University of Ghana, Legon.

Fish analysis at laboratory

The fish samples were washed with distilled water and dried in a hot air oven at 105_0C for 48 hours. The wet digestion method was used in digestion of fish tissues. The dried muscles of the fish were removed with steel blade and plastic forceps and grounded into powder. 2 g of these were digested with 25 ml of a mixture of 500 ml concentrated nitric acid and 20 ml perchloric acid in digestion tubes inside a fume chamber. The sample mixture was then filtered and the filtrate was analyzed for heavy metals using the AAS. The AAS was calibrated with standard solutions and de-ionised water before measurement was made. Recoveries of 103.3%, 100.4%, 103.9%, 95.2% and 96.6% for Fe, Mn, Zn, Cd and Pb respectively were used for the analysis.

Ecological risk of water and bioaccumulation status of fish species analysis

Ecological risk associated with the concentration of heavy metals in the water samples were analyzed after Hakanson (1980). The formula used was

$Er = T_f \times C_f$, where T_f is the toxic response factor or metal and $Cf = \frac{Cs}{Cf}$ where C_s is the concentration of element in sample and C_f is the concentration of element in the background (Hakanson, 1980).

Toxic response value for Cd, Pb, Zn and Mn are 30, 5, 1 and 1 respectively. There is no known toxic response value for Fe hence its ecological risk was not computed. There is criteria for assessing the risk associated the metals and their attendant risk on the environment as shown on table 2.

Table 3: Ecological risk assessment criteria

Er	Ecological risk criteria for heavy metal	ERi	Ecological Risk Criteria of environment
Er<30	Low risk	Eri<100	Low risk
30<Er<50	Moderate risk	100<Eri<150	Moderate risk
50<Er<100	Considerable risk	150<Eri<200	Considerable risk
100<Er<150	Very high risk	200<Eri<300	Very high risk
Er>150	Disastrous risk	Eri>300	Disastrous risk

Source: Hakanson (1980)

The bioaccumulation potential of metals was assessed in the muscles of fish species. Bioaccumulation factors (BAFs) were calculated as a ratio between the concentration levels of biota (those in water) and the living environment of the specimens was expressed according to Ahmed, Sultana, Habib, Ullah, Musa, Hossain, Rahman & Sarker (2019) as

$BAF = Cn_{Biota} / Cn_{water}$

where Cn_{Biota} is the concentration of metal in the tissues (mg/kg) and Cn_{Water} is the metal concentration in the aquatic environment (mg/l). BAF is categorized as follows: BAF < 1000: no probability of accumulation; 1000 < BAF < 5000: bioaccumulative; BAF > 5000: extremely bioaccumulative (Arnot & Gobas, 2006).

Interview Method

Purposive sampling technique was also used to select key informants such as chiefs who are well informed in the traditional knowledge and managements system used in protecting the lagoon. Other experts two (2) each from the Wildlife Division of the Forestry Commission, Effutu Municipal Assembly, community leaders (assemblyman and fish fisherman), and A Rocha Ghana (non-governmental organization) were purposively selected and interviewed in relation to the approaches in conserving the lagoon. These experts were selected because the Wildlife Division of the Forestry Commission is responsible for the organisms within the catchment, the Municipal Assembly responsible for planning of the communities, and NGOs as they provide alternative livelihoods and contribute in restoration exercises.

Data analysis

Among the software used in this study for analysis were the ArcGIS 10.1, and ERDAS imagine which were used to analyze the Landsat images. These software were used to determine the extent to which anthropogenic activities have encroached into the watershed of the Muni Lagoon. SPSS version 20.0 was used in running Pearson moment correlation test to establish relationship between temperature and rainfall within the study area. Microsoft Excel 2017 software was used to generate line and bar graphs for the temperature and rainfall data. The data from heavy metals concentration was also subject to statistical analysis using the SPSS version 20.0. Kriging tool in ArcGIS 10.1 was used to estimate the values for non- sampled points within the lagoon. This provided a pictorial representation of the spatial variation of concentration of the various heavy metals analyzed in the lagoon in the form of maps. The data from interview was analyzed manually where transcription was made and data grouped under themes for the purpose of the study. Where necessary, results were presented on tables in frequency and percentages as other pictorial forms.

Limitations

The study was successfully conducted though some challenges were faced. The researcher wanted to use an older year map other than map of 1990 but the Municipal Assembly did not have any of such topographical maps. Again, some of the departments visited were not willing to release some important data to be used for the study.

Ethical consideration

A written permission (with the Department of Geography Education, UEW letter head) was sought from the Head of the Forestry Commission (Wildlife Division), Lands Commission and Water Resource Commission before interviews are conducted. Traditional authorities contacted in this study were officially informed before conducting interview as tradition demands. Respondents were assured that their names would be dealt with in the strictest confidence. The principle of voluntary participation was explained to the respondents and they were also informed that they had the right to withdraw from the study at any time. The principle of informed consent was verbally explained to the interviewees. Both principles were upheld in explaining the research process and its purposes to the participants.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter is a synthesis of data collected from the field and their related discussions. Data was presented and discussed on encroachment, heavy metal concentration and climatic variations occurring within the Muni lagoon and its catchment. Multi-stakeholder interviews conducted were also presented and discussed here.

Modelling encroachment on the Muni Lagoon catchment

The growth in human population and the necessity to provide for human's basic need has led to the use of any available space for building, farming and other developments. This notwithstanding has multiple effects on resources especially those that are delicate such as wetlands. Wetlands have reserved space which needs to be kept untouched, however these areas are now becoming the preferred zones for all kinds of activities. This study employed remotely sensed images to model how human developments are extending from the Winneba township towards the lagoon. The community and the Wildlife Commission has set the extent to which human activities such as construction of buildings and agricultural activities should occur. However, due to limited space and the continuous increase in population resulting from the increase in student's enrolment, workers intrusion and the scarcity of land within the town for building to serve the populace, the reserved areas within the catchment have become the preferred development site. Again, most areas closer to the lagoon is being used for vegetable farming where most of the farmers even use the rivers feeding the lagoon (Pratu and Ntakofa) as source of irrigation to promote their agricultural activities.

The Water Resource Commission have instituted a buffer of 30m for lagoon within which no activity should be carried out. However, during inundation the lagoon can flood to a greater extent beyond the established buffer, therefore with consultation from the Wildlife Division of the Forestry Commission, the study looked at activities carried on within two (2) kilometers buffer from the lagoon over years. The map of 1990 was used as the base year to assess how human activities are extending to the lagoon from that time to the current year 2019. It would be best to use older map than that of 1990 but 1990's map was used for the study because that is the oldest map you can ever chance on. The Effutu Municipal Assembly lack older maps that can be used as the basis for comparison hence the 1990 was used to give idea on the land use and land cover change that is occurring within the 2km buffer of the Muni catchment that has been set for the study.

Surface area of land cover units in 1990

In 1990 which forms the base year for the study, the level of anthropogenic activities within the catchment was very minimal. Built up and other human activities such as agriculture covered 0.4km^2 which was just 1.6% of the total 26km^2 area under study as shown on the table below. Within this period, the Muni lagoon had an area extent of 1.1km^2 that is 4.1% of the total area. Open forest and grassland within the area in 1990 covered 7.8km^2 making up 29.9% and 12.3km^2 covering 47.2% respectively. The barren land consisting of the beach, abandoned or dried salt pan and the bare land covered 4.5km^2 (17.2%) of the area. It can be inferred that, during the year 1990, within 26km^2 of the lagoon catchment under study, has most areas being covered up with vegetation which is the open forest and grassland as shown in figure 6. This encouraged ranching and farming activities during those days. Human interference within the Muni catchment was very minimal.

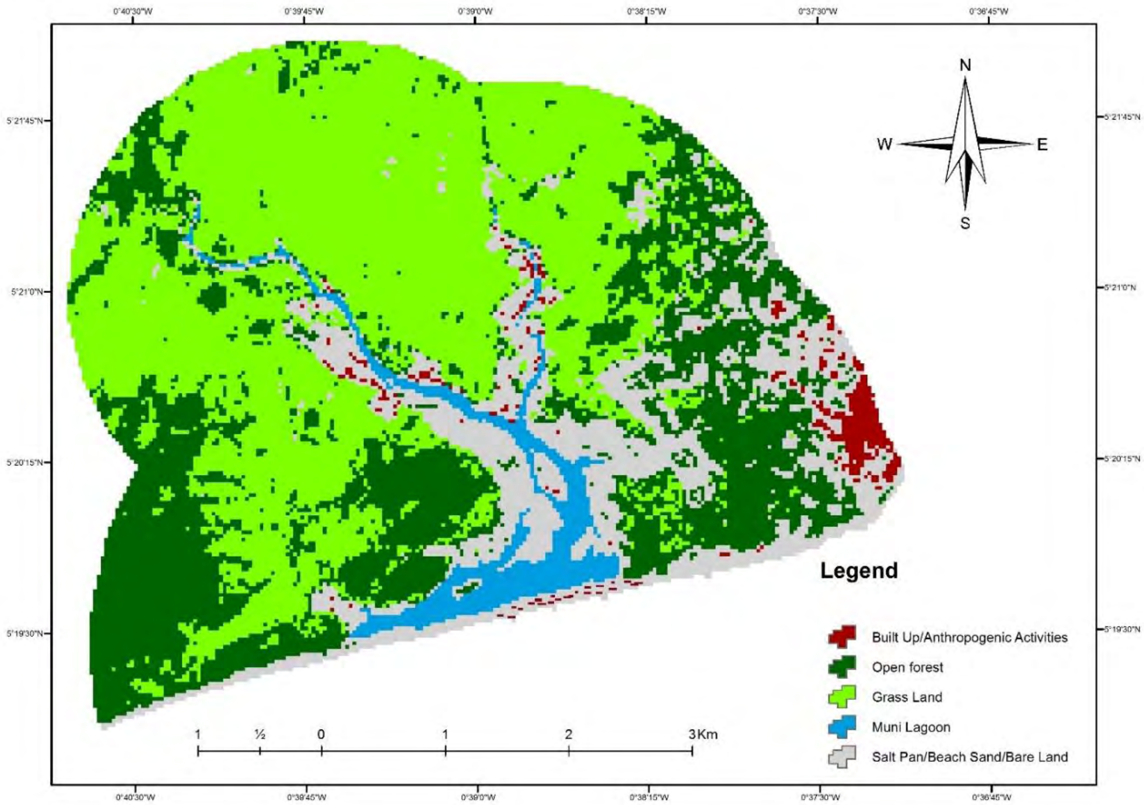


Figure 6: Land cover characteristics of the Muni catchment within 2km buffer in 1990
Source: Field work (2020)

Though within this year, the city was still extending towards the lagoon area, it was very low covering 1.6% of the total catchment. It could be seen from figure 6 that the built up area was even far from the lagoon growing from the eastern side of the catchment. This confirms Gordon et al. (2000) assertion that in the Winneba township, many new houses are being built on the eastern parts of the wetland, up to areas that had been used for the winning of salt in the 1970s.

With open forest and grassland covering majority of the catchment, they served as protection for the lagoon against excess evaporation. This helped to prevent excess evaporation, regulate and maintain temperature of the lagoon and go a long way to prevent drying up of the lagoon. Table 4 shows the area coverage of the land use units

Table 4: 1990 land use unit coverage

Land use unit	Surface area (Km^2)	Percentage (%)
Built Up/Anthropogenic Activities	0.4	1.6
Vegetation	7.8	29.9
Grass Land	12.3	47.2
Muni Lagoon	1.1	4.1
Salt Pan/Beach Sand/Bare Land	4.5	17.2
Total	26.1	100

Source: Field work (2020)

Surface area of land cover units in 2000

In 2000 which was 10 years from the base year, changes were recorded on the land cover within the catchment. Built up and anthropogenic activities in this year covered 1.0km^2 which was 3.8% of the catchment. The Muni Lagoon in this year also covered 1.0km^2 that is 3.7% of the assessed area. Open forest and grassland covered 7.7km^2 and 12.2km^2 that is 3.8% and 47.1% respectively. The barren areas covered 4.1km^2 that is 15.9%. Comparing figure 7 with that of figure 6 for 1990's land cover, it could be inferred that there was an increase in built up and anthropogenic activities signifying an increase in encroachment.

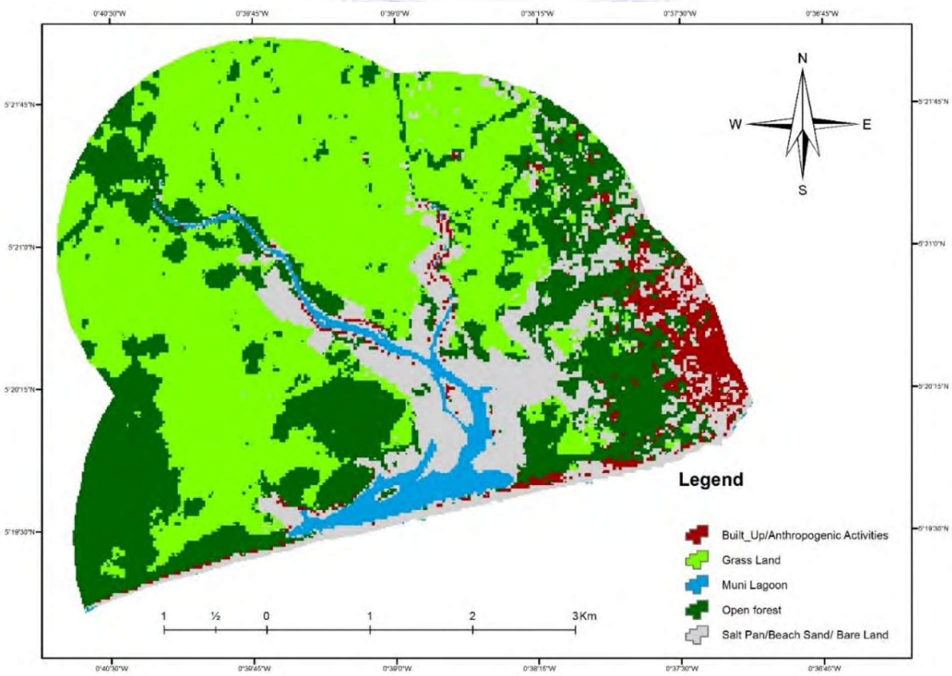


Figure 7: Land cover characteristics of the Muni catchment within 2km buffer in 2000
Source: Field work (2020)

Within the 10 year period, there was 2.2% increase in the rate of encroachment within the 2km buffer of the lagoon catchment under assessment. Notwithstanding, this had a ripple effect on the lagoon as its area coverage decreased from 1.1km^2 (4.1%) in 1990 to 1km^2 (3.7%) coverage in 2000. This is a clear indication that as more areas of the lagoon is encroached, we should expect a future dwindling and resulting diminishing of the lagoon with time. Figure 7 shows the increase in encroachment within the catchment whiles the coverage extent of the lagoon and vegetation keeps decreasing comparing it with that of figure 6 for 1990. The land use unit coverage for year 2000 is tabulated on table 5.

Table 5: 2000 land use unit coverage

Land use unit	Surface area (Km^2)	Percentage (%)
Built Up/Anthropogenic Activities	1.0	3.8
Open Forest	7.7	29.5
Grass Land	12.2	47.1
Muni Lagoon	1.0	3.7
Salt Pan/Beach Sand/Bare Land	4.1	15.9
Total	26.0	100

Source: Field work (2020)

Surface area of land cover units in 2019

With the 2019 remotely sensed image analysis, it was revealed that built up and other anthropogenic activities within the area of assessment covers 2.0km^2 with a percentage of 7.8. Interestingly, in this year, the water body covered 1.2km^2 (4.5%) being the largest coverage within the 30 year period under study. Open forest as at this year has reduced drastically from 7.8km^2 within the 30 years period to 3.2km^2. Considering grassland, it could be seen from figure 8 below that most of the area under study was now being turned to grassland from 12.3km^2 to 15.6km^2 comparing it with figure 6 and 7 of 1990 and 2000 results respectively.

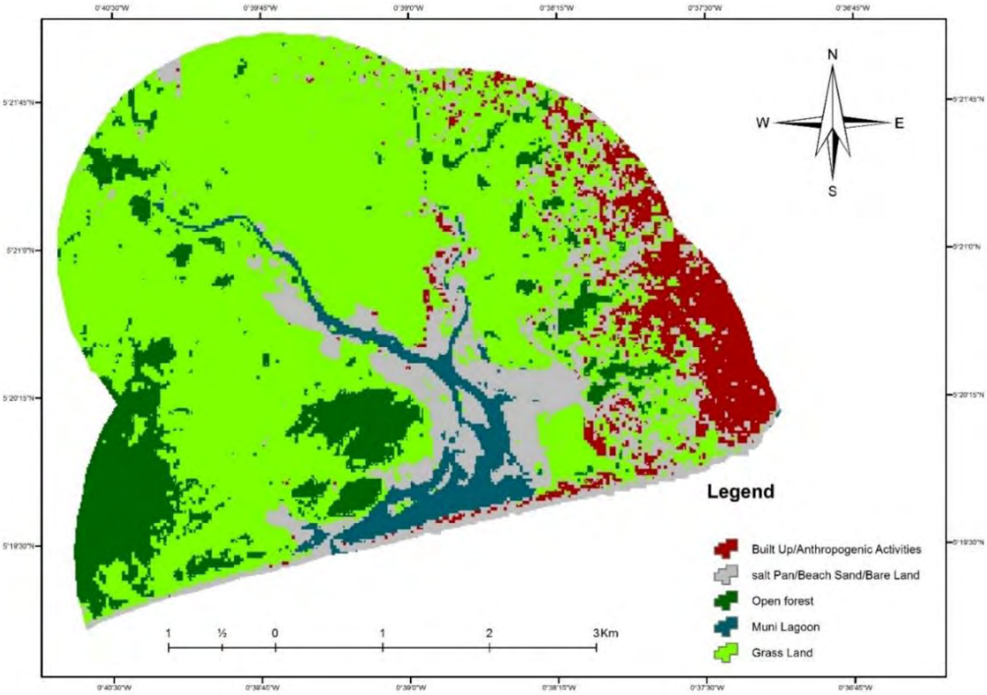


Figure 8: Land cover characteristics of the Muni catchment within 2km buffer in 2019
Source: Field data (2020)

Bare land areas decreased comparing results for 2019 with that of 1990 and 2000, which is likely to may have been lost to build- up areas and possibly some turned to become grassland. The surface area covered by each of the land use units and their percentages are shown on table 6

Table 6: 2019 land use unit coverage

Land use unit	Surface area (Km^2)	Percentage (%)
Built Up/Anthropogenic Activities	2.0	7.8
Open Forest	3.2	12.4
Grass Land	15.6	59.9
Muni Lagoon	1.2	4.5
Salt Pan/Beach Sand/Bare Land	4.0	15.4
Total	26.0	100

Source: Field work (2020)

Encroachment dynamics from 1990 to 2019

A lot of changes have occurred within the 30 years of assessment that is from 1990 to 2019. The rate of encroachment has quintupled. The change in land cover within the Muni Lagoon catchment can be attributed to the fact that vegetation has been replaced with the built up (settlement) and agricultural activities. There has also been a lot of deforestation activities within the area. Within the period from 1990 to 2000, the study revealed that built- up which covered 1.6% of the assessed area in 1990 increased to 3.8% in 2000. From 2000 to 2019, built up within the area increased 7.8% doubling compared to the years back. Considering the lagoon, it could be seen that it decreased in area extent from 4.1% in 1990 to 3.7% in 2000. This reduction could be attributed to the uncontrolled growth of the city and rapid encroachment into the lagoon catchment. That period saw losing of the open forest to agriculture and settlement which invariably affected the lagoon. This is in line with the environmental sustainability theory by Basiago (1999) and a section of the conceptual framework that capitalizes that in achieving sustainability of the resources (lagoon), biodiversity within an area should not be exploited above their rate of regeneration by ensuring integrity of our ecosystem. However the size of the lagoon increased to 4.5% of the catchment from the period of 2000 to 2019. This increment can be attributed to the opening of the lagoon to have direct interaction with the sea forcing it to erode new areas. Again, activities of the Wildlife Department of the Forestry Commission where they embarked series on demolition exercise and stopped most construction activities within the site as well as planting of mangroves along the banks of the lagoon may have led to the reduction of pressure on lagoon.

Plate 1: A recent encroachment in the catchment which the Wildlife Division has halted. This is located at the northern part of the Muni lagoon close to the Ntakofa River
Source: Field work (2020)

Considering the area and percentage changes over the 30 year period, it could be seen from the table below that, for every 10 years, built up areas with the catchment increases by about 3.1%. That is 2.2% from 1990 to 2000, 4.0% from 2000 to 2019 and 6.2% from 1990 to 2019. This gives a clear indication of the speed of encroachment within the catchment. The Muni Lagoon however follows a different format. The lagoon decreased by 0.4% within the 10 period from 1990 to 2000. However from 2000 to 2019, the lagoon increased by 0.8% whilst considering the 30 year period from 1990 to 2019, we can say there was an increment of 0.4%. From table 6, it can be said that the increase in built up over the years is having an inverse effect on vegetation. What is being said is that, as built up increases, it can be seen that vegetation decreases. What this means is that, most of the vegetation within the catchment is being lost to settlement, agriculture and other anthropogenic activities. It is also known that decrease in vegetation in an area and increase in built up leads to increase in surface temperature.

Table 7: Land cover changes from 1990 to 2019

Land use unit	Area in 1990		Area in 2000		Area in 2019		Change from 1900 - 2000		Change from 2000 – 2019		Change from 1900 - 2019	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Built Up/ Anthropogenic Activities	0.4	1.6	1.0	3.8	2.0	7.8	0.6	2.2	1.0	4.0	1.6	6.2
Open Forest	7.8	29.9	7.7	29.5	3.2	12.4	-0.1	-0.4	-4.5	-17.1	-4.6	-17.5
Grass Land	12.3	47.2	12.2	47.1	15.6	59.9	-0.1	-0.1	3.4	12.8	3.3	12.7
Muni Lagoon	1.1	4.1	1.0	3.7	1.2	4.5	-0.1	-0.4	0.2	0.8	0.1	0.4
Salt Pan/Beach Sand/Bare Land	4.5	17.2	4.1	15.9	4.0	15.4	-0.4	-1.3	-0.1	-0.5	-0.5	-1.8

–represent loss

From the discussion, it means that if encroachment is not controlled within the catchment, temperatures will increase which will induce high evaporation on the lagoon that can possible lead to dwindling of the lagoon with time. Jiang, Huang and Han (2014) affirms this by putting forth that type of temperature change is consistent with the process of land use change and urbanization in a study they conducted in Beijing. The table below shows that most of the bare areas within the catchment is being used for built up whilst part is covered with grasses. However, most of the grass shown on the land cover images are also agricultural areas which had reflections as grass.

Plate 2: An area found at the central portion of the catchment close to Gerald International School cleared for agricultural activity
Source: Field work (2020)

Comparing the rate of encroachment within catchment against the size of the lagoon, it can be said that encroachment keeps increasing at a geometric rate whiles the lagoon also keeps eroding new areas but at a very slow rate. Therefore it can be said the increase in encroachment has not had effect on the lagoon as though the lagoon covered 1.1km^2 in 1990, still in 2019 it covered 1.2km^2. However, from 1990 to 2000, encroachment rate increased by 2.2% within the decade whilst the lagoon decreased by 0.4%. From 2000 to 2019, the rate of encroachment was controlled hence there was 1.8% increase leading to the lagoon increasing by 1.2%. In general it can be said that though over the years, the lagoon is not accreting, it is not eroding new areas as much. These findings are in consonance with Atampugre (2010) findings that land cover changes (encroachment) was as a result of construction, urban expansion and agricultural activities in the Muni catchment.

The reasons for encroachment could be attributed to rapid urban growth where land is becoming a scarce resource in Winneba with the rise in student population and intrusion of workers. This has led to high prices of land and rent which induces people to move towards the lagoon catchment to get land at less expensive prices to put up structure to serve the rising population. Again, due to urban development, there are limited open spaces for agricultural activities and for construction making the open space within the catchment the available area for such developments. Moreover, it can be said that, there is lack of policy of the extent to which lands should be given out for anthropogenic activities in relation to the lagoon catchment. This confirms the work of Shrestha (2015) who worked on encroachment within the Bagmati River in India where she found out that encroachment within the river catchment is as a result of lack of demarcation, lack of space and urbanization.

It was necessary to gather information from the field to support what was acquired from the image analysis. During interaction with key informants from the Akosua Village and the Wildlife department, they revealed that indeed there has been a lot of encroachment on the lagoon catchment.

The wildlife department stated that;

> *"In 2017, the coordinates we took for the catchment was up to the seed company around Lowcost but now they have built deep into the catchment hence the coordinates we just took this year (2020) was far from the seed company indicating a great range of encroachment. The pillars we placed some years back within the catchment are now found closer to people's house".*

The wildlife department further added that, as people build within the wetlands, they do a lot of filling which has led to dwindling of the lagoon making wetland areas suitable for building. The regular encroachment has also a lot of siltation in the lagoon.

They reiterated that people are just building closer to the lagoon day in day out. They added that, there have been a lot of demolishing exercise within the area yet people are still putting up structures. One participant added that, most areas that were formerly having vegetation and coconut cover within the catchment are being replaced with structures affirming that people are actually encroaching and building close to the lagoon. The Wildlife department elaborated on how vegetation has reduced because people are clearing vegetation to put up buildings which has led to seizure of ecological services. Concerning the area coverage of the lagoon, one of the participants stated that, there have been a slight reduction in the extent of the lagoon. They explain that in recent years, the lagoon is exhibiting characteristics which is not usual. One of the participants said;

> *"Last year, the lagoon flooded as never before affecting lots of houses. It went very far and persisted for days. This affects fingerlings as they are being carried away and cannot easily return to the lagoon when floods recedes"*

The above indicates that the carrying capacity of the catchment is exceeded as captured in the conceptual framework and as put forth by Basiago (1999). The participants said that, most houses were affected because areas that were formerly bare are now replaced with houses. Again, the flood persisted because the houses has blocked it was that could allow it to move to and fro during the peak of the rainy season. They believe that, building within the catchment has led to increase in sand wining along the beach, something they have been cautioned against. The findings is in consonance with Mureti (2004) study at the Rukaka River riparian zone where he found out that, the effects of encroachment on this zone include loss of vegetation, soil erosion and flooding.

Another participant added that, he believes it is the presence of the abandoned salt pan that causes the annual flooding of the lagoon. He said that the salt pans acted as barrier preventing the free movement of the lagoon. These structures are all part of the anthropogenic activities that was recorded from the image analysis. Talking of the changes, another participant indicated that, he hasn't seen any change with regards to the area extent of the lagoon within the 44 years he has stayed there. The only area coverage change is with regards to seasonal variations and opening of the lagoon but he is aware of other changes associated with the lagoon. He said;

> *"During the early years, the lagoon produced salt by itself during the dry season which we went there to pick and bring home but now, we don't see any of such things. Again, there has been a lot of changes with the vegetative cover. Women come from the Winneba town to harvest the neem trees and the mangroves planted by the Wildlife Division".*

However, the Wildlife Division stated that indeed there has been dwindling of the lagoon due to siltation. They stated that though the lagoon acquires new areas through eroding due to how shallow it is becoming and its closed nature.

The researcher tried to inquire how people acquire land within the catchment to build. The participants explained that, two groups of people own the land traditionally. That is the "Dente and the Tuafo" groups. They got this ownership due to the areas assigned to them for bushbuck hunting during the Aboakyir festival. Though they added that they are not sure whether they give out the land within the catchment but they know they are in custody of portions of the lagoon catchment. However, the Wildlife Division gave a more concrete response on how lands are acquired. They said that, though most of the lands are vested lands, the traditional council specifically the "Tumpa Anona

Royal Family" sell lands to rich people to build within the catchment. Moreover, people also acquire lands from the lands commission.

The information gathered through the interview affirms the findings from the satellite imagery analysis that indeed encroachment is actually taking place and vegetation is decreasing. However, the interview indicated dwindling of the lagoon area in recent years whilst the imagery analysis showed that the lagoon has extended slightly in area coverage in 2019. Further investigations revealed that, the lagoon was opened in 2019 to have direct access to the sea and that might have caused the water volume within the lagoon to increase forcing it to acquire new areas through erosion.

Plate 3: An ongoing building which is found less than 30m from the lagoon found at the south- eastern edge of the catchment
Source: Field work (2020)

Relationship between the Muni Lagoon and climatic variations

The impact of climatic variations on waterbodies is necessary to provide an idea on climatic variables and their relationships with water balance and ecosystem. Using climatic parameters such as temperature and precipitation give insight into how climate is affecting a known catchment and this is what was done within the Muni Lagoon catchment. A commonly-used technique for conducting hydrological impact studies at the catchment scale is to use climate parameters (e.g. precipitation and temperature) provided by climate models as input for hydrological models (Teutschbein & Seibert, 2010).

It has been shown that urban expansion has significant impact on local climate by modifying energy balance, surface temperature, and precipitation patterns (Kumi-Boateng, Stemn & Agyapong, 2015) hence it was necessary to analyze how temperature and precipitation patterns within the catchment is changing amidst encroachment and expansion of the city towards the catchment. Again, the study tried to established relationship between the climatic variables and the changing area coverage of the lagoon. Data for both precipitation (rainfall) and temperature were analyzed over the 30 years under discussion.

Average annual temperature trend analysis

Temperature trend within the study area was analyzed. Temperature data showed that over the 30 year period, temperature is rather varying and not necessary changing as shown by the figure below. Temperature shows a continuous upward and downward trend over the 30 year period. The base year which was 1990, average temperature was high at 27.51°C. However, temperature declined thereafter below that of the base year up to 1997 and rose again in 1998 which happens to record the average highest temperature for the 30 year period with 28.03°C. Temperature fell the years after. Average temperature fell to record the least within the 30 years under study recording 18.09°C in 2000. The years after, there was a steady average annual temperature which clustered around 27°C. The years 2014 and 2015 rather recorded annual average temperatures of 26.7°C and 26.46°C respectively. Annual average temperature after 2015 saw a rise again to the 27°C range the years after. Figure 9 shows the varying nature of temperature within the study area.

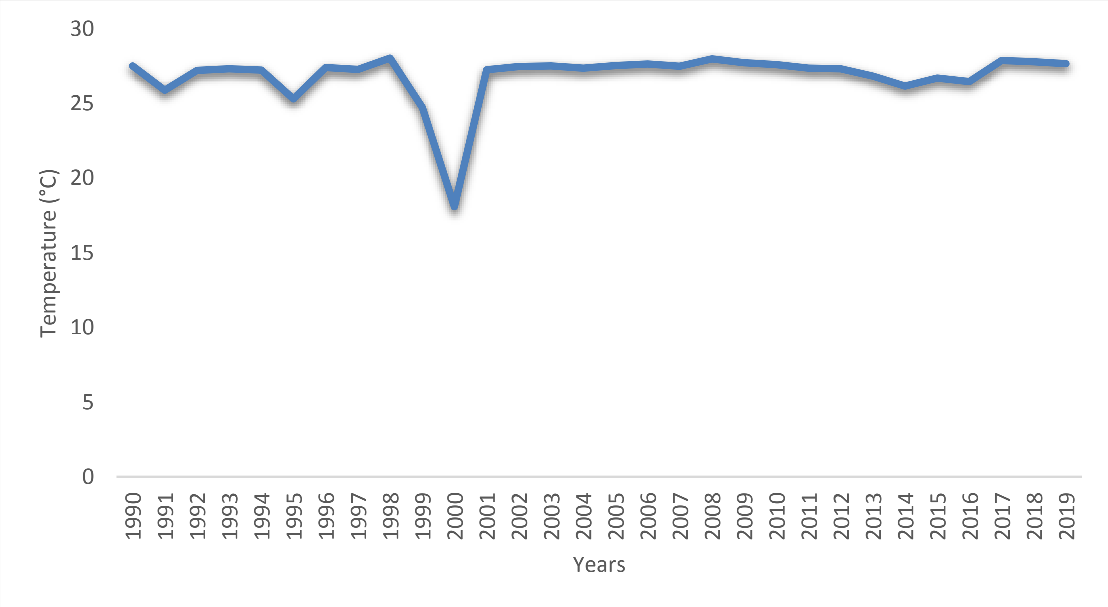


Figure 9: Annual average temperature over 30 years (1990 – 2019)
Source: Ghana Meteorological Agency (2020)

The average maximum temperature for the 30 year period was 26.86°C while the three hottest years from the highest to the lowest were 1998 with 28.03°C, 2008 with 27.99°C and 2017 with 27..87°C. The lowest average annual maximum temperatures were recorded in 2000 with 28.09°C followed by 1999 with 24.72°C and 1995 at 25.0°C.

The deviations of the various years from the 30 year average was computed. The reference normal was 26.86 which was used to find the anomalies over the period. The annual average temperature anomalies are shown in the figure 10

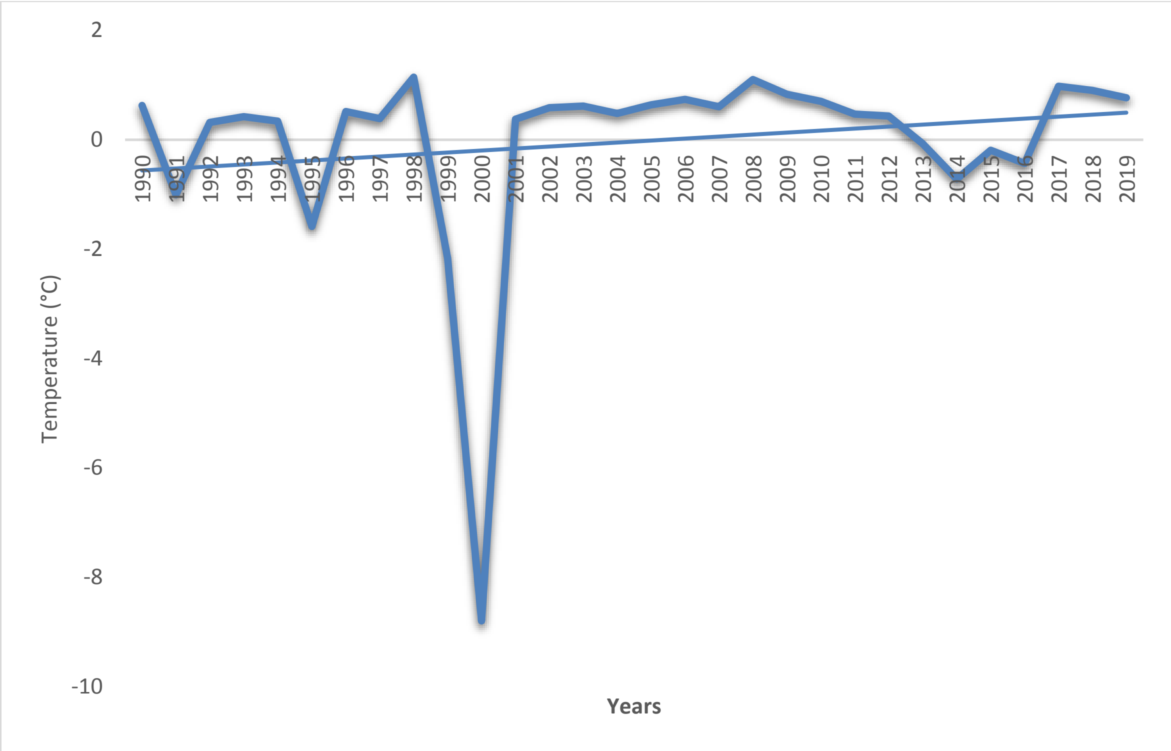


Figure 10: Annual average temperature anomaly
Source: Ghana Meteorological Agency (2020)

From figure 10, the highest negative anomalies were -8.8°C in 2000, -2.17°C in 1999 and -1.59°C in 1995 while the highest positive anomalies were in 1998, 2008 and 2017 with 1.15°C, 1.1°C and 0.98°C respectively. The positive anomalies were indications of higher average annual temperatures than the reference normal while the negative anomaly values indicated the average annual temperatures were lower than the reference normal. The overall total average anomaly for the 30 year period was -0.03°C. This figure is an indication that temperature is not rising in the study area though there is population increase and urban growth. The falling temperature within the study area can be attributed to the presence of the sea which to large extent influence climatic conditions within the area.

Average annual rainfall trend analysis

The study of the hydrological history within the catchment shows that rainfall is highly varying and not changing. In 1990 which represents the base, average rainfall was generally low (454.6mm), however, it rose in 1991 to 1015.0mm and started declining again from until 1993 (570.2mm). Rainfall appreciated up to 1997 recording an average of 1025.0mm where there was a decline again from 1998. The rainfall regime followed this upward and downward trend. The highest average rainfall was recorded in the year 2015 (1135.4mm) whilst the least was recorded in 1990 with an average of 454.6mm. However, for 4 years after 2015, rainfall has been declining within the catchment with the year 2019 recording 592.9mm.

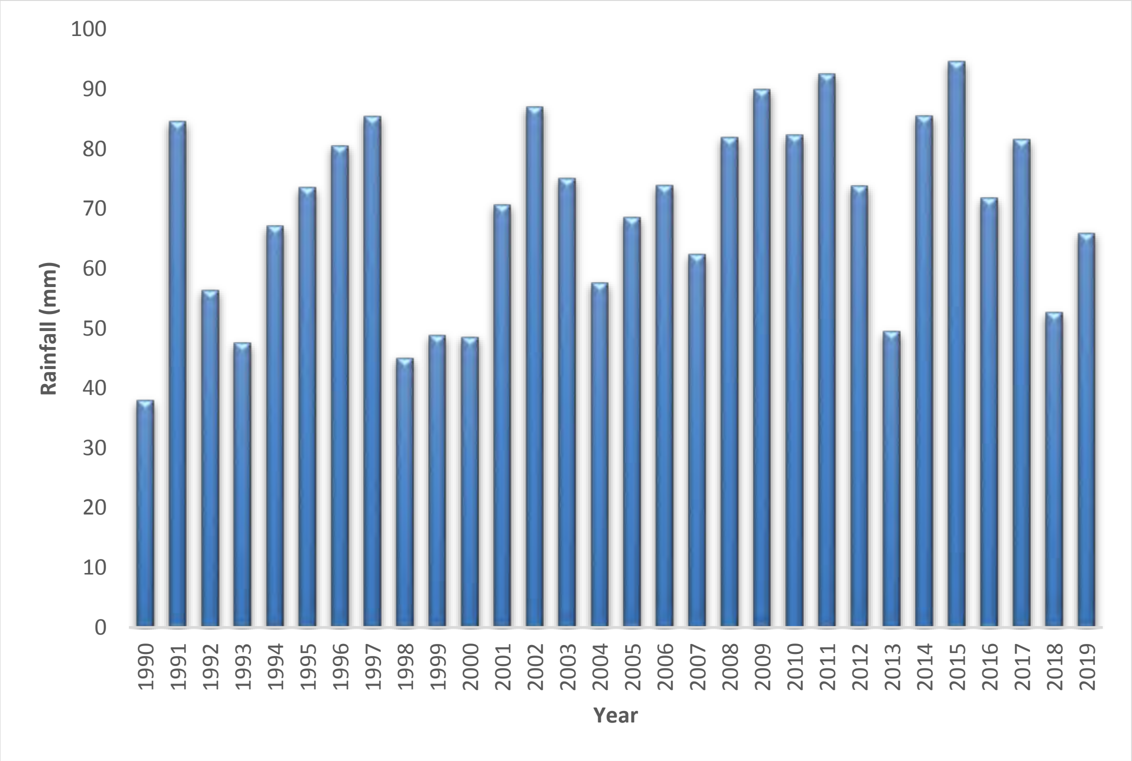


Figure 11: Annual average rainfall over 30 years (1990 – 2019)
Source: Ghana Meteorological Agency (2020)

The average annual rainfall for the 30-year period was 830.3mm. The highest total annual average was 1135.4mm in 2015 followed by 1110.6mm in 2011 and coming third with 1079.4mm in 2009. Within the 30-year period the lowest average annual rainfall was in 1990 when only 454.6mm of rainfall fell, 1998 with 539.6mm and 1993 with 570.2mm.

The rainfall anomaly for the area over the 30 year period was calculated to give an idea on how averages for the year are above or below the average for the whole 30 years which was 830.3mm. A positive anomaly indicates the observed annual average rainfall was higher than the 30 year average while a negative anomaly indicates the observed annual rainfall was below the 30 year annual rainfall. The highest negative anomaly was in 1990, 1998 and 1993 with -375.7mm, -290.7mm and -260.1mm respectively an indication that in those years the average rainfall received was far below the reference normal as suggested by Zhao, Wang, Wang and Tibig (2005) cited in Maina, Wandiga, Gyampoh, and Charles (2019). 2015, 2011 and 2009, on the other hand, received the highest rainfall above the reference normal of 305.2.88mm, 280.4mm and 249.2mm respectively as illustrated in figure 12.

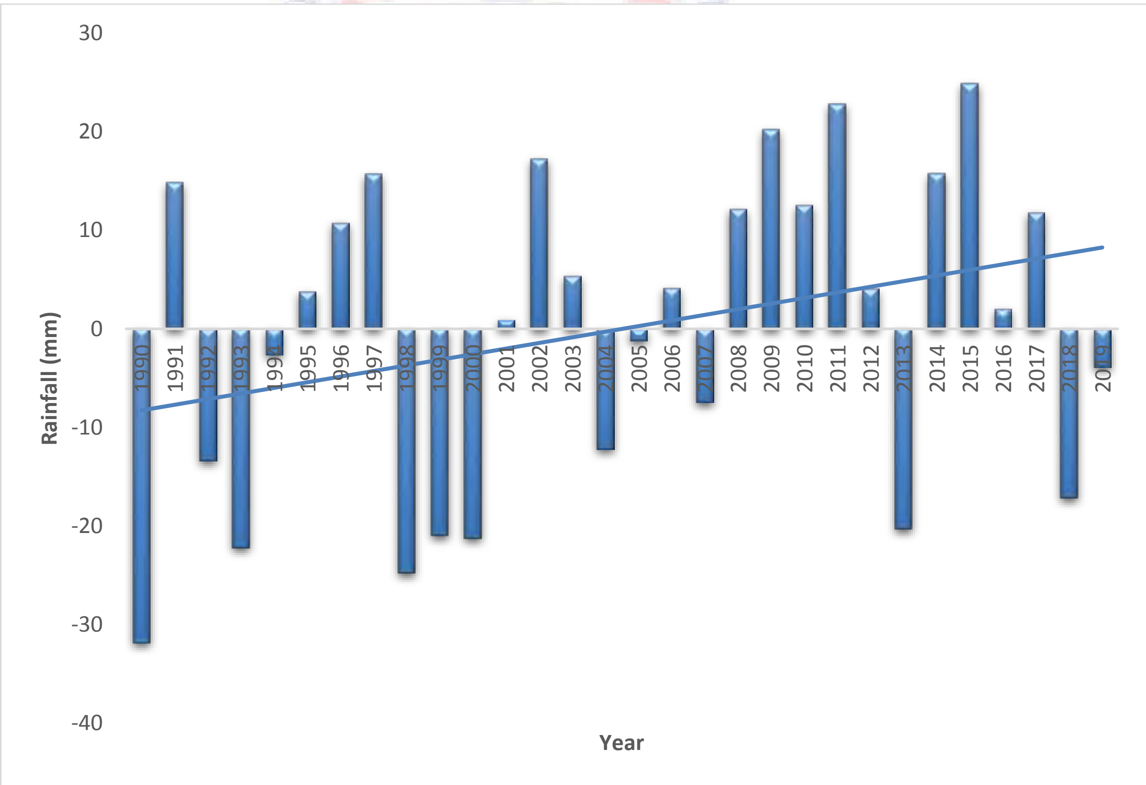


Figure 12: Annual average rainfall anomaly
Source: Ghana Meteorological Agency (2020)

It can be inferred from figure 12 that, 13 out the 30 years have negative anomalies indicating that they received annual rainfall below the 30 years average rainfall. Though most of the years had positive anomaly, the total average anomaly was -0.15mm which was slightly lower than the calculated reference normal. The above results shows a slight decline in the annual average rainfall recorded in the study area over the 30 year period. It can therefore be concluded that there had been a negative change in rainfall regime in the study area.

Relationship between temperature and rainfall at the study area

The researcher tried to find out the extent to which temperature within the study area affects rainfall. This was achieved through a correlational analysis. The Pearson moment correlation coefficient was used to estimate the relationship between temperature and rainfall. Table 8 displays the correlation test results.

Table 8: Correlation between rainfall and temperature

		Rainfall
Temperature	Pearson Correlation	.232
	Sig. (2-tailed)	.217
	N	30

Significant at 0.05

Per the correlation result above (r=0.232, p-value=0.217), it can concluded that there is a statistically weak positive relationship between temperature and rainfall. Given a p-value of 0.217 which is greater than the alpha significance level of 0.05, it can be concluded that the relationship between temperature and rainfall is insignificant. In this case, the null hypothesis has to be accepted, that, there is no significant relationship between the extent of temperature and rainfall within the Muni Lagoon catchment. The implication is that, there may be other underlying factors affecting either temperature or rainfall than the two variables themselves. The reduction of rainfall within the study area could be attributed to the loss of vegetation within the area. Vegetation within the study area is lost through clearing the land for agriculture, construction (urban growth), annual forest fires and harvesting for fuel. Degradation at the Muni-Pomadze site is largely due to agriculture, development (construction), sand and salt winning, bush fire, hunting, and fishing with some of these activities being the main occupation within the study area (Wuver & Attuquayefio, 2006; Ramsar, 2002). Ramos da Silva, Werth and Avissar (2008) put forth that, deforestation is a major cause of decrease in rainfall when they did a study on the Amazon forest using the coarser resolution model. These couple of factors may have upsurged or downshifted the variables of rainfall or temperature rather than either of the variables.

Relationship between the changing area coverage of the Muni Lagoon and climatic variables

The area covered by the Muni Lagoon has changed slightly over the years. Land cover analysis done on the Lagoon showed that its area coverage decreased by 0.4% within the 10 period from 1990 to 2000. However from 2000 to 2019, the lagoon increased by 0.8% therefore considering the 30 year period from 1990 to 2019, it can be said there was an increment of 0.4%.

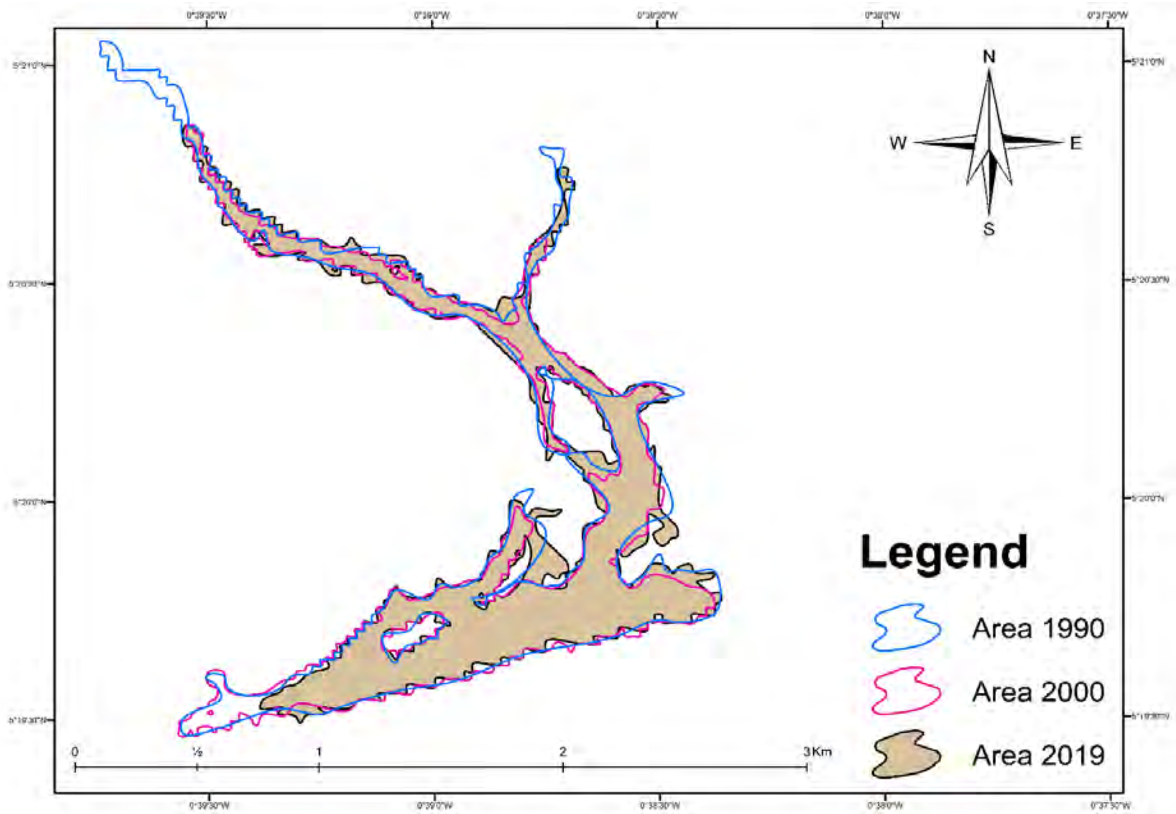


Figure 13: Area coverage of the Muni lagoon in 1990, 2000 and 2019
Source: Field work (2020)

From figure 13, it can be seen that, in 1990, the main tributaries of the lagoon (Ntakofa on the east and Pratu on the west) had enough water in their channel that fed the lagoon. Again, on the south western portion, the lagoon covered to the extreme arm which is dried up currently (2019). During the year 2000, it can be seen that the upper portions of the tributaries had dried off completely with its middle portion also dwindling. However, the south western arm was still intact. In 2019, a lot of change is observed at the south western portion where large part of the lagoon is dried up completely. The upper portion of the lagoons where its tributaries were could not revive as seen from the 2010 coverage. However, a careful observation reveals that the lagoon has eroded new areas at its middle portion breaching some of the sand bars to cover them with water. Though, the lagoon has gained new areas, careful study show that the lagoon is dwindling from its extreme ends as shown on figure 8. The extreme northern and south western portion of the lagoon is dried completely which calls for action.

Relating this to the temperature and rainfall variations, it can be said that temperature is not having so much effect on the lagoon in the sense that temperature is not increasing to cause evaporation on the lagoon but rather decreasing. However, rainfall within the study area is decreasing which could be a good basis for the drying up of most portions of the tributaries. The major sources of water in the channels of these rivers are rain therefore reduction in rainfall implies reduction in the amount of water present in the river channels to feed the lagoon. The tributaries of the lagoon are now found within the town due to urban growth where vegetation around them have been cleared. Per the works of Ramos da Silva et.al, (2008) deforestation is a major cause of decrease in rainfall hence clearing of vegetation around the study area induces low rainfall. The reduction in rainfall has had serious effects on the lagoon. The area coverage would have been more serious than observed but with the artificial opening of the lagoon to have interaction with the sea has helped to maintain the water level within the lagoon. This confirms the work of Adu-Boahen, Dei, Antwi and Adu-Boahen (2015) where they found out that, reduction in rainfall level at the Lake Bosomtwi area affected its tributaries including Ebo, Aberewa and Konkoma which had declined water levels in their river systems ultimately affecting the water level of the lake. Again, Odada, Oyebande and Oguntola (2004) had similar findings on the Lake Chad where they concluded that significant reduction in direct rainfall led to reduction in the lake and leading to a reduction in its shoreline.

Analysis of heavy metal concentrations in water and fish samples in the Muni Lagoon

Water and aquatic organisms are mostly disturbed with heavy metal concentrations which affect the overall functioning. During the wet and dry seasons, five heavy metals namely lead, iron, manganese, cadmium and zinc were tested through water sampled from the Muni lagoon and its tributaries for laboratory analysis to determine their concentration within the lagoon. A control sample was also tested using the water from the Ayensu estuary which rather showed high level of pollution compared to the lagoon therefore was not used for analysis. ML1 to ML6 represents samples taken from the Muni lagoon, which is from its lower and middle portions. CF7 denotes sample taken from the confluence where the two rivers Pratu and Ntakofa mix with the lagoon whilst PR8 and NF9 denotes samples taken from the Pratu and Ntakofa respectively. CF7, PR8 and NF9 represents the upper portion of the lagoon. The results is shown on table 9

Table 9: Heavy metal concentrations in the Muni Lagoon

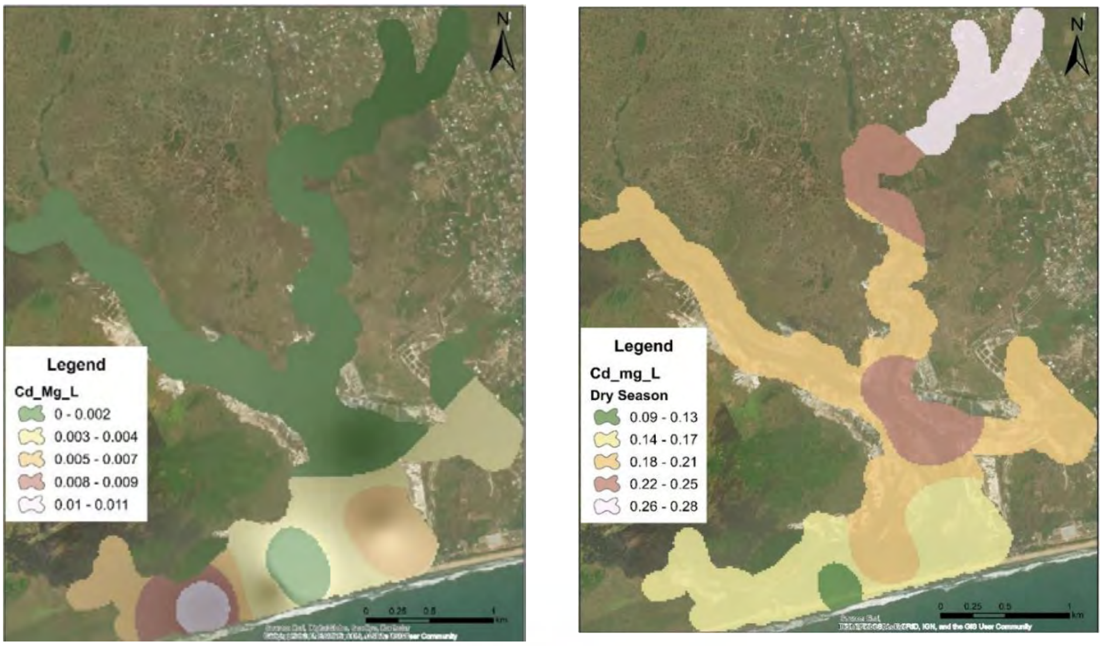
Sample ID	Cadmium (Cd) Mg/L		Zinc (Zn) Mg/L		Iron (Fe) Mg/L		Manganese (Mn) Mg/L		Lead (Pb)Mg/L	
	Wet	Dry	Wet	dry	Wet	Dry	Wet	dry	Wet	Dry
Control Sample	BDL	0.128	0.0766	0.150	1.4263	0.493	BDL	0.10	1.0111	BDL
ML1	0.0112	0.163	0.0061	BDL	0.1510	0.044	BDL	BDL	0.2101	BDL
ML2	0.0026	0.090	0.0058	BDL	BDL	0.395	BDL	BDL	0.3515	BDL
ML3	BDL	0.201	0.2004	BDL	0.7725	0.239	BDL	0.006	0.2645	BDL
ML4	0.0049	0.168	0.1056	BDL	0.8083	0.340	BDL	0.058	0.4261	BDL
ML5	0.0065	0.135	0.0125	BDL	0.4394	0.881	BDL	0.023	0.1013	BDL
ML6	BDL	0.244	0.0009	BDL	0.1384	0.581	BDL	0.046	0.1557	BDL
CF7	BDL	0.212	0.0418	BDL	0.4375	0.963	BDL	0.105	0.1521	BDL
PR8	BDL	0.178	0.0490	BDL	0.5934	0.202	BDL	BDL	0.1285	BDL
NF9	BDL	0.285	0.0133	BDL	0.2673	0.298	0.3418	0.382	0.1013	BDL

BDL= below detection limit
Source: Field work (2020)

Cadmium concentration

Seven (7) samples of water were collected from the lagoon together with one sample each from the Ntakofa and the Pratu rivers which are the major tributaries of the Muni Lagoon giving a total of 9 samples. Cadmium was below detection within the tributaries as well as other areas within the lagoon. Four of the points recorded some amount of cadmium with the range of 0.004 to 0.01. The point ML1 where the highest concentration was recorded is the mouth of the lagoon that is closer to the sea when its opened to get contact with the sea. The values recorded are below the USEPA threshold level of 0.05Mg/L maximum contaminant level. From this, it can be said that, the small concentration found within the lagoon poses no threat to aquatic organisms within the lagoon. In the dry season, cadmium concentration ranged from 0.09 to 0.29. This concentration was higher than that of the wet season and above the maximun contaminant level which signals threat to aquatic organisms. This could be attributed to redeuction of inflow of rain water into the lagoon and increase in evaporation making the metal more concentrated. Moreover, the concentrations found within the lagoon can be attributed to the agricultural activities carried on around 2km within the catchment where fertilizers are applied in vegetable farming. Cadmium is also present as an impurity in several products, including phosphate fertilizers, detergents and refined petroleum products (Weggler, McLaughlin, & Graham, 2004).

The application of agricultural inputs such as fertilizers, pesticides, and biosolids (sewage sludge), the disposal of industrial wastes or the deposition of atmospheric contaminants increases the total concentration of Cadmium (Campbell, 2006). In low doses, cadmium can produce coughing, headaches, and vomiting according to EPA (1999) which implies that the little concentration found in the lagoon even calls for concern as they can accumulate in tissues of fishes to be eaten by humans. When cadmium accumulates in soils, it can contaminate crops that are grown on such soil. In the 1940s in Japan, an epidemic known as Itai- itai disease occurred when people ate from cadmium contaminated rice that were grown on contaminated soil along riverbanks downstream of a mine (Nogawa et al., 2004).



a b

Figure 14 (a, b): Cadmium concentration in the Muni Lagoon for wet and dry seasons
Source: Field data (2019)

Zinc concentration

The presence and concentration of zinc was also analyzed in the lagoon. The results indicated that there was the presence of zinc in all the areas sampled including the Pratu and the Ntakofa rivers. It is not surprising that zinc was found throughout the lagoon because according to Haynes, Lide, and Bruno (2016), it is the most abundant element in the earth crust. The concentration of zinc within the lagoon was found to be in a range of 0.009 Mg/L to 0.2 Mg/L. The higher concentration was found within the lagoon and not in the tributaries. It can therefore be said that, the existence of zinc in the lagoon is not supplied into the lagoon from its major tributaries. The tributaries rather recorded 0.04 Mg/L and 0.01 Mg/L in the Pratu and Ntakofa respectively. The results of zinc in the lagoon indicates that it is free from zinc pollution since the concentration here is far less than the USEPA (2017) recommended concentration of 5.0 Mg/L. However, during the dry season, zinc was below detection limit. This may be due to the breaching of the closed sand bar to that gave interaction of the lagoon to the sea. The mixing of the sea may have neutralized the zinc content in the lagoon making it not detectable.

The concentration of zinc in the lagoon may be attributed to the pesticides used by the vegetable and other crop farmers during the planting season. Cattle dung may have also been washed into the lagoon since the site serves a grazing grounds for cattels that belong to the university. Moreover since houses and other settlement are being put up within and close to the catchment, it could be that other metals and alloys as building materials may have been washed by rain into the lagoon and its tributaries. Forstner and Prosi (1979) cited in Eshun (2011) avers that the well-known anthropogenic sources of zinc are usually smelting, mining, metallurgy, electro-galvanising, pesticides, various alloys. Zinc oxide is widely used as a white pigment in paints, and also in the manufacture of rubber and other plastics (Emsley, 2001). With increasing encroachment to the lagoon, it is likely some of these products might have gotten into contact with the lagoon releasing zinc into it. The Ntakofa river flows through most part of the Winneba town before it joins the lagoon hence it may have come into contact with these paints and plastics resulting in the concentration of zinc. The ML3 at the lowest portion of the lagoon where the highest concentration (0.2) was recorded could be attributed to leaching of zinc from the sand bar into the lagoon where zinc may have been accumulated. Moreover it could also be as a result of natural source where weathering of minerals and soils have introduced zinc into the lagoon (Merian, 1991).

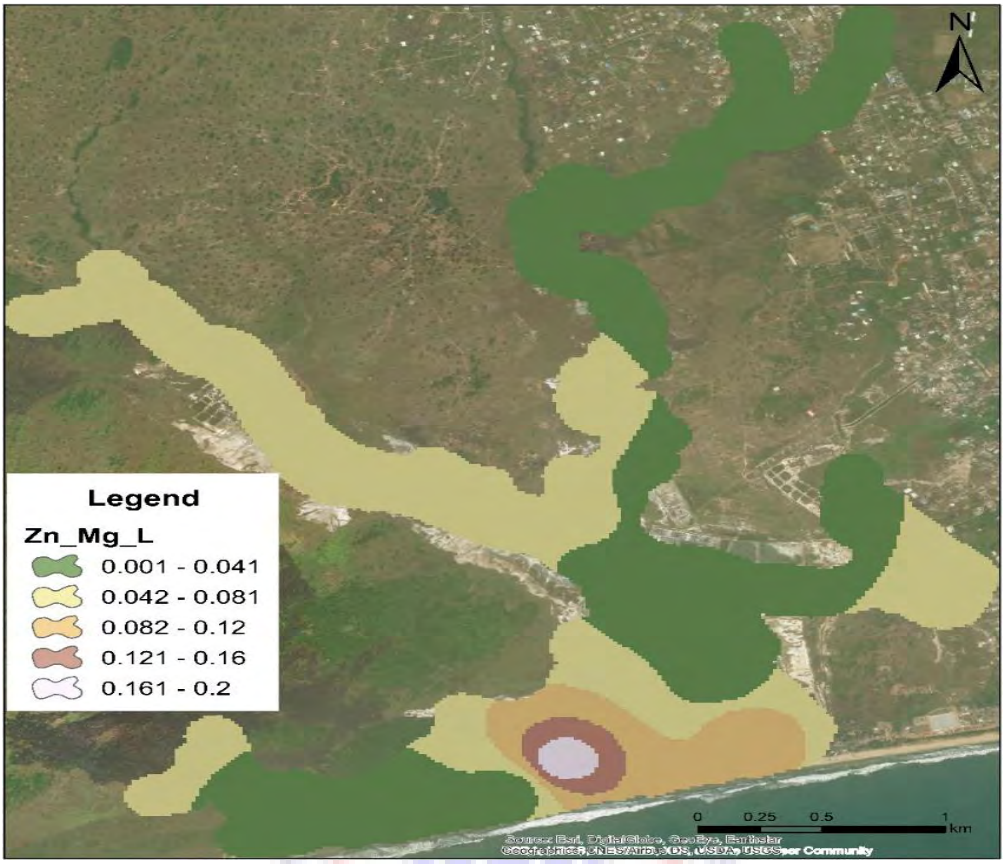
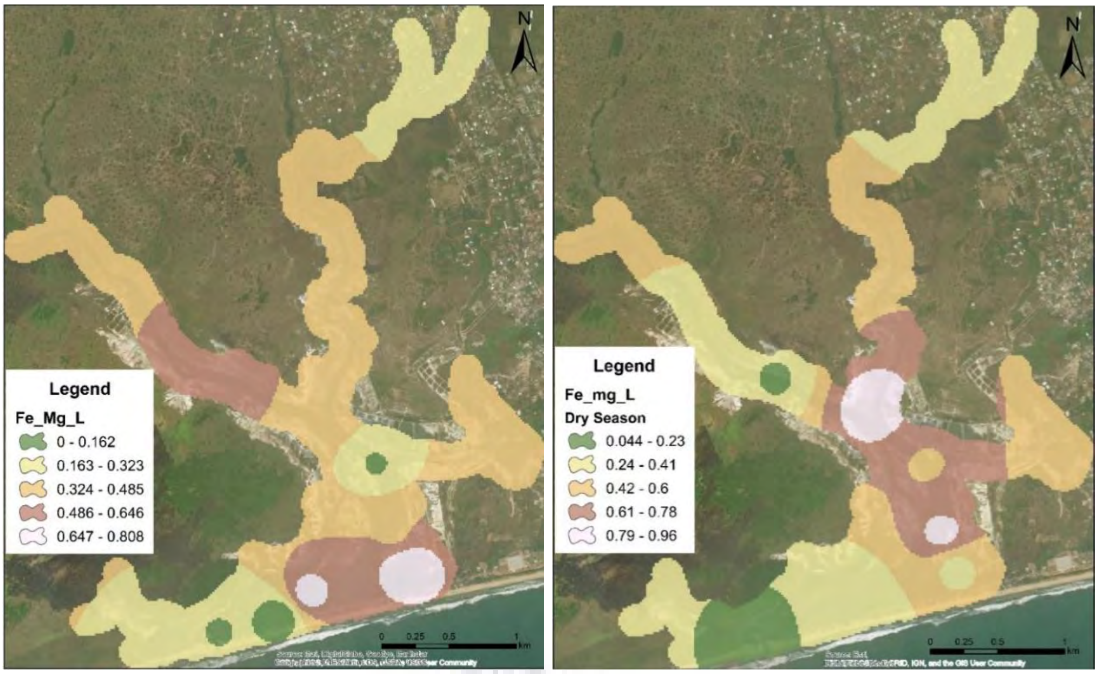


Figure 15: Zinc concentration in the Muni Lagoon during the wet season
Source: Field data (2019)

Note: Zinc concentration was below detection limit during the dry season hence only wet season results image displayed

Iron concentration

Iron, is known to be the generally abundant element in the Earth's crust (Aisen et al., 2001). Iron is the fourth most abundant element and second most abundant metal in the Earth's crust after aluminium (Rose, Hawkes, & Webb, 1979). In the analysis, iron concentration was also tested. The results indicated the presence of iron in the lagoon and also in its tributaries. Iron concentration had a range from 0.1 Mg/L to 0.8 Mg/L. Comparing this range to the USEPA threshold of 0.3 Mg/L, and the Water Resource Commission of Ghana (WRC, 2003) target water quality range of 0.01 Mg/L, it can be said that the lagoon is significantly polluted with iron. The highest value recorded at the ML4 is the part of the lagoon where the Akosua Village residents have used as a dumping site for their waste. Due to frequent flooding of the lagoon during the rainy season, the residents of the aforementioned communities have decided to deposit their waste along the shores of the lagoon to serve as a barrier or defense to protect them so that they lagoon may not be able flow over that waste- barrier and get to them when the lagoon inundates. In the dry season, iron concentration ranged from 0.06Mg/L to 0.38Mg/L. This concentration was lower than that of the wet season and above the USEPA threshold. The dry season results may be influenced by the artificial breaching of the closed sand bar to have direct interaction with the season. Inflow of sea water into the lagoon may have caused a reduction in the pollution level within the lagoon leading to low concentration of iron. Reimann, and de Caritat (1998) reported that the anthropogenic sources of iron include the iron and steel industry, sewage and dust from iron mining. However, this is not the case in the Muni since these activities do not occur there. The occurrence of iron there can rather be attributed to the farming activities carried on around the lagoon since there is the high likelihood of the farmers applying fertilizers, pesticides and herbicides. Iron sulphate is also used as a fertilizer and herbicide (Reimann et al., 2003). The concentration of iron found within the lagoon calls for action. Consuming heavy metal of iron may have detrimental effects of humans when they accumulate in tissues. Iron may cause conjunctivitis, choroiditis, and retinitis if it contacts and remains in the tissues (Braun & Killmann, 1999).



a b

Figure 16 (a, b): Iron concentration in the Muni Lagoon for wet and dry season
Source: Field data (2019)

Lead concentration

Lead occurs naturally in the environment. However, most lead concentrations that are found in the environment are a result of human activities (ATSDR, 2008). Lead has been known to be toxic since the 2nd century BC in Greece according to Asio, (2007). After testing for the concentration of lead in the lagoon, it was realized that there is the presence of lead with range from 0.1 Mg/L to 0.4 Mg/L. The values recorded are far above the USEPA recommended threshold of 0.015 Mg/L maximum contaminant level. During the dry season analysis, lead concentration was below detection limit which may be attributed to the interaction of the sea with the lagoon as at the time the samples were taken unlike the wet season where the lagoon was closed. The figures recorded calls for greater concern as their concentration may be found accumulated in tissues of fishes consumed from the lagoon. Worldwide, lead has been known to be a toxic substance that has numerous effects when inhaled or consumed. Lead is highly toxic to fish (Rompala, Rutosky, & Putnam, 1984 cited in Obodai et al., 2011). The biological effects of high concentrations of lead include delayed embryonic development, suppressed reproduction and inhibition of growth. It also causes increased mucus formation, neurological problems. It may also cause enzyme inhibition and kidney malfunction ((Rompala et al., 1984; Leland, & Kuwabara, 1985 cited in Obodai et al., 2011).

Just like zinc, the highest concentration was recorded at ML4 where the Akosua Village folks have heaped waste to serve as artificial barrier against flood or to control flood. Moreover domestic effluence discharged into the tributaries may have been introduced into the lagoon increasing its concentration. Again, due to the numerous agricultural activities carried in around the lagoon and along its tributaries can be cited as source of lead in the lagoon. The farmers use fertilizers and herbicides which all contain lead. Also, the site serves as ranching grounds for cattle grazing where their dung may be washed into the lagoon during rainfall. Moreover, with urbanization and increasing settlement around the lagoon, it is likely building materials in form of metals and paints (which lead is used in their manufacturing) may have come into contact with the lagoon causing lead concentration. It was the first metal to be linked with failures in reproduction (Asio, 2007). The main sources of lead entering an ecosystem are atmospheric lead (primarily from automobile emissions), paint chips, used ammunition, fertilizers and pesticides and lead acid batteries or other industrial products (UNEP, 1991). Per the words of Salem, Eweida and Azza (2000), then it can be said that consuming fish from the lagoon is dangerous. They stated that lead is found in trace amounts in various foods, notably fish, which are heavily subject to industrial pollution. Lead when consumed accumulates in the human bones. Most of the lead taken into the human body is removed through urine; however, there is still risk of buildup, particularly in children (Salem *et al*., 2000).

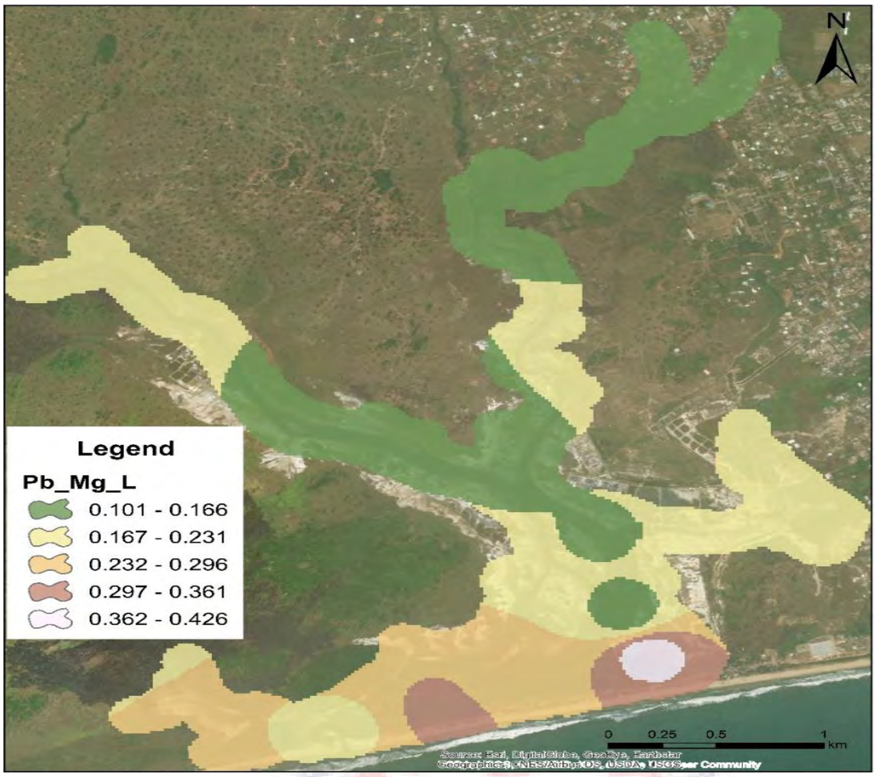


Figure 17: Lead concentration in the Muni Lagoon during the wet season
Source: Field data (2019)

Note: Lead concentration was below detection limit during the dry season hence only wet season results image displayed

Manganese concentration

Manganese was below detection limit within the lagoon. Its concentration was found only in the Ntakofa River with a value of 0.32 Mg/L. it was not surprising to record manganese within the aforementioned river due to the activities that goes on around the river and where the river passes before emptying into the lagoon. There is a big gutter where domestic effluence, other household and waste from the Trauma specialist hospital is linked to which flows and joins the river at the Klimovic hospital. At the Klimovic hospital also, other waste is discharged into the river. The river then flows eastward where an observed house channels waste from the bathroom into. From this point, the river flows through an area where vegetables are cultivated with the river serving as a form of irrigation. At this point, there is no doubt that chemicals from fertilizers, herbicides and pesticides get into contact with the lagoon. All the instances cited probably might be the reason for the concentration of manganese within the river. In the dry season, the Ntakofa River still recorded the highest concentration of manganese (0.38Mg/L). The other points which where manganese was not detected had some concentration in the dry season except the ML1 and PR8 sampling points. Manganese concentration in the dry season ranged from 0.06Mg/L to 0.38Mg/L little above the wet season concentration. The above concentration is higher than the USEPA acceptable limit of 0.05Mg/L in surface waters. This pose threat to the environment.

Though the river joins the lagoon, there are lot of natural reeds which the river flows through behind the Winneba senior high before getting into contact with the lagoon and this can be a reason why manganese below detection within the lagoon. In the dry season, the second highest concentration of manganese was found at the confluence (0.11Mg/L) which indicates that manganese may have been transported from the Ntakofa River into the lagoon. It can therefore be said that, the tributary in this case is influencing the manganese level within the lagoon. In the developing nations, the pollution of the environment by trace metals through industrial emission, effluent discharges, solid waste disposal, usage of agro-chemicals and sewage sludge in agricultural practices as well as automobile activities is evident (Oladeji et al, 2016). Anthropogenic sources of manganese include mining and smelting, engineering, traffic and agriculture. It is also used in the manufacture of steel, glass, dry batteries and chemicals (Yang & Sanudo–Wilhelmy, 1998). According to ATSDR (2000), accumulation of manganese occurs in the subsoil rather than on surface which could mean that they may be manganese in the lagoon but can be detected using analysis from its bed sediment. Moreover the concentration in the Ntakofa River calls for action as farmers use it for irrigation and others also fish from it using hook and line. The traces of manganese can get into humans through the aforementioned medium that can be dangerous to human health. Symptoms of manganese poisoning are hallucinations, forgetfulness and nerve damage. A syndrome that is caused by manganese has symptoms such as schizophrenia, dullness, weak muscles, headaches and insomnia (ATSDR, 2000).

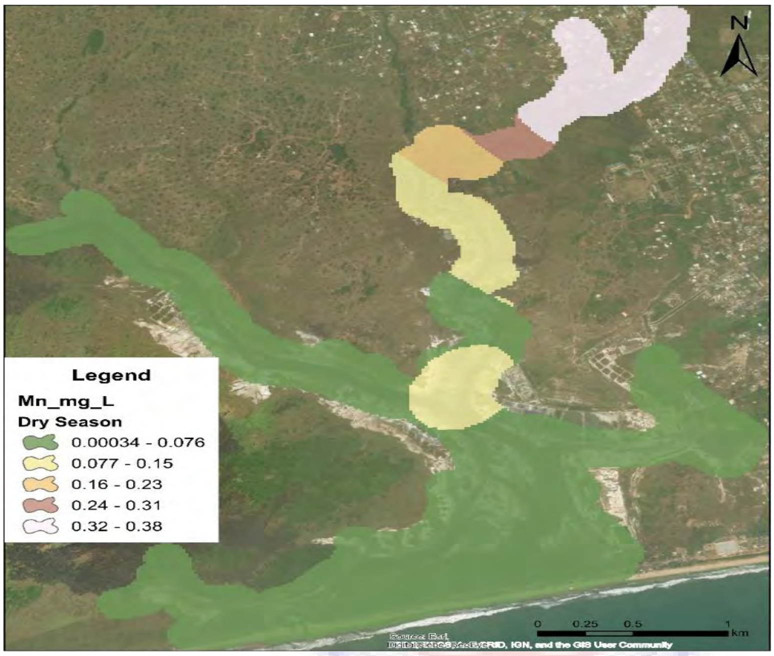


Figure 18: Manganese concentration in the Muni Lagoon during the dry season
Source: Field data (2019)

Note: Manganese concentration was below detection limit during the wet season hence only dry season results image displayed.

Ecological risk associated with the heavy metal concentration in the Muni Lagoon

According to the USEPA, ecological risk assessment involves making an evaluation of the likelihood of environmental stressors such as chemicals, land change, disease, invasive species and climate change may impact the environment. The impact could be on humans or ecology such as plants, fishes and birds among others. After analyzing the concentration of heavy metals within the lagoon and its tributaries, there was the need to evaluate the risk associated with the metals. The assessment was done as shown below

Where Er is ecological risk potential of heavy metal and ERi (risk index) is ecological risk potential of environment.

$Er = T_f \times C_f$, where T_f is the toxic response factor or metal and $Cf = \frac{Cs}{Cf}$ where C_s is the concentration of element in sample and C_f is the concentration of element in the background (Hakanson, 1980).

After computing, it was revealed that three out of the five metals analyzed has some risks posed to the environment. Zinc had low risk that is the rate with which it impacts humans and organisms that are in contact with the lagoon is low. Cadmium rather had considerable risk implying that it may pose danger to fishes, plants and humans who interact with the lagoon. The greatest of all was lead with ecological risk index of 251.5 as shown in table 10. It should be noted that, Mn was below detection in the wet season whilst Fe has no toxic factor hence their ERi was not computed. Again, lead and zinc was below detection in dry season whiles iron has no toxic factor hence their ERi was not calculated.

Table 10: Risk associated with heavy metals concentration in the Muni Lagoon

Heavy Metal	**ERi Value**	**Ecological risk criteria of environment**
	Wet season	
Cd	189.0	Considerable risk
Zn	0.718	Low risk
Pb	251.5	Very High risk
	Dry season	
Cd	570.0	Disastrous risk
Mn	10.0	Low risk

Source: Field work (2020)

The assessment revealed that for the wet season analysis, lead poses very high risk to aquatic and human life within the lagoon. Lead had risk index of 251.5 which is very dangerous and calls for immediate action. Lead has been known to be a toxic substance since the 2^{nd} century according to Asio (2007) and poses a lot of danger to organisms. It is being said that lead easily accumulates in fish tissues and all humans who consume such fishes stand the risk of suffering from kidney failure with time. It is there necessary that immediate actions are put in place to minimize the risk associated with these metals on the environment. In the dry season, the ecological risk associated with the heavy metals indicated that, cadmium poses a disastrous risk to the environment with ecological risk index of 570.0 implying that cadmium poses greater risk to all elements within the environment of the lagoon. Manganese however posed low risk to the environment with ecological risk index of 10.0 as shown on table 10. This means that though manganese poses some amount of risk to elements within the assessed domain, its effect is not that detrimental. In order of environmental risk, cadmium poses the highest risk, followed by lead, manganese and zinc in that order (Cd > Pb > Mn > Zn). This findings is in contrast to the results found by Tay et al. (2009) who conducted similar studies on the Muni Lagoon and reported that cadmium concentration was lowest within the lagoon.

Test results in Fish

The concentration of heavy metals tested in water samples were also analyzed in 3 same species of fishes sampled from the lagoon acquired with cast net. The black chin fish is the common species of fish found in the lagoon and was caught from three different sample sites thus, the upper (MUS), middle (MMS) and low (MLS) sites of the lagoon. The results is tabulated below

Table 11: Heavy metal concentration in fish

Sample ID	Fe Mg/Kg	Mn Mg/Kg	Zn Mg/Kg	Cd Mg/Kg	Pb Mg/Kg
MLS	0.955	0.116	0.080	0.278	BDL
MMS	1.651	0.345	0.258	0.368	BDL
MUS	0.623	0.100	0.119	0.462	BDL
Mean	1.076	0.187	0.152	0.369	-

Source: Field work (2020)

The concentration of iron was higher in the fish caught in the middle portion of the lagoon. The mean concentration of iron found in the fish tissue was 1.076Mg/Kg which is below the WHO (1989) maximum permissible limit (MPL) of 100Mg/Kg in fish tissue cited in Mokhtar (2009). Manganese concentration also occurred at a mean of 0.187Mg/Kg which is also below the WHO (1989) MPL of 1.0Mg/Kg cited in Mokhtar (2009). However, the highest concentration was found within the fish caught at the middle site of the lagoon. Zinc had a mean concentration of 0.152Mg/Kg which is also below the FAO/WHO (1989) MPL of 40Mg/Kg. The highest concentration of zinc was again found in fish sampled from the middle site of the lagoon. Cadmium concentration did not differ from all the other metal. Its concentration had a mean value of 0.369Mg/Kg which is below FAO/WHO (1989) MPL of 0.5Mg/Kg. Lead was not detected in the fish as same was found for water samples in the dry season. The above results implies that, there is no health risk or harm associated with consuming fishes from the Muni lagoon because all the heavy metals concentration tested were below the FAO/WHO maximum permissible limits in muscles of fish. The results may in part be influenced by the regular fishing activities that occur in the lagoon. Fishes do not spend so much time in the lagoon before they are harvested making it possible for heavy metals in the lagoon to be concentrated much in their tissues. This can be supported with the use of drag net to fish in the lagoon leading to harvesting of fingerlings. This is a clear indication of fishes not staying long in the lagoon to accumulate heavy metals in their tissues before they are caught by fishermen. The results also indicate that, except for cadmium, fishes caught in the middle portion of the lagoon had the highest concentration for all the other metals. This confirms Tay et al. (2009) results when they found out that, heavy metals in the Muni Lagoon was more concentrated in the middle site than the northern and southern sites. The results obtained in the Muni Lagoon were far below the results of fish analysis Eshun (2011) obtained within the Fosu lagoon with means of 27.9Mg/Kg, 20.65Mg/Kg, 9.95Mg/Kg, 6.75Mg/Kg and 2.25Mg/Kg for Mn, Zn, Fe, Pb and Cd respectively.

Bioaccumulation status of fish species

The bioaccumulation potential of metals was assessed in the muscles of fish species. Bioaccumulation factors (BAFs) were calculated as a ratio between the concentration levels of biota (those in water) and the living environment of the specimens was expressed according to Ahmed et al. (2019) as

$$BAF = Cn_{Biota} / Cn_{water}$$

where Cn_{Biota} is the concentration of metal in the tissues (mg/kg) and Cn_{Water} is the metal concentration in the aquatic environment (mg/l). BAF is categorized as follows: BAF < 1000: no probability of accumulation; 1000 < BAF < 5000: bioaccumulative; BAF > 5000: extremely bioaccumulative (Arnot & Gobas, 2006). The results is tabulated below

Table 12: Bioaccumulation in fish species

Heavy metal	Cn_{water} (Mg/L)	Cn_{fish} (Mg/Kg)	BAF
Cd	0.09625	0.369	3.83
Zn	0.0609	0.152	2.50
Fe	0.44455	1.706	2.42
Mn	0.13454	0.187	1.39
Pb	0.2101	-	-

Source: Field work (2020)

The results above indicate a bioaccumulation factor of 3.83, 2.50, 2.42 and 1.39 for cadmium, zinc, iron and manganese respectively. The BAF figures above are all less than 1000 indicating no probability of bioaccumulation according to Arnot and Gobas (2006). This results affirm the results already presented that there is no health risk associated with consuming fishes from the lagoon. This level of bioaccumulation may be due to the absence of industrial and mining activities within the study area. The accumulation of the metal elements in an aquatic organism depends upon the classification of species, invasion pathways, metabolic characters of the sampled tissues and finally, the surrounding environmental condition in which the species live (Ozmen, Ayas, Gungordu, Ekmekci & Yerli, 2008). Heavy metals can effectively influence the vital operations and reproduction of fish when they bioaccumulate in their tissues; weaken the immune system, and induce pathological changes (Nwabunike, 2016) which can affect biodiversity within the lagoon.

Multi- stakeholder coordination and approaches in conserving the Muni lagoon

The Agenda 21 of the United Nations Conference on Environment and Development is considered as the first UN document to address issues on coalition of many stakeholders to discuss issues on agreement for sustainable development where they stated that, “the philosophy of involving multiple stakeholder groups in resource management seems unstoppable in recent years". Edmunds and Wollenberg (2002) talked about the increasing intrusion of dialogue and co-management into management of common-pool resources (CPRs) like coastal management, fisheries and forestry that brought about the concept of multi-stakeholder platforms (MSP). This idea brings together various institutional settings such as policy makers, donors, NGOs and water managers among others for participating in resource management. In doing this, there is the possibility of conflict solving and reduction to attract stronger support base from all the aforementioned quarters.

Kooiman (2000) reiterated that the application of both integrated water resource management (IWRM) and MSP are sure ways of managing increasing degrees of variety (diversity) and variability (dynamics). By diversity, he meant different perceptions and arguments likely to pool myriad of overlooked issues to table bringing about integrated and sustainable outcomes. The Global Water Partnership (GWP) also defined IWRM as 'a process which promotes the co-ordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems', emphasizing that water should be managed in a 'basin-wide context', with principles of good governance and public participation (Jønch-Clausen, 2004). Stakeholders are individuals, groups or institutions that are concerned with or have an interest in resources and their management. They include all those who affect or are affected by policies, decisions and actions of the system (Warner, 2005).

The UNCED puts Ghana among the nations that are implementing IWRM on medium- low scale. This implies that Ghana's effort in ensuring multi-stakeholder dialogue in resource management is not that encouraging. The Muni Lagoon catchment is a resource zone of international importance serving lots of purpose from local to national and even international levels. It is on cultural importance supporting the Aboakyir festival; socio- economic importance providing fish and source of employment, tourism where people all over the world visit and a hub for research. This study tried looking at how various stakeholders coordinate to put ideas together as a way of conserving the resource. Various stakeholders include the Wildlife Division of the Forestry Commission that oversees activities carried out within the catchment, local assembly that plans the community including the catchment, traditional council who are custodians of the lagoon, the community (Akosua Village) that daily interact with the resource and the university that uses the resource for research purposes. These stakeholders were consulted to know their role in conserving the resource and their level of involvement in decision making concerning the lagoon.

In level of influence and decision making, the people in the community who directly depend on the resource are mostly considered the lowest among the stakeholders. The leaders of the people in the Akosua Village were consulted to know how much they are involved in decision making toward the Muni Lagoon resource management. In their interaction they made it clear that they play vital roles in conserving the lagoon. They believe that they are the people who live with the lagoon and make sure it is protected due to the numerous benefits they derive from the resource. One of the participants stated that,

> *"We make sure our fellow fishermen do not use drag net for fishing though they are faced with lot of resistance due to lack of power backing their actions"*

The Assemblyman explained that, there is lack of coordination between them and the other stakeholder who work towards conserving the resource. He explained that except the Wildlife Department who of late involve them in their activities, they do not hear anything from the Municipal Assembly or the traditional council. He gave an instance where coconut was planted within the catchment but only the former assemblyman was involved and so when his he lost the position, he took the coconut as his personal property until they died out. To add up, one participant explained that;

> *"We were here when the traditional council started putting up structure without any knowledge of what they doing until we asked and we were told it's a shrine". They see us to be strangers and they see no need to involve us in any decision making meanwhile we stay within the catchment. How can you conserve resource without involving those who sit with it"?*

They stressed on the necessity of having numerous stakeholders come together to take decisions in conserving the lagoon catchment. They explained that the different stakeholders will help pool variety of ideas that may be rich enough to see the area develop. They recommended stakeholders such as the elders of the town (traditional council), the Wildlife Commission and their leaders (Akosua Village). They stated they should even be the most important within the stakeholders. They further recommend that to conserve the place, they should employ people from village to will be paid to guard activities within the catchment and not on voluntary basis. Again, coconut trees should be planted to serve as buffer in which people cannot put up buildings.

The next stakeholder the researcher contacted was the Wildlife Division of the Forestry Commission. They talked about the many roles they play in conserving the catchment. Key among them are regulating activities within the catchment through regular monitoring, developing boundaries and educating the community. They outfit explained that,

> *"We used to have site management committee sometime back where the traditional council and municipal assembly invite us to discuss issues, which*

is dormant now. Now we try our best to do what we call collaborative management where we involve the communities, the town and country planning and at times too write to the traditional council".

They stressed on the importance of multi-stakeholder coordination as a way of seeing to the effective management of resource. Due to this, they have tried their best to introduce community resource management area (CReMA) within their Ramsar where they involve various stakeholders in decision making concerning available resources. In their opinion, stakeholders such as the Traditional Council, Municipal Assembly (engineering and town planning unit), law enforcement agencies, fishing groups, farmers and the surrounding communities should form the multi- stakeholder commitee. They suggested that the best way to see effective management of resources is to bring all stakeholders on board. Their acting manageress however stated that;

"We faced challenge from the traditional authorities where they continue to sell lands within the catchment to people. The lands commission also sell lands where they tell us they don't have map and site plan of the catchment".

They therefore recommended that, there should be well designed map of the area to clearly demarcate boundaries. Again, there should be redemarcation of the protected area since most of the site is already encroached. Education should also go down well with the people as well as allow ecotourist to develop the place. All these will go a long to help conserve the resources.

Interacting with the Municipal Assembly, the director of town and country planning made it clear that, they do their best in protecting the catchment. He stated that,

"The protected area has not been factored into the developmental areas of the town. The area is not earmarked for residential, educational or infrastructural developments, it is purely set aside as a reserved area. Moreover, he stated

> *that their outfit do not process permit for people who buy land within the protected area".*

He stated that, the Wildlife Division involves them in almost every step they take to the point that they do go to the site together at times to monitor and take actions on developments going on within the protected area. However, with regards to multi-stakeholder collaboration, they do not have. He stated for instance that most of the lands being sold within the area are sold or given out by some section of the traditional council. He stated that;

> *"We hardly organize meetings between all the stakeholders as far as conserving the lagoon is concerned except the one we are doing involving the University of Virginia and Winneba cooperation. Apart from that, we as an assembly, as Forestry Commission, or as a Municipality hardly meet with traditional authority, lands commission, town planning and other stakeholders to deliberate on issues concerning the ramsar site because an element within the traditional authority (Ayirebi Acquah) are rather selling those lands so why do you have to collaborate with the person who is actually committing the crime".*

It was further stated that those who are actually selling the lands are aware of the fact that the area is a protected yet the go on with that activity. He further stated how necessary it will be for all those stakeholders to be involved in deliberations concerning the protected area. He suggested that to achieve multi-stakeholder collaboration,

> *"The Forestry Commission and the Effutu traditional council must organize stakeholder consultation or meeting and invite all the stakeholders involved including the lands commission so we go to the site. I think the meeting should even happen at the ramsar site so we can have first-hand information as to what is actually going on there and discuss the way forward".*

Some of the suggested stakeholders he mentioned are the traditional council, the Municipality (town and country planning, and works department), lands commission, Forestry Commission and the one or two assembly members. Putting all these stakeholders together will help us to know what to do as far as protection of the ramsar site is concerned, that is, the Lands Commission will register lands within the protected area, town and country planning will not process permit and the traditional authority will not also go and sell land that falls within the ramsar site. He stated that all those who have built within the catchment do not have permits. He added that, the other challenge is that, the physical boundaries of the protected area is not clearly established so it is very difficult to declare who has actually encroached. Lot of suggestions were made as to how to manage the area. Among them were, first of all, there should be physical boundaries to clearly demarcate which areas fall within the ramsar site. Again, the Forestry Commission must all have about 5 security posts to monitor closely what activities go on at the site. Also, we must get investors to help develop the place into ecotourist site. Lastly, the people must be sensitized on the benefits of the ramsar site and the implications should we lose the ramsar site.

Interacting with the traditional council, it was revealed that the traditional authorities ensure that sacred days and taboos are observed. They explained that, they make sure no one goes for fishing on Wednesdays and that fishermen use the appropriate nets. This confirms the work by Adu-Boahen, Dadson and Atubiga (2018) where they stated that the traditional authorities within the ramsar site ensure people observe the sacred day of no-fishing on Wednesdays. Commenting on stakeholders' involvement in conserving the lagoon, the council stated that the Forestry Commission writes to them from time to time concerning happenings within the protected area where they make input. One of participants stated that;

"Sometime back, the Wildlife Division requested for the plan of the area and we provided to them to aid their activities"

The council further stated that, there is no multi- stakeholder committee that meets from time to time to discuss issues on the ramsar site, however when the need arises, the appropriate quarters is contacted. They explained that, the government did not compensate land owners before the lands were vested but the lands are the resources which they sell to take care of themselves. The participants further emphasized their readiness to collaborate with other stakeholders to see the site conserved. One of the participants said;

"As encroachment is occurring around the lagoon, it has extended to the traditional hunting grounds which may hit on hard in our tradition as far as the celebration of the Aboakyir festival is concerned. The paramount chief as well as the traditional council is seriously concerned and we are ever ready working with the Forestry Commission and the Municipal Assembly to handle the issue of encroachment".

The council suggested that regular monitoring and sensitization of the citizens is necessary in conserving the ramsar site.

From the results above, it could be said that, all the various stakeholders play very important roles in seeing to the conservation of the site. However, it could be seen that, there is no coordination between the stakeholders. Each work on their own without necessarily contacting the other. This lack of coordination stems from the fact that, there is no single stakeholder that has volunteered to bring all the stakeholders together to have regular meetings and decide on the fate of the lagoon. There is however a crucial role played by the University of Education and other international universities such as the University of Virginia in USA and Delft University of Technology in the Netherlands. These institutions collaborate annually to conduct studies on the lagoon and report on the conditions within the catchment. The University of Virginia however tried bringing together some stakeholders to plan on how to keep the lagoon in shape. This is the only multi- stakeholder platform that meets occasionally to deliberate on issues concerning the lagoon but lacks representation from the communities especially the Akosua Village that lives with the resource. Shahabuddin and Rao, (2010) emphasized this by asserting that, communities close to natural resources are able to ensure sustainable management of their resources therefore based on their levels of interactions with the lagoon, there is the need to involve them in whatever decision taken such resources.

Interaction with the stakeholders again revealed that, all the stakeholders have rich ideas on how to preserve the site therefore when they come together, great designs can be formulated to conserve the site. This is line with a section of the conceptual framework that stresses on the need of multi- stakeholder collaboration in achieving sustainability of the lagoon. The UN status report on integrated approaches to Water Resources Management (UNEP, 2012) asserted that, in poorer countries, there is weak progress in overcoming constraints on financing for development of water resources, infrastructure development and coordination among sectors in application of management instruments. There are also Non- governmental organizations such as the A Rocha Ghana that works in areas of biodiversity conservation which has been of numerous help towards sustaining the Muni Pomadze Lagoon ramsar site. They contribute to planting of mangroves, providing alternative livelihoods for the people and embarking on community sensitization campaigns. Another issue identified from the interview is the problem of representation. This was seen from the angle of various stakeholders suggesting different groups who should form part of the management team. This may be due to how each of the stakeholders value the resource and those they think may be important in its management. Lotz- Sisitka and Burt (2006) found similar challenge in South Africa where they put forth that, a constraint in enabling meaningful multi-stakeholder participation has to do with issues of representation in community of diverse stakeholders. Table 13 gives a summary of the various stakeholders, their roles in conserving the Muni Lagoon catchment, how effective their roles are and their sustainability.

Table 13: Various stakeholders, their roles, effectiveness and how sustainability of these roles

Stakeholder	Roles	Effectiveness	sustainability
Forestry Commission	regulating activities within the catchment through regular monitoring, developing boundaries and educating the citizenry	Very effective as these activities are carried often. Monitoring is done on monthly basis, weekly radio education program and frequent reporting to appropriate quarters	Short and long term effect. Will help in sustaining the lagoon over long period
Local Community Leaders	Ensuring that wetland laws are obeyed within the community, assist in mangrove planting, monitor activities of fishermen and farmers within the catchment, report illegal activities, and assist in opening of the lagoon.	Local laws are obeyed but other regulations are not strictly adhered to, voluntary assistance in mangrove planting and opening of lagoon is effective, monitoring activities are not that effective as fishermen still use drag nets	Local laws may lose their effectiveness over time as years go by. People's willingness to volunteer may depreciate over time
Traditional Council	Enact local laws, ensure taboos and sacred days are opened, perform rituals for opening of the lagoon	Very effective as local laws are strictly adhered to, sanctions for offenders are appropriately meted out, opening of the lagoon rather faces some resistance from some groups of people.	Local laws may lose their effectiveness over time as years go by. Lagoon may be opened without rituals over time
Municipal Assembly	Respect the site as protected area free from developmental activities, non-processing and registration of permits and lands within the site, monitor activities within the catchment, assist in demolition exercises and prosecution of offenders	The assembly actually do not give lands in the protected area for residential, industrial or any development. All structures within the site do not have permit nor are such lands registered, prosecution have not been effective to deter further building within the protected, boundaries for the protected area not clearly spelt to encourage effective monitoring. Mostly relies on the Forestry Commission for information within the protected area	Long term effect as people may need permit and land registration before building in the site. Demolition and punishing of offenders may discourage encroachment.

University Researchers	Conduct researches to comment on the status of the catchment, collaborate with other international universities to conduct researches on the lagoon and hold seminars on the conserving the lagoon	Students within the university conducts researches on the lagoon, however, their recommendations do not get to policy makers. The University annually receives students and researchers for collaborative research which is very effective.	Long term effect as researches will go a long way to provide information on the lagoon. Recommendations may receive attention over time
NGOs	Awareness creation programs, provide alternative livelihood such as grasscutter rearing, beads making, snail rearing, skill training in construction of kilns etc, and mangrove planting.	Regular follow up on their activities is a challenge, most people trained in alternative livelihood mostly abandon them after sometime to go back to their former way of life.	Short and long term effect. Alternative livelihood creates immediate source of living, mangroves will protect lagoon over time.

Source: Field work (2020)

From table 13, the various stakeholders play distinct and different roles aim at conserving or sustaining the site. However, it can be seen that some of the roles are effective now but may lose their effectiveness over time. Looking at the wave of modernization, people have started rising against the issues of sacred days and taboos by giving scientific meanings to them rather than upholding the integrity of such local laws. Again, interacting with the community leaders, some revealed that, monitoring of activities within the catchment is ineffective because the Forestry Commission for instance seek for volunteers to assist in monitoring rather than paying them. This sends a signal that voluntary activities the communities engage in these days may not be so with time. The diagram below gives a pictorial idea of the proposed multi- stakeholder coordination.

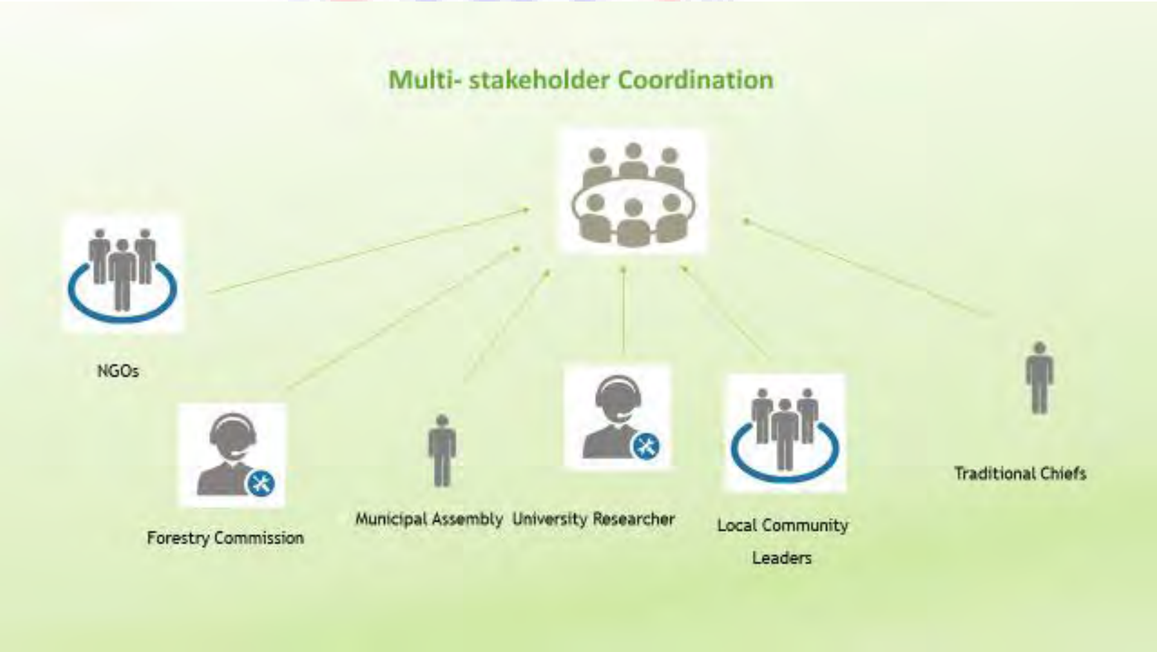


Figure 19: Proposed multi-stakeholder groups for the Muni Lagoon Catchment management

Table 14 gives a description of the drivers of change within the Muni Lagoon catchment. The pressure inducing the change, impact and state of the catchment as well as the responses put forth by the various stakeholders to manage the drivers.

Table 14: DPSIR within the context of the Muni Lagoon Catchment

Driver	Pressure	State	Impact	Stakeholders Response
Encroachment and Agriculture	Pollution, deforestation, beach sand wining, cattle grazing	Heavy metals pollution, reduced biodiversity	Flooding, siltation, dwindling of lagoon, coastal erosion	Demolition of structures within the catchment, mangroves and coconut tree planting, Physical setting of catchment boundaries
Climatic variation	Deforestation, changing rainfall and temperature pattern, cattle grazing	Reduced rainfall, increased period of dryness, reduced water levels in tributaries feeding the lagoon	Drying of tributaries, dwindling of lagoon size, open forest converting to grassland	Planting of trees, mangroves and coconut trees, regulation of human activities within the catchment.

Adapted from The European DPSIR framework (after Gabrielsen & Bosch, 2003) cited in Xingqiang, (2012).

Source: Field work (2020)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter presents summary of the study, major findings, conclusions and recommendations for institutions and stakeholders are drawn.

Summary of the research

The purpose of the study was to conduct the various hydro-morphodynamics occurring in the Muni Pomadze lagoon catchment as a result of growth in the Winneba town. Heavy metal analysis was done at the University of Cape Coast Chemistry Laboratory and Ecological Laboratory for wet season and dry season samples respectively. Remotely sensed images were used in modelling encroachment within the Muni catchment for the period of 1990- 2019. Temperature and rainfall data were acquired from the Ghana Meteorological Agency to investigate climatic variations and its attendant effects on the catchment. Purposive sampling technique was employed to select 10 respondents to participate in interviews for multi- stakeholder cooperation and encroachment issues. Content analysis were resorted to where necessary to support evidences gathered from the field.

Major findings of the study

1. There is high rate of encroachment occurring within the Muni Lagoon catchment through the remotely sensed images analysis which was confirmed by the community through consultation and interaction with Wildlife Division of the Forestry Commission. The encroachment is rampant and not easily monitored as a result of unclearly defined boundary of the protected area. Based

on the remotely sensed images (1990-2019) analysis, there is high loss of the open forest to settlement and agricultural activities. Area coverage of the lagoon has also changed over the years with most part of its upper portion where the tributaries are drying up. Grassland is however increasing within the catchment. The catchment is kept free from developmental planning of residential, educational or industrial activities within the municipality. Land for residential development was mainly acquired from a section of the traditional authority who claim ownership of lands within the catchment. The study revealed that all lands within the catchment are not registered neither do buildings have permit. Encroachment within the catchment has led to increase in flooding of the lagoon during the major rainy season. Moreover, frequent building within the study area has influenced increase in sand wining activities along the Winneba beach likely to result in coastal erosion.

2. Analysis of temperature data revealed that temperature within the study area follows an upward and downward trend. The 30 year period average temperature anomaly showed that temperature within the study area has fallen which may be as a result of the influence of the sea. There is also varying trend of rainfall within the study area. Rainfall data analysis also showed there has been a decline in the average rainfall received in the study area which could be attributed to vegetation decline within the catchment. Pearson moment correlation coefficient revealed that, there is no significant relationship between temperature and rainfall in the study area. The study again revealed that, temperature variation has no effect on the lagoon but rather rainfall reduction has influence on the changing area coverage of the lagoon over the 30 year period. The extent of coverage of the lagoon has dwindled over the years.

3. Heavy metal analysis revealed that, there is high levels of lead in the lagoon during the wet season as a result of introduction of waste into the lagoon. However, lead was absent during the dry season as a result of mixing of the lagoon with sea water. Cadmium and iron concentration were however high during the dry season. The study revealed that, manganese concentration was high in the Ntakofa River during both seasons due to the numerous agricultural and household waste that comes into with the river and is likely to be the major source of manganese in the lagoon. Ecological risk assessment done revealed that cadmium poses a disastrous risk to organisms that are in close contact with the lagoon. Heavy metals result in fish showed that there were concentrations found in the tissues of the fish, however, the concentrations were below the FAO/WHO maximum permissible limits. This means consuming fishes from the lagoon pose no harm or risk to consumers. Bioaccumulation factor (BAF) calculated were less than 1000 for all the metals signifying no probability of accumulation in the fishes. Heavy metal concentration in the lagoon was as result of agricultural, household waste and chemicals from building materials washed into the lagoon.

4. The study revealed that, there are various stakeholders who play various important roles on their own towards conserving the lagoon and its catchment. It was further revealed that, there is no multi- stakeholder meeting or forum for the stakeholders to deliberate and discuss issues towards the sustainability of the lagoon. Again, it was revealed that there is no coordination among the stakeholders in the performance of their roles concerning the lagoon and its catchment. Moreover, interactions with the stakeholders exposed the fact that

there is the problem of who should organize all the stakeholders or bring them together to take decisions affecting the resource.

Conclusions

Based on the results and key findings, the following conclusions were drawn;

1. Encroachment is rampant and increasing within the catchment due to growth of the city and lack of physical boundaries to clearly demarcate the protected area from other land uses. Open forest within the catchment keeps decreasing to other land use units such as settlement and agricultural activities. Chieftaincy issues occurring within the community influences acquisition of land within the protected area.

2. Temperature and rainfall within the catchment keeps varying over the years. Average temperature and rainfall is declining within the catchment. Decline in average rainfall has led to dwindling of the tributaries supplying the lagoon with water. Vegetation decline and the influence of the sea is affecting average rainfall and temperature respectively. There is also no significant relationship between rainfall and temperature within the study area. The extent of coverage of the lagoon keeps changing over the years.

3. The Muni Lagoon is polluted with heavy metals such as cadmium, iron, lead and manganese. The pollution is as a result of anthropogenic activities occurring within the lagoon such as agriculture, household waste and chemicals from building materials. Fishes within the Muni Lagoon poses no harm to consumers due to concentration below the FAO/WHO permissible limit. This is as a result of low industrial activities occurring with the catchment. Opening of the lagoon to have interaction with the sea improves the quality of the lagoon.

4. Stakeholders are willing to form a multi- stakeholder group to deliberate on issues towards sustaining the lagoon. Coordination among the different stakeholders with varying interest will allow for plans to reduce conflict in management of the resource. Voice of the local people will be taken into consideration in the formulation and implementation of policies for sustaining the resource. The Forestry Commission is the stakeholder group that can possibly lead and organize all the other stakeholders to discuss issues of importance toward conserving the catchment.

Recommendations

Based on the findings and conclusions of the study, the following recommendations were made

1. Traditional authorities together with the Wildlife Division of the Forestry Commission should ensure that the lagoon is opened more often to reduce the pollution rate of the lagoon as heavy metal content was low as at the time the lagoon was opened. Moreover, more mangroves should be planted along the banks of the lagoon to control excess evaporation and provide spawning grounds for fishes. Agricultural activities carried out within the catchment should be controlled to avoid the introduction of chemicals into the lagoon

2. The town and country planning unit of the Municipal Assembly, and the Lands Commission should work in close collaboration with the Forestry Commission and the local people to establish the physical boundaries of the protected area to clearly control encroachment. Demolishing exercise should be carried on all structures that do not have permit from the Municipal Assembly. The Municipal Assembly should check the environmental impact assessment of all industries

that are closer to the protected area to be sure their activities do not adversely affect the ecosystem within the site.

3. The Forestry Commission should regulate mangrove and tree harvesting within the catchment to control climate variations within the study area. Reafforestation should be carried out within the catchment by the Forestry Commission. Coconut palm should be planted to serve as buffer beyond which no developmental activity should be carried on. Proper monitoring and enforcement of laws and regulation set up by the Ramsar convention and the traditional authorities to control anthropogenic activities within the site.

4. Forestry Commission that oversees all activities within the lagoon should lead in setting up a strong multi-stakeholder committee that meets regularly to deliberate and make decisions towards ensuring sanity of the protected area. The stakeholders should include but not limited to the Forestry Commission, Municipal Assembly, Lands Commission, Traditional Council, The University of Education and representatives of the interested international universities, community leaders (assembly men and women), fishermen, farmers and other Non- Governmental Organizations that came in often to support in conservational activities such as A Rocha Ghana.

5. Again, the Geography Department of the University of Education, Winneba should collaborate with the Forestry Commission and other stakeholders to set up “Nature Conservation Clubs” in all the schools within Effutu Municipality from the basic to the university level as a means of sensitizing the future leaders on the importance of resources like the Muni ramsar site and their role in sustaining such resources.

6. The Wildlife Division of Forestry Commission should set up permanent security post within or close to the catchment to monitor all activities going on within the site. Again, the Municipal Assembly should get people who will be paid to work as security within the site making sure people comply with rules and regulations set out in protecting the resource.

Areas for further research

Further work should be done on microplastic concentration within the lagoon. Again, institutional weakness should be assessed as a factor militating against conserving the Muni Lagoon catchment.

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APPENDICES

APPENDIX A: Interview guide

UNIVERSITY OF EDUCATION WINNEBA

SCHOOL OF GRADUATE STUDIES

FACULTY OF SOCIAL SCIENCES

DEPARTMENT OF GEOGRAPHY EDUCATION

INTERVIEW GUIDE FOR STAKEHOLDERS

I would like to take you through the interview schedule below to solicit information on the changes you observe on the Muni- Lagoon catchment and also explore multi-stakeholder coordination in conserving the lagoon. This work is for purely academic purpose

Encroachment and changes observed in the Muni Lagoon catchment

1. How many years have you lived here?
2. How do you see the lagoon now comparing it to past years?
3. What can you say about area coverage of the lagoon?
4. In your opinion, what are causing the changes?
5. What changes can you observe in relation to the vegetation cover?
6. What can you say is the cause of encroachment on the lagoon catchment?
7. Do you think the encroachment has had any effect on the lagoon?
8. What are some of the effects?

Multi- stakeholder coordination in conserving the Muni catchment

9. What do you do to contribute in protecting the lagoon and its catchment?
10. Are you and your people involved in decision making concerning the lagoon?
11. Do you think you are involved in stakeholder decision making?
12. In your opinion, is it necessary a multi-stakeholder team is put together towards protecting the lagoon?
13. Which stakeholders would you recommend?
14. What will be the benefits when different stakeholders are put together?
15. What suggestions will you give as far as protecting the lagoon is concerned?

APPENDIX B: Wet season results

UNIVERSITY OF CAPE COAST

COLLEGE OF AGRICULTURE AND NATURAL SCIENCES - SCHOOL OF PHYSICAL SCIENCES

INSTRUMENTAL ANALYSIS LABORATORY

Summary Report

Method: APHA 3111 (Flame AAS)

Instrument: Shimadzu AA-7000

Date of Analysis: 14/08/2019

Sample Type: Unknown digests

Sample ID: AAF/2019/018

Client ID: Emmanuel O. Yeboah, (Mphil student, UEW)

Analyzed by: Dr. J. K. Adjei (signature) SCHOOL OF PHYSICAL SCIENCES DEPARTMENT OF CHEMISTRY UNIVERSITY OF CAPE COAST

Replicate analysis report n = 2

Mean Concentration ± SD

Sample ID	Cd: mg/L	Zn: mg/L	Fe: mg/L	Mn: mg/L	Pb: mg/L
ML control	BLD	0.0899 ± 0.0028	1.6260 ± 0.0307	BLD	0.1527±0.0003
ML 1	0.0128 ± 0.0009	0.0722 ± 0.0022	0.1723 ± 0.0174	BLD	0.2395 ± 0.0004
ML 2	0.003 ± 0.0002	0.0092 ± 0.0021	BLD	BLD	0.4007 ± 0.0001

ML 3	BLD	0.2510 ± 0.021	0.8857 ± 0.0134	BLD	0.7015 ± 0.0603
ML 4	0.0056 ± 0.0004	0.1230 ± 0.005	0.0215 ± 0.0144	BLD	0.4875 ± 0.0009
ML 5	0.0074 ± 0.0002	0.0565 ± 0.0022	0.5009 ± 0.049	BLD	0.1155 ± 0.0005
ML 6	BLD	0.0366 ± 0.0007	0.1578 ± 0.0085	BLD	0.1775 ± 0.0005
CF 7	BLD	0.0473 ± 0.0014	0.4088 ± 0.017	BLD	0.1731 ± 0.0022
PR 8	BLD	0.0585 ± 0.0028	0.5765 ± 0.014	BLD	0.1465 ± 0.007
NF 9	BLD	0.0178 ± 0.0001	0.3048 ± 0.0317	0.3897 ± 0.0067	0.1155 ± 0.0002
Blank	BLD	0.0026 ± 0.0015	BLD	BLD	BLD

BLD – Value below detection limit

Detection limits: Pb (0.05); Cd (0.003); Zn (0.002); Fe (0.03); Mn (0.012)

27/08/2019

SCHOOL OF PHYSICAL SCIENCES
DEPARTMENT OF CHEMISTRY
UNIVERSITY OF CAPE COAST

APPENDIX C: Dry season results

ECOLOGICAL LABORATORY UNIVERSITY OF GHANA LEGON

WATER PPM CONCETRATIONS 14/05/2020

CODE	Fe PPM	Mn PPM	Zn PPM	Cd PPM	Pb PPM
CONTROL	0.493	0.010	0.150	0.128	<0.01
ML1	0.044	<0.01	<0.01	0.163	<0.01
ML2	0.395	<0.01	<0.01	0.090	<0.01
ML3	0.239	0.006	<0.01	0.201	<0.01
ML4	0.340	0.058	<0.01	0.168	<0.01
ML5	0.881	0.023	<0.01	0.135	<0.01
ML6	0.581	0.046	<0.01	0.244	<0.01
PR8	0.202	<0.01	<0.01	0.178	<0.01
CLF7	0.963	0.105	<0.01	0.212	<0.01
NT9	0.298	0.382	<0.01	0.285	<0.01
%RECOVERY	103.3	100.4	103.9	95.2	96.6

FISH RAW DATA

CODE	Fe	Mn	Zn	Cd	Pb
P1	0.955	0.116	0.080	0.278	<0.01
P2	1.651	0.345	0.258	0.368	<0.01
P3	0.623	0.100	0.119	0.462	<0.01

FISH CALCULATED DATA

CODE	%Fe	% Mn	% Zn	%Cd	%Pb
P12	0.0095	0.00116	0.0008	0.00278	<0.01
P2	0.0165	0.00345	0.00258	0.00368	<0.01
P3	0.00623	0.00100	0.00119	0.00462	<0.01
%RECOVERY	103.3	100.4	103.9	95.2	96.6

For any information on the analysis, please contact Mr Prince Owusu on 0243077119

ANALYST

SIGN

HEAD OF THE LAB