Kwame Nkrumah University of Science and Technology, Kumasi

College of Engineering
Department of Materials Engineering

Assessing the Ecology of Wetlands in Kumasi and the Adaptations of the Communities to Floods

BY
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By

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A thesis submitted to the Department of Materials Engineering of the College of Engineering, in partial fulfilment of the requirement for the degree of Master of Science, in Environmental Resources Management.

FEBRUARY, 2012

DECLARATION

I, Abdul-Razak Iddrisu, hereby declare that the submission is my own work towards the award of MSc. Environmental Resources Management and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

In an attempt to maintain wetland sustainability, it is important to manage anthropogenic activities on wetlands. Due to the ever increasing population, wetlands are abused by society leading to degradation. This research aimed at studying the ecology of wetlands in Kumasi and the adaptations of the wetland associated communities to flooding. The wetland areas namely Aboabo, Ahinsan, Atonsu, Asokore Mampong, Bantama and Kwadasu Estates and the associated land uses were delineated and their physicochemical and heavy metal characteristics analyzed using the Atomic Absorption Spectrometry. With the aid of questionnaire, the adaptations to flooding by wetland communities were studied. Results showed an increased trend for urban development (70%) with non-forested vegetation and wetlands suffering the consequences. High variation existed among some physicochemical parameters (TDS, temperature, conductivity, dissolved oxygen and salinity). pH was neutral to alkaline. The study showed that land use activities that take place in wetlands in Kumasi and its environs have negative effect on the functioning of the wetlands. Most of the streams are being used as waste disposal sites causing the wetland areas to flood in the least rain. The communities adapt to flooding by dredging the streams, creating embankment at the shoulders of the stream and sweeping away the flood water and in extreme cases vacate their home only to return after the flood subsides. It has become difficult if not impossible for city authorities to enforce the statutory laws of urban development and thus demolish buildings that flout these laws.

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LIST OF ACRONMY AND ABBREVIATION

AAS	Atomic Absorption Spectrophotometry
CBD	Central Business District
C_f	Contamination Factor
CO_2	Carbon Dioxide
COP	Contracting Parties
CSIR	Council for Scientific and Industrial Research
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FRNR	Faculty of Renewable and Natural Resources
GIS	Geographic Information System
GPS	Geographical Positioning System
GRASAG	School of Graduate Studies
HGM	Hydrogeomorphic
HM	Heavy Metals
IPCC	Intergovernmental Panel on Climate Change
KMA	Kumasi Metropolitan Assembly
KNUST	Kwame Nkrumah University of Science and Technology
LULC	Land Use Land Cover
MC_d	Modified Degree of Contamination
MEST	Ministry of Science and Technology
NADMO	national Disaster Management Organization
RC	River Corridor
RF	River Frontage
RS	Remote Sensing
TCPD	Town and Country Planning Department
UNFCC	United Nations Framework Convention on Climate Change

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND ND JUSTIFICATION OF STUDY

Wetlands are a significant a portion of the landscape in terms of habitat and biodiversity, the regulation of watershed hydrology, and mediation of biogeochemical cycles (Detenbeck *et al.*, 1999; Bhatti and Preston, 2006). Although wetlands occupy only 4% of the earth's ice-free land surface (Prigent, 2001) or an estimated 1.2 million square kilometres (Millennium Ecosystem Assessment, 2005), their importance cannot be overemphasized and ranges from social, economic, recreational, scientific, and cultural perspectives; to providing ecological habitats for flora and fauna. They also perform crucial ecological functions, such as enabling groundwater recharge, nutrient retention, flood and erosion control, and sediment filtration (Rundquist *et al.*, 2001; Junk, 2002; Millennium Ecosystem Assessment, 2005).

In an attempt to maintain wetland sustainability, it is important to manage the effects of human operations on wetlands in activities such as forestry, agriculture, recreation, and urban development (Christensen *et al.*, 1996; Findlay and Bourdages, 2000; Turner *et al.*, 2000). The World Bank's Environment Department (2001) prepared an article which notes that, wetlands are both the most fragile and the most productive of earth's ecosystems. Home to 7% of all animals and 40% of fish species, wetlands also supply water for agriculture, maintain moisture, stabilize shorelines, purify water by filtering and transforming chemicals and pollutants, provide food, sustain groundwater recharge and human livelihoods.

One indispensible need for setting clear policy objectives and effective management with regard to wetlands is the development of knowledge inventories concerning the location, size, and type of wetlands (Turner *et al*., 2000). Appropriate information of mapping and inventory is needed for setting policy targets for the protection and conservation of wetlands, formulating specific wetland management objectives, developing guidelines for best wetland management practices, and integrating scientific wetland information with socio-economic considerations.

Mapping precise wetland inventories is a very instructive source of information for planners. With effective use of remote sensing and GIS technology, field data can be integrated, manipulated and analysed with other data layers to allow more effective planning and management. Wetlands are lost or threatened because of information failures linked to the complexity and 'invisibility' of spatial relations among groundwater, surface water, and wetland vegetation (Turner *et al*., 2000).

In 1999, Ghana became the third African country to have an explicit wetlands policy or strategy. For Ghana, taking action on wetlands was more than following an international trend towards recognition of the problem. It was a response to tackling the environmental challenges faced by most cities in Ghana. The African Convention on the Conservation of Nature and Natural Resources, signed by Ghana in 1968, requires parties, among other things, to "manage aquatic environments, whether in fresh, brackish or coastal water, with a view to minimizing deleterious effects of any water and land use practice which might adversely affect aquatic habitats".

Physical development or land use has been growing at an increasing rate, over the last 20 years (Owusu, 2001). The 2000 Housing and Population Census indicates that more than 43% of Ghana's population live in urban areas while about 57% live in rural areas. The urban housing has increased more than 159% as against about 53% in the rural areas (Adarkwa and Oppong, 2007). Based on this astronomical increase and demand for housing, almost every available piece of land in major cities in Ghana is being used by prospective developers for the construction of buildings (Da Rocha and Lodoh, 1999).

Kumasi, the largest metropolitan area in Ghana, is experiencing an unprecedented problem of physical developments in and around wetland areas culminating in flooding and the adverse loss of lives and properties. Again human settlements and their associated socioeconomic activities along the catchment areas of rivers tend to reduce its flow. Barely two years ago, 30 houses were submerged at Atonsu, a suburb of Kumasi, when the Subin River overflowed its banks. The 2009 NADMO flooding report suggests that over 640 inhabitants of Oforikrom, Ahensan and Krofrom all hosting the main wetlands in Kumasi were seriously affected by flood mainly as a result of a block in a tunnel causing an overflow of the drains during the rainy season. If this trend is not curbed, the situation has the potential of escalating and resulting in a bigger and unpredictable disaster in the near future.

Based on this premise, this study tries to outline the boundaries of wetlands in the city on a satellite image. The study also assesses the various socioeconomic factors along wetlands that have had a direct impact on wetlands over the years and the activities causing wetland depletion. Finally this study evaluates the most effective way of managing wetlands in Kumasi. It is hoped that the lessons drawn from the findings of this study could be related to other urban environments in Ghana and ensure sustainable and judicious use of the country's wetlands in accordance with the 2006 Ramsar Guidelines.

1.2 PROBLEMS WITH WETLANDS DEGRADATION AND FLOODS IN KUMASI

Africa still has a significantly higher number of pristine wetlands compared to Europe or parts of North America (Da Rocha and Lodoh, 1999). However, some wetland areas are experiencing immense pressure from human activities, the most important being drainage for agriculture and settlement, excessive exploitation by local communities and improperly planned development activities.

The increasing vulnerability of natural resources in general and wetlands in particular is one of the grand challenges to the people of Ghana in recent times. Anthropogenic activities have resulted in wetland degradation which in turn promotes perennial flooding among other things lead to loss of lives and properties. Of all natural hazards, floods are by far the most hazardous, frequent and widespread throughout the world (Dhar and Nadargi, 2002). This makes flooding an important subject of study, particularly in developing countries, where consistent and appropriate research on it has been lacking.

Despite the various calls by some metropolitan assemblies and government agencies to demolish buildings on waterways in order to curb the annual flooding that has cost this nation lives and millions of cedis, the floods have still caught up with society. The situation calls for a more scientific and holistic approach to solving this canker. Furthermore, efforts towards integrated wetlands management in Ghana including the prepared wetlands policy is still very sectoral and does not recognise the multiple functions of wetlands. Planning for land and resource use in wetlands is limited and where they exist, these plans are seldom put into practise. Furthermore, the present national environmental policies are yet to be enforced in the country.

A basic need for setting clear policy objectives and effective management with regard to wetlands is the development of knowledge in spatial and attributes inventories concerning the location, size, and type of wetlands. This is an effective way of ensuring sustainable wetland use and the mitigation of the effects of uncontrolled development. This study therefore, seeks to provide baseline information for a future integrated and sustainable management of wetlands in Kumasi.

1.3 AIM AND OBJECTIVES

The aim of this thesis is to examine the relationship between urbanization, wetland degradation and flooding in Kumasi and also assess the adaptation of communities along wetlands to floods.

The specific objectives are:

- to delineate the spatial distribution of wetlands in Kumasi;
- to describe the socioeconomic factors which cause wetland degradation in Kumasi;
- to assess the flooding situation and adaption of communities along wetlands to floods.

1.4 RESEARCH QUESTIONS

1. What are the characteristics of wetlands in Kumasi and in which ways have they been encroached upon?
2. How does the economy of wetland communities influence their environmental concerns?
   a. What are the activities associated with wetland communities in Kumasi?
   b. What are the ecological effects of these economic activities?
3. How do wetland associated communities and authorities want to manage the associated wetlands?
   a. Who are the users or direct beneficiaries of wetlands in Kumasi?
   b. What are the existing management practices on these wetlands?
   c. What is the people's willingness to participation in planning and policy formation on these wetlands?

1.5 SCOPE OF THE RESEARCH

This study is localised in the Kumasi Metropolitan Area. It focuses on the state of 6 major wetlands within Kumasi and an overview of the land use and ecology along these wetlands, which are associated with the Aboabo, Bantama, Kwadasu, Sisai, Subin and Wewe rivers. A study involving physicochemical characteristics affecting these ecosystems was conducted. To determine the level of understanding and community/institutional involvement regarding wetlands, questionnaire and interviews were administered to stakeholders.

CHAPTER TWO

LITERATURE REVIEW

The knowledge of ecology and biodiversity of the wetlands of Ghana are very uneven, both geographically and in terms of species groups. As could be expected, research has focussed on well-known plants and animal species especially those of economic interest. There are some distinct geographical focal points, notably the ever disappearing creeks and streams in the various urban regions of Ghana. This chapter will attempt to review available published literature on the biodiversity of African wetlands, urbanization and land use and particularly wetland management in Ghana among other subjects of interest.

2.1 METHODS OF GATHERING WETLAND DATA

Studies of wetlands in Africa with respect to hydrology, flora and fauna, collation of appropriate databases and analytical technologies such as Geographic Information System (GIS) and Remote Sensing (RS) are yet to be consolidated. This is frequently hampered by the lack of reliable records (Bonell and Balek, 1993), and to date there has been little or no attempts to collate and integrate findings of those few existing studies in a comprehensive manner. However, the Centre for African Wetlands located at the University of Ghana is making frantic efforts to gather and manage studies on African wetlands as a first step in creating appropriate databases through activities that can be categorized as:

- wetland (baseline) **inventory** is used to collect information to describe the ecological character of wetlands;
- **assessment** considers the pressures and associated risks of adverse change in ecological character; and

- **monitoring** which can include both survey and surveillance, provides information on the extent of any change.

All three are important and interrelated data gathering exercises. They can be considered as linked elements of this overall integrated framework which, when implemented, provides for identification of key features of the character of wetlands. Taken together, they provide the information needed for establishing strategies, policies and management interventions to maintain the defined wetland ecosystem character and hence ecosystem benefits/services. It is expedient to understand the dynamics of urban wetland hydrology, mapping and wetland biodiversity in Africa which is a key step toward wetland management.

2.2 DEFINITION AND IMPORTANCE OF WETLANDS

Wetlands are generally defined as transitional area between permanently flooded deepwater environments and well drained uplands (Turner *et al.*, 2000). Many more definitions have been used in the past, however, that developed for the Ramsar Convention Secretariat (2006) is not particularly useful in the context of this research. The Convention takes a broader approach in determining the wetlands that come under its aegis, be it "natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, including areas of marine water the depth of which at low tide does not exceed 6 metres" (Ramsar Convention Secretariat, 2006).

The Ramsar Convention defines wetlands to include a wide variety of habitats such as marshes, peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, and seagrass beds, but also coral reefs and other marine areas no deeper than six metres at low tide, as well as human-made wetlands such as waste-water treatment ponds and reservoirs. Instead the definition given by Breen (1991), adapted from that used by the US Fish and Wildlife Service, has been adopted in this study *"Land where an excess of water is the dominant factor determining the nature of soil development and the types of animal and plant (flora and fauna) communities living at the soil surface. It spans a continuum of environments where terrestrial and aquatic systems intergrade".* This definition is more biological, defining a wetland on the basis of the species occurring there.

By these definitions, wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by shallow water.

More often than not, estimates of land value are more a reflection of the assessor's values than any intrinsic quality of the land. Wetlands have been given the lowest estimate in terms of value, because land is assessed based on the potential benefits it could provide to the purchaser. In most cases, wetlands are seen as land unfit for both farming and building. Wetlands are indeed valuable ecosystems although they occupy only 4% of the earth's ice-free land surface (Prigent, 2001). Freshwater in-land wetlands are areas of great ecological importance and play a vital role in:

- hydrological stability and the control of flooding;
- surface and groundwater supply;
- the recharge and purification of groundwater;
- sediment accumulation and filtration; and
- providing a habitat for flora and fauna (Prigent, 2001).

2.3 AFRICAN WETLANDS

The African region making up a total of 53 states has 23 Contracting Parties to the Ramsar Convention as of July, 2010. In the report of FAO (1999), the Okavango Delta, the Sudd in the Upper Nile, Lake Victoria basin and Lake Chad basin, and the floodplains and deltas of the Congo, Niger and Zambezi rivers are some of the largest wetlands in Africa (Hails, 1996).

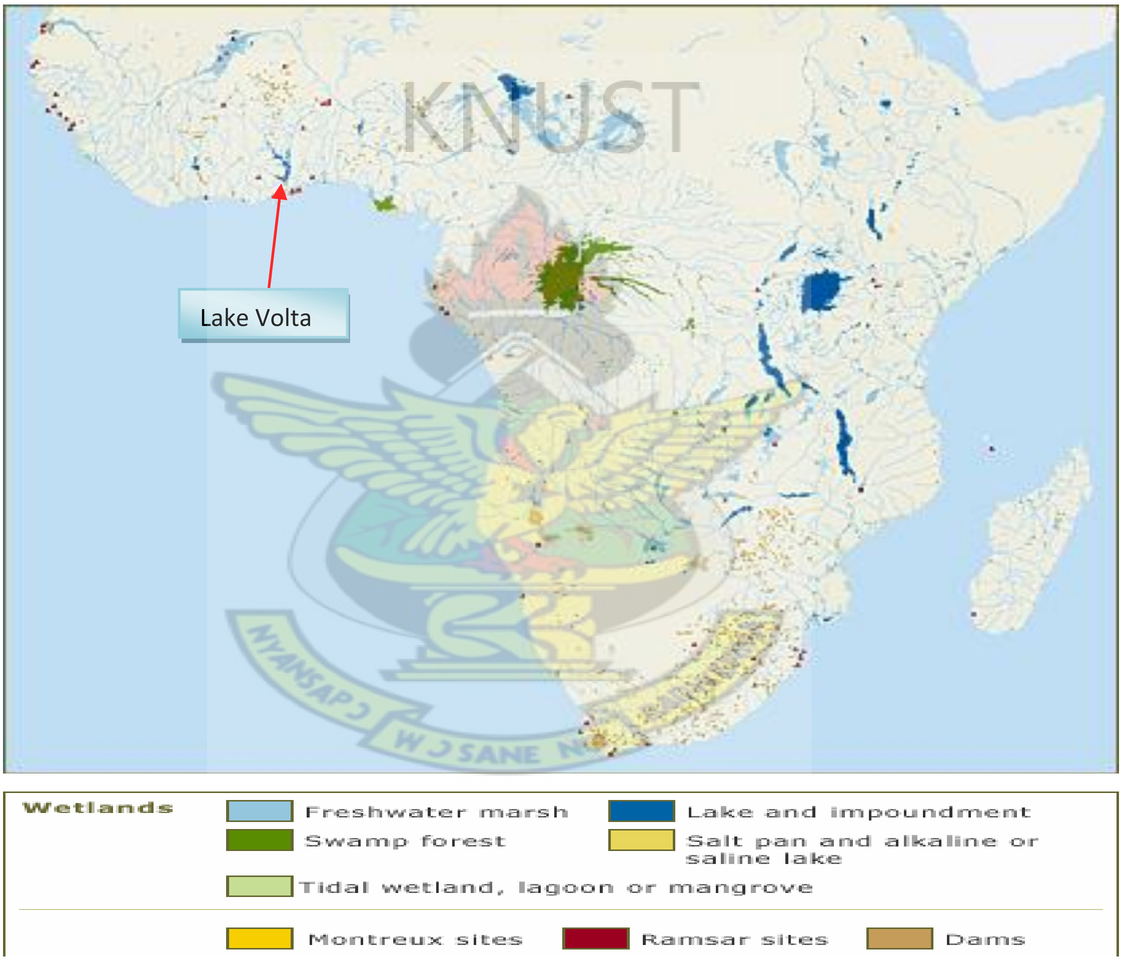

Figure 2.1: Wetlands, dams, and Ramsar sites in sub-Saharan Africa (FAO, 1999)

In an attempt to examine the potential use and methods of conserving Africa wetlands, FAO and World Conservation Monitoring Centre, have generated approximation of wetlands in located areas in Africa (FAO, 1999) as shown in figure

2.1. From the freshwater forests to the saline lakes and massive floodplains, Africa's many wetland types support a great diversity of plants and animals, and their productivity provides the natural resources essential to the survival of a significant part of the African rural population.

The biological diversity of wetlands on the continent is unevenly distributed. In particular, wetlands in areas of high rainfall and warm climates, such as the Congo Basin, display richer species diversity than those of drier regions north and south of the 15ºN to 20ºS zone. Of course, the importance of any given wetland from a biodiversity perspective is assessed not only by the overall richness in number of species present, but on the uniqueness of the area in terms of the number of localized species, particularly the endemic species. In this regard, most African wetlands display both characteristics, richness in number of species and endemism (Kabii, 1996). There are, for example, over 2,000 known species of indigenous freshwater fishes in Africa (Kabii, 1996).

It has become unarguably clear that African wetlands include some of the most productive ecosystems in the world. They are important, and in many cases the exclusive source of natural resources upon which rural economies depend. These wetlands provide food and energy, medicine, building material, dry season grazing and transportation for large human populations. In the inner Delta of the Niger River, over 550,000 people with about a million sheep and a million goats use the floodplains for post-flood dry season grazing. There are many more examples of how local communities make use of the diversity and high productivity of wetlands (Kabii, 1996).

Kabii (1996) again states that, the heavy dependence of large mammals on wetlands in Africa is of immense economic value to African countries since they are the mainstay of the tourist industry. These animals include elephants, buffaloes, antelopes, crocodiles, hippos, and zebras and the major predators, lions, wild dogs and hyenas. The lives of Africa's large mammals are often inextricably linked to wetlands. For example, the Amboseli swamps in Kenya are the only water source for animals in the surrounding area. Equally, the rich, riverine vegetation of the Masai Mara Game Reserve supports antelope and other mammals during the dry season.

Therefore, the threat to African wetlands has global effects on the world's biodiversity. The future of African wetlands lies in a stronger political will to protect them, based on sound wetland policies and encouragement for community participation in their management. Although the goal for protected wetlands should continue to be conservation of endangered and fragile sites, greater efforts should be focused on wetlands outside protected areas, and new management strategies formulated which incorporate all stakeholders (Mclanahan, 1994).

2.4 BIODIVERSITY OF WETLAND

The combination of aquatic and terrestrial conditions that produce what we describe a 'wetlands' make these ecosystems among the most complex in the world. Within a wetland, the environmental characteristics are determined largely by hydrological processes which may exhibit daily, seasonal or longer-term fluctuations, in relation to regional climate and geographic location of the site. These factors produce a great range of wetland types globally, the majority of which have extremely variable conditions in the many habitats which they contain. As a consequence, the variety of living organisms which has adapted to the different wetland habitats tends to be high, with all major groups of plants and animals present (Hails, 1996). Wetlands are of different types depending on depth and period of inundation and on substrate, and comparisons should compare like with like. Swamps are generally not particularly species-rich and tend to be similar between areas, possibly owing to the limited number of species that can tolerate flooded conditions and the easy dispersal of species between wetland sites through the medium of water currents.

2.4.1 DIVERSITY AND PRODUCTIVITY OF WETLAND PLANTS

A variety of topographic gradients exist in wetlands and these influence the nature of colonising vegetation. Gradients exist between terrestrial uplands and flooded basins, lakes or river beds. In coastal situations they occur in relation to tidal fluctuations which produce great habitat variability on the shoreline, as they do across lagoons and the zones of near-shore coral reefs. Wetland vegetation may respond to the topography and hydrology with a distinct pattern formed by the dominant plant species, particularly in tidal situations, or produces a complex mosaic of plant communities around minor local variations in height (Hails, 1996).

Unlike swamps, which show similarities in vegetation across the basin, floodplains and dambos can hold a greater diversity of plant life including some unusual woody plants on the ecotones or closer to the woodland margins (Hails, 1996). Some of these species are geographically restricted to certain areas, and have perhaps evolved *in-situ*. Pans, likewise, support some very unusual small herbaceous species. One conclusion, therefore, is that based on present evidence, it is the floodplains and dambos that are more diverse in terms of plant species, and possibly also of dependent animal species, than swamps (Timberlake, 1998).

2.4.2 DIVERSITY OF ANIMALS IN WETLANDS

The species diversity and high production levels of wetland plants support even more diverse animal communities. The vegetation distribution patterns and water level fluctuations make a range of continuously changing wetland habitats available at different times of the year to aquatic, terrestrial and arboreal animals (Hails, 1996). The concept of wetland diversity also holds for mammals, birds and fish, (for example the *Reduncine* antelope). Only the *sitatunga* appears to be adapted to swampy conditions. The grazing potential of floodplains is much higher than that of swamps, and in addition swamp plants show silica-enrichment or tough stems as defence against herbivores. Patterns of distribution of wetland mammals across the basin do not show any marked differences, except those related to habitat availability.

There are a large number of wetland birds but an assessment of which are found on swamps, floodplains, dambos and pans has yet to be done. The palaearctic migrants, mostly waterfowl, are dependent on swamp habitat, but are not apparently restricted to particular ones – individuals can readily move between them. Cranes, on the other hand, although frequently moving between wetlands, need certain conditions for breeding, and these conditions can be interfered with by human activities such as hunting and river impoundment.

Fish tend to be restricted to the riverine system in which they evolved, and rarely do species cross watersheds. They are therefore more susceptible to marked changes in habitat or water quality than most other aquatic organisms and those that have a non-aquatic adult phase (e.g. many insects). Fish species of shallow slow-water habitats are, almost by definition, restricted to what is here termed wetlands. Therefore destruction or major modifications to wetlands will have major repercussions on their status, possibly resulting in extinction.

2.5 THE RAMSAR CONVENTION AND ITS ROLE IN CONSERVATION AND WISE USE OF WETLAND BIODIVERSITY

The year 1971 marked an important year for a world-wide convention on wetland. In a town called Ramsar in Iran, a group of 81 nations recognising the interdependence between man and his environment, and considering the fundamental ecological functions of wetlands. Being convinced that wetlands constitute great economic, cultural, scientific and recreational values, the loss of which is irreparable, and desiring to stem the progressive encroachment on the wetland, the 81countries got together to sign an agreement to protect wetlands. This agreement has since been referred to as the Ramsar Convention on wetlands. The Convention entered into force in 1975 and as of July, 2010 had 160 Contracting Parties, or member States. Ghana became a signatory on the 22nd of June, 1988 and The Lao People's Democratic Republic is the 160th signatory to the agreement. The convention's inventory on wetlands around the world has identified 1,891 designated sites, covering a total surface area of 185,464,092 hectares (Ramsar Convention Secretariat, 2006), larger than the surface area of France, Germany, Spain, and Ghana combined.

According to the convention, its broad aim is to halt the worldwide loss of wetlands and to conserve those that remain through wise use and management. This requires international cooperation, policy making, capacity building and technology transfer. Furthermore, the implementation of the convention is guided by the mission statement adopted by the Parties in 1999 and refined in 2002, *"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".* This means ensuring that activities which might affect wetlands will not lead to the loss of biodiversity or extinction of the many ecological, hydrological, cultural or socio-economic values of wetlands.

All nations who agree to be signatories to the agreement, by the terms of the convention, must make commitment to:

a. designate at least one site that meets the Ramsar criteria for inclusion in the list of wetlands of international importance;
b. protect the ecological character of the sites;
c. include wetland conservation with their national land-use planning;
d. establish nature reserve on wetlands to promote wetland training; and
e. consult with other contracting parties about the implementation of the convention.

2.5.1 WISE USE OF WETLANDS

Following the Conference of the Contracting Parties (COP 9) in 2005, under article 3.1 on the convention, members agree to *'formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory'.* In much broader perspective, the Ramsar 'wise use' concept applies to all wetlands and water resources in a Contracting Party's territory, not only to those sites designated as Wetlands of International Importance. Based on the above, the COP's recognized the need for greater precision and adopted revised definition of wise use of wetland at the 3rd meeting in Regina, Canada, in 1987. This definition was revised in Resolution IX.1 Annex A (2005) as follows: *"Wise use of wetlands is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development."* In this context, sustainable development could be explained as human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Plate 2.1: The Nzulenzu village on the Amazuri Wetland in Ghana

(Source http://www.nzulezo.com/)

Plate 2.2: The Sakumo wetland in Accra, Ghana (Ghana Wildlife Department, 1995)

Essentially, the wise use concept means that the natural productivity and biodiversity at a site can be utilized as long as the basic ecological functioning of the wetland is not disturbed (Hails, 1996). An example of the wise use of a wetland is the Nzulenzu village in the centre of the Amazuri Lake (Plate 2.1). The village is well known for its natural presence, flora and fauna. People from all over the country visit this site for recreational purpose. A whole village is also located on this wetland deriving its livelihood from the wetland whilst maintaining and conserving its use. Another well preserved wetland is the Sakumo wetland in Accra (Plate 2.2). Table 2.1 shows 6 designated Ramsar sites in Ghana covering a surface area of 178,410 hectares.

Table 2.1: Ramsar Sites in Ghana as of 2010

Ramsar Site	Date of Designation	Region	Area (ha)	Coordinates
Anlo-Keta lagoon complex	14/08/1992	Volta	127,780	$05^{0}55'$N $000^{0}50'$E
Densu delta	14/08/1992	Greater Accra	4,620	$05^{0}33'$N $000^{0}18'$W
Muni Lagoon	14/08/1992	Central	8,670	$05^{0}22'$N $000^{0}40'$W
Owabi	22/02/1988	Ashanti	7,260	$06^{0}44'$N $001^{0}41'$W
Sakumo Lagoon	14/08/1992	Greater Accra	1,340	$05^{0}40'$N $000^{0}10'$W
Songor Lagoon	14/08/1992	Greater Accra	28,740	$05^{0}45'$N $000^{0}30'$E

Another example is the Wadden Sea, Europe's biggest estuary, which is located in a densely populated area and shared by Denmark, Germany and the Netherlands. The entire estuary is a Ramsar site and the three states have developed a joint management concept, based on wise use. It aims at controlling hunting, oil exploration, fisheries (especially shellfish) and tourism, and reconciling them with nature conservation (Hails, 2006).

There also exist the ‘Wise Use Guidelines’ emphasising the importance for Contracting Parties to:

- **adopt national wetland policies** that involves a review of the existing legislation and institutional arrangements to deal with wetland matters either as separate policy instruments or as part of national environmental action plans, national biodiversity strategies, or other national strategic planning;
- **develop programmes** of wetland inventory, monitoring, research, training, education and public awareness; and

- **take action at wetland sites** which involves the development of integrated management plans covering every aspect of the wetlands and their relationships with their catchments.

The Ramsar Convention believes that the Wise Use Guidelines would ultimately emphasize the benefits and values of wetlands in today's environmentally compromised world.

2.6 DELINEATION AND MAPPING OF WETLANDS

Over the past three decades, various criteria and methods have inadequately been developed to identify and delineate wetlands for regulatory purposes in the United States (Tiner, 1993). The USA federal system for defining and delineating wetlands is based on specific hydrology, soils and vegetation criteria (Brinson, 1993). Such a system of delineation is difficult to apply, because wetlands have high seasonal hydrology, indistinct hydric soil indicators, small ephemeral wet-season plants, and ambiguity about sub-species and wetland status of dominant shrubs (Clausniter and Huddleston, 2002). Therefore, wetland hydrology in any setting requires periodic or permanent inundation of the soil surface or saturation at a shallow depth below the surface, which must occur within the root zone of the prevalent vegetation. In other words, inundation and saturation must be continuous for at least the greater part of the growing season with a high probability of occurrence in any year (Brinson, 1993; Dewey *et al*., 2006).

For such reasons that wetland delineation is difficult to assess accurately, mapping or wetland boundary determination is most difficult. There are unclear boundary between upland vegetation to down stream wetland vegetation, from nonhydric to hydric (wetland) soils and from land that is not flooded to areas that are subject to flooding or saturation (Nyarko *et al*., 2006). In other words, what is crucial in effective management of wetlands is accurate mapping by comprehensive spatial information on location, size, classification, and connectivity in the landscape.

Basically, two distinct methods to wetland mapping can be distinguished. A traditional method described by Grunwald (2006), is in respect to soil mapping by defining crisp map units. These discrete mapping units are associated with representative attributes (binary membership functions) such as wetland type and are defined by abrupt changes at the border of the unit; in this case, from wetland to non-wetland. These units are typically mapped as vector (polygon) data in a GIS. However, the defects of this approach is that it ignores spatial variability within the units and does not represent ‘‘fuzzy’’ boundaries, where properties change gradually (Murphy *et al*., 2007).

With recent advancement in remote sensing and GIS technologies, Murphy *et al.* (2007) address the second approach to involve continuous field model in which soil properties are displayed as pixels with continuous coverage across the landscape. This spatial model can describe gradual change in properties, spatially, and is typically mapped as raster data in a GIS interface. The figure 2.2 and 2.3 shows a relationship between two types of areas which were often used to set geographical context of some indicators:

a. **The River Corridor (RC)** - the river or watercourse and the adjacent areas on both sides are directly influenced by it.

b. **The Riverfront (RF)** - is the direct contact area between the river and the first line of buildings (Tiner, 1989).

Figure 2.2: River corridor base on a buffer of 500m

Figure 2.3: River corridor base on a river frontage

2.7 CLASSIFICATION OF WETLAND TYPES

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. This classification by Kulser and Kentula (1992), categories wetlands under mapping, planning, acquisition, regulatory and other purposes. Hydrogeomorphic (HGM), hydrogeology and landscape systems are just a few of the many wetland classification systems developed to categorize wetlands.

The premises of HGM scheme of classification is based on the fact that wetland structure and functions are expressions of geomorphic setting, water source and hydrodynamics (Nyarko *et al.*, 2006). Based on HGM dynamics of wetlands Gwin *et* *al.*, (1999) defined four classifications of naturally occurring wetlands. These are depression, lacustrine fringe, riverine, and slope. However, Brinson (1993) identifies a more detailed listed HGM 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 HGM method has two basic advantages; it has an intrinsic link between hydrology and geomorphic setting and could also augment other wetland classification systems (ibid). It is also inexpensive because existing map data which are easy to come by are used.

The alternative classification method is proposed by Tiner (1989) based on the hydrology of the wetland, these descriptions of wetland classes include:

a. those fed by surface water runoff and wetlands that receive river flooding
b. those receiving aquifer discharge in addition to some surface water,
c. those fed by surficial groundwater in addition to some surface water,
d. those receiving both surficial groundwater and aquifer discharge,
e. those fed predominately by aquifer discharge with minor surface water input,
f. those fed by unconfined main aquifer, and
g. those receiving total surficial groundwater.

2.8 WETLAND HYDROLOGY

The term wetland hydrology generally refers to the inflow and outflow of water through a wetland and its interaction with other site factors (Gwin *et al*., 1999). This definition is closely related to the processes by which water is introduced, temporarily stored, and removed from a wetland. Consequently, water is introduced to a wetland through direct precipitation, overland flow (or runoff), channel and overbank flow, groundwater discharge, and tidal flow. Temporary storage includes channel, overbank, basin, and groundwater storage. Water is removed from the wetland through evaporation, plant transpiration, channel, overland and tidal flow, and groundwater recharge. Surface water processes within a wetland are tied to both local and regional precipitation patterns. Precipitation can influence a wetland water budget directly through rain and snowfall within the physical boundaries of the wetland and the associated runoff, or indirectly through inflows from upstream watersheds.

2.8.1 WATER BALANCE

Different wetland types differ in water balance due to a number of biophysical characteristics which include: landscape position, soil saturation, sediment/level of decomposition of the organic soil, vegetation density and type of vegetation (Taylor *et al*., 1990). Wetlands play a critical role in regulating the movement of water within watersheds as well as in the global water cycle (Mitsch and Gosselink, 1993; Richardson, 1994). In another setting, Mitsch and Gosselink (2000), ascertain that wetland hydrologic budget is the primary cause of inputs and withdrawals that apply to other ecosystems.

2.8.2 EVAPORATION ESTIMATION

An indispensible component of wetland hydrologic cycle is evaporation and evapotranspiration where approximately more than 60 percent of precipitation over land is lost through these phenomena globally (Dingman, 2002; Rivas and Caselles, 2004). Management of wetlands and other freshwater ecosystems needs estimates of open water evaporation. Therefore a basic understanding of open water evaporation is crucial in planning economic uses of these water resources.

For several reasons, modelling evaporation of arid region wetlands is difficult and in most cases inconclusive or conflicting. The various types of wetland in the world range from open-water dominated wetlands to those where the water table is often below the surface, and water accessibility for evaporation is controlled by vegetation factors (Reikerk and Korhnak, 2000). The former is affected by excessive heat flow from adjacent hot dry land. In other words, large amount of adjective energy flux density increases the evaporation rate of free surface water bodies. For this reason, it is very difficult to estimate evaporation of open water using ordinary methods. There are two major methods to estimate wetland evapotranspiration using remotely sensed data.

2.8.3 WETLAND RIVER INTERACTION

In the past 70 years, seasonal wetlands in many parts of Africa and particularly Zimbabwe are believed to be responsible for the maintenance of dry season river flows (Bullock and McCartney, 1996). Following regional flow analysis, seasonal wetlands rather reduces dry season river flows because its storage is depleted more by evapotranspiration than it is by base flow. However, the degree of influence will depend to a large extent on the nature of the surrounding vegetation.

Another distinguishing phenomena that affect flow regime is decreasing anisotropy and sediment resistance and increasing water body length which tend to affect the flow-through behaviour. Matos *et al*. (2002) examined aquifer heterogeneity and channel pattern on flow interactions between stream and groundwater systems. The team used a numerical model to evaluate the magnitude, direction and spatial distribution of stream-subsurface exchange flows. After intense run-off producing rainfall events, the soil textural composition enhances infiltration of the surface run-off waters culminating in underlying sediment acting as an aquifer resulting in groundwater flow. In the infiltration and/or percolation process of groundwater along the hydraulic gradient, impeding fine clay and silt layer is reached which has the potential of lowering the hydraulic conductivity; thus less water is transmitted per unit time (Nyarko *et al*., 2006).

2.9 WETLAND AND CLIMATE CHANGE

Climate change is undoubtedly the most pervasive, complex and challenging of the global environmental issues facing contemporary society. Perceptions of climate change causes, effects, approaches and solutions are diverse, and are often divided on the basis of equitable environmental, social and development opportunities between the industrialized and developing world (Patterson, 1999). Basically, climate change is the change in the statistical distribution of the average weather or a change in the distribution of weather events over a period of time. This may be limited to specific region, or may occur across the whole earth (Patterson, 1999).

In the past decade, it has been called everything from the "greatest hoax ever perpetrated on mankind" to the "greatest challenge to face man". There have been conventions, coalitions, and conferences held in its name. Notable of them is the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCC) which reached a significant milestone in addressing the global threat of climate change (IPCC, 2007). As a result of this convention, industrialized countries which are signatories agreed to commitments to limit or reduce greenhouse gas emissions by at least 5 percent below 1990 levels during the first commitment period of 2008-2012. Furthermore, the Protocol mandated industrialised and developing countries in addition to join in the reduction of greenhouse gas (basically CO_2) emission to enhance activities which removes CO_2 from the atmosphere (carbon sinks); emissions banking, trading and other measures which limit and reduce emissions of greenhouse gas. In this respect, most ecologists believe that wetlands if managed well can serve as carbon sinks as part of mitigating the impacts of climate change through carbon sequestration (Twilley, 2007).

2.9.1 WETLAND CARBON STOCKS

Globally, wetlands cover 6 per cent of the land surface but contain 14 per cent of the terrestrial biosphere carbon pool. When peatlands are included, as is the case in the Ramsar wetland definition, wetlands represent the largest component of the terrestrial biosphere carbon sequestration (Dixon and Krankina, 1995). Table 2.2 shows estimation of carbon pool for terrestrial biosphere, wetlands carbon reservoir, agroecosystem etc.

Table 2.2: Current estimates of terrestrial biosphere carbon pools and flux by biotic systems

Biotic System	C Pools (Pg)	C Flux (Pg)
Boreal forests/tundra	559	+0.4 to +0.8
Temperate forests	159	+0.2 to +0.4
Tropical forests	428	-2.0 to +1.2
Agroecosystems	150	-0.1 to +0.1
Grasslands/Savanna/Deserts	417	0 to +0.6
Wetlands	230	0 to +0.2
Total	**1,943**	**-1.5 to +0.2**

2.9.2 WETLANDS AS SINKS AND SOURCES

To consider an ecosystem as a sink for carbon dioxide, its assimilation of carbon through photosynthesis (gross production-P) should exceed its loss of carbon through respiration (community respiration-R) and harvest. In aquatic ecosystems, R is scaled approximately as two-thirds power of P, implying that the role of aquatic biota as carbon dioxide sources or sinks depends on their productivity. Thus, productive aquatic ecosystems $(P > R)$ tend to function as sinks, and unproductive aquatic ecosystems $(R > P)$ tend to function as sources (Duarte and Agusti, 1998).

However, Patterson (1999) emphasized that, this idea does not directly apply to two classifications of freshwater wetlands namely: peatlands and rice paddies. The parameters which determine the carbon storage in peatlands are: the extent to which the hydrology allows water to flow through the system; the nutrient status of the wetland; and the proportion of time which the wetland is under anaerobic conditions (its seasonality). Thus, carbon storage is maximized in these nutrient poor, closed basins that are permanently inundated. At the other end of the spectrum, created wetlands such as rice paddies, which are nutrient rich (naturally and with fertilizer treatment), with seasonal flow through of water, allow no significant carbon accumulation. Moreover, the anaerobic conditions of rice paddies contribute to substantial methane emissions, which are globally in the order of 100 mt/yr (Adger, 1995).

While wetlands constitute a major carbon reservoir, they can function as either greenhouse gas sinks or sources depending on their type, their use and ambient conditions. Some wetlands are characteristically sources and others are sinks. Some have a different role at different times as determined by hydrology. In some wetland types there is a trade-off between being a carbon sink and a methane source (Patterson, 1999).

2.10 URBANIZATION AND LAND USE

Land in its natural existence is described as land cover which is the observed (bio) physical cover of the earth's surface (FAO, 2000). Land cover is greatly affected by land use which is defined as the arrangements, activities and input that people undertake on a certain land cover type (ibid). From these definitions it can be seen that land cover refers to physical conditions on the ground or natural cover of the land such as forest, grassland, etc, whilst land use refers to the human activities (man-made things) such as residential areas, industrial areas, and agricultural fields.

The most basic definition of urbanization is the transformation of land from rural land uses, such as agriculture, to urban land uses, such as housing (Centre for Watershed Protection, 2003). However, summarizing the many environmental effects of urbanization as a variable in scientific studies is less straightforward. Popular replacement measures for urbanization in recent literature include general measures of urban land use, population density, and the extent of impervious surface (Arnold and Gibbon, 1996; Centre for Watershed Protection, 2003).

Over the past half century, a great rural-to-urban population shift has occurred and the process of urbanization, (i.e. the concentration of people and activities into areas classified as urban) is set to continue well into the 21st century. It is understandable that as urbanization expands the land with its natural vegetative and forest covers are cleared to give way for residential and industrial purposes. It has been shown (Jin-Yang *et al.*, 2003) that there has been an increase in runoff after vegetation removal, as a result of urbanization. It is presently clear that the complex and in some cases complicated urban drainage systems allow a quick runoff of precipitation away from surfaces. The net effect of which culminates into less evaporation and less groundwater recharge, thus affecting the local hydrological cycle (Marsalek *et al.*, 2001).

2.11 MODELS USED IN STUDYING WETLANDS

Wetlands have a critical role in ecosystem function and biodiversity. Effective management of wetlands requires accurate, comprehensive, best solution and practice in sustaining the role that wetlands plays in our environment. In wetland studies, model applications have recently become a tool to understand the role the wetlands play and ascribe the appropriate management procedure or application. Of the numerous wetland models that exist, scientists have not been able to come to a consensus as to which model is the best to apply to specific problems (Janssen and Hemke, 2004). However, a general distinguishing feature for modelling wetland can be grouped as those models based on data and models based on processes.

A stochastic model describes models based on data. They are also considered as a black box system that uses mathematical and statistical techniques to link model inputs to outputs. Common techniques are regression, transfer function and neural networks. In this scenario wetlands are treated as a black box, where time series of input data are related to outputs. Wetlands themselves are excellent simplifiers, converting a spatial complexity of patterns and processes into a relatively simple and well understood output like a hydrograph (Mulligan and Wainwright, 2004).

Nyarko *et al.*, (2006) describes the second model (deterministic model), to be sub-divided into single event models and continuous simulation models. This type of model represents;

- physical processes observed in the wetland,
- representations of surface runoff,
- evapotranspiration, and
- sub-surface flow.

However, the use of this kind of model can be complicated, due to the large number of parameters that usually are required to be estimated from limited data input-output observation (Young, 2001). To effectively use this model require very good understanding of the nature of the system and internal working of the connection and interaction between its sub-systems and components, together with knowledge of the physical laws governing the processes occurring in the system (Dooge, 2003).

2.12 ENVIRONMENTAL CONSEQUENCES OF URBANIZATION

Although urbanization is the driving force for modernization, economic growth and development, there is increasing concern about the effects of expanding cities, principally on human health, livelihoods and the environment (Centre for Watershed Protection, 2003). The implications of rapid urbanization and demographic trends for employment, food security, water supply, shelter and sanitation, especially the disposal of wastes (solid and liquid) that the cities produce are overwhelming. Physical development in wetlands largely destroys the environmental functions of the wetlands due to its adverse effects. It ranges from flooding through pollution of groundwater and rivers to the ultimate destruction of the wetland itself (Arnold and Gibbon, 1996).

The primary cause of urban flooding according to Andjeilkovic (2001) is a severe thunderstorm or a rainstorm proceeded by a long lasting moderate rainfall that saturates the soil. Floods in urban conditions are flashy and occur on both urbanized surfaces (streets, parking lots, yards, parks, etc), and in small urban creeks. Some causes of urban floods are improper land use and channelization of natural waterways, failure of the city protection dikes, and inflow from rivers during high stages in urban drainage system. Other causes of urban flooding are surcharge due to blockage of drains and street inlets by silt and garbage and inadequate street cleaning practices (Kolsky and Butler, 2002).

Water pollution is any contamination of water that reduces its usefulness to humans and other organisms in nature. Pollutants such as herbicides, pesticides, fertilizers, and hazardous chemicals can make their way into our water supply. As human settlement along the banks of river bodies increase, the volume of household and industrial waste discharged into the river greatly increase, and in most cases beyond the threshold at which the stream can assimilate and thereby become polluted (Leopald, 1997). In other words, stream may have assimilation capacity, but as the population increases and urbanisation become the sole objective and motivation for human strive, the natural assimilative and refinery ability of these water bodies are exceeded causing our water bodies to be contaminated. This results in deterioration of human, animal, and plant health unless it goes through a costly purification procedure.

Cunningham and Saigo (1999) suggested that wetlands are naturally converted to dry land largely through sedimentation, eutrophication or stream-cutting and draining, and that human activities have largely accelerated these processes in many places. The main activity that destroys the wetland either directly or indirectly is physical development. In the same light, human settlements along river bodies promote the use of wetlands as waste disposal sites (Plate 2.3) thus polluting surface and groundwater through the process of percolation and infiltration.

Plate 2.3 A Wetland used as refuse dump at Anloga, Kumasi

Leopald (1997) study indicated that, surface water such as wetlands and river bodies are linked to groundwater. This implied that if surface water were polluted it meant that polluted water seeped down to recharge groundwater. Furthermore, leachate from refuse dumps sites in the residential areas also seeps through the sub-strata and contaminate groundwater.

2.13 WETLAND MANAGEMENT IN GHANA

The Government of Ghana recognizes the importance of wetlands as habitat for wildlife, maintenance of the water table, mitigation of flood conditions and water purification. For these reasons the country has availed herself with several opportunities that exist for the management and conservation of wetlands. These stem from sectoral policies, traditional management practices and available scientific knowledge that have encouraged both utilization and conservation of wetlands. The following policies, which are already in existence or have been enacted into laws, are among those that have widely affected wetlands usage:

- Fisheries Law,
- Environmental Policy,
- Wildlife & Forestry Policy,
- Medium-Term Development Policy (Ghana Vision 2020),
- Water Resources Commission Act (522)
- Land Policy.

According to the Ministry of Lands and Forestry (1999) report, these legislations mentioned above are scattered throughout the statute books, and though obsolete and failing in addressing adequately the problem of wetlands in their entirety, they do provide a starting point for the formulation of appropriate laws. On the brighter side, to ensure the judicious use of the nation's land and all its natural resources, the Ministry of Lands and Forestry launched the National Land Policy in June 1999. The policy recognizes wetlands as environmental conservation areas and precludes the following practices: physical draining of wetland water; draining of streams and water courses feeding the wetlands; human settlements and their related infrastructural developments in wetlands; disposal of solid waste and effluents in wetlands, and mining in wetlands (Ministry of Lands and Forestry,1999).

These policies also seek to promote the use of wetlands for farming, grazing, fishing, timber production and salt-winning, provided that such uses also serve to conserve the ecosystem, biodiversity and sustainable productivity of the wetlands.

The Government of Ghana also implemented the Global Environmental Facility, to fund Coastal Wetlands Management Project from 1993 to 1999; carried out public education and awareness-creation programmes to enlighten the general public on the values, benefits and functions of wetlands and the need for their conservation and sustainable use.

What has become a milestone success chopped by the Ministry of Lands and Forestry in consultation with key stakeholders is the preparation of a comprehensive document–*Managing Ghana's Wetlands: A National Wetlands Conservation Strategy* – to promote participation of the local communities and other stakeholders in the sound management and sustainable utilization of Ghana's wetlands and their resources. This is an attempt to integrate wetlands issues into national land-use planning and decision-making in other sectors of the Ghanaian economy. The country has also encouraged scientific research and papers to address and put the issues and constraints of wetland management in the country.

The protection and conservation of wetlands resources involve a number of activities. These include data collection, monitoring, standard setting and execution of projects and programmes. They are carried out by a number of government and non-governmental institutions, including: Wildlife Department; Ministry of Environment, Science and Technology (MEST); Environmental Protection Agency (EPA); District, Municipal and Metropolitan Assemblies; Ministry of Food and Agriculture; Survey and Meteorological Services Department, Ministry of Lands and Forestry, Forestry Department; Universities; Council for Scientific and Industrial Research (CSIR), as well as NGO's.

One major initiative is the establishment of the Centre for African Wetlands Management, located at the University of Ghana-Legon, which is helping to co-ordinate wetlands research for the West African sub-region. The time frame for the implementation of the various strategies to manage wetlands are defined in terms of "short-term" (1-2 years) "medium term" (3-5 years) and "long-term" (more than 5 years), effective six months after the Strategy is adopted by the Government of Ghana (Ministry of Lands and Forestry, 1999).

CHAPTER THREE

MATERIALS AND METHODS

3.1 DESCRIPTION OF STUDY AREA

Kumasi is the regional capital of the Ashanti Region, located in the transitional forest zone about 270 km north of the national capital, Accra (Figure 3.1). The Kumasi Metropolitan area lies within latitudes 6^0 35'N - 6^0 40'N and longitudes 1^0 30'W - 1^0 35'W, with an elevation which ranges between 250 m-300 m above mean sea level. It is bounded on the north by the Kwabre district and on the South by Bosomtwe-Kwanwoma District. On the West and the East, Ejisu-Juaben District and the Atwima District bound KMA respectively (KMA, 2006).

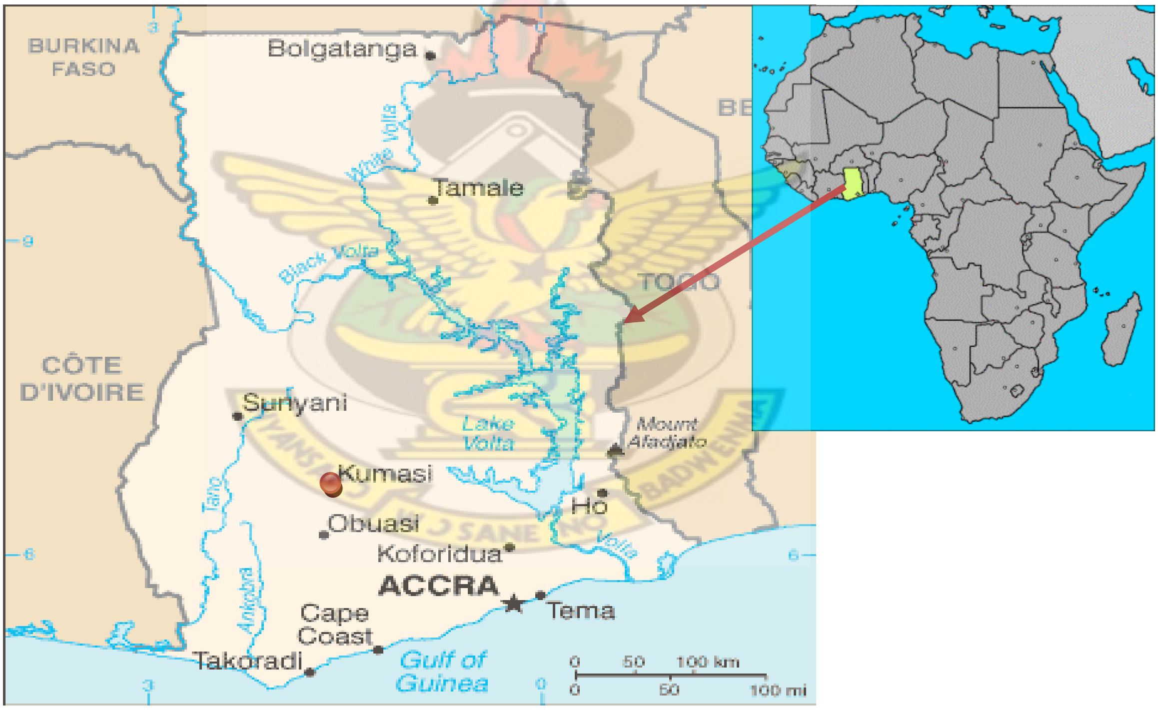

Figure 3.1: Map of Ghana Showing Major Towns and Water Bodies
(Source: https://www.cia.gov/library/publications/the-world)

The metropolis has a total land area of 254 sq km (Ghana Statistical Service, 2002). The city is divided into 10 main Sub-metros. These are the Asokwa, Bantama, Asawasi, Kwadaso, Nhyiaso, Oforikrom. The others are Suame, Tafo, Subin and

Manhyia sub-metros. From the three communities of Adum, Krobo and Bompata, it has grown in a concentric form to cover an area of approximately ten (10) kilometres in radius.

Kumasi is currently Ghana's second largest city and has a long and proud history as the centre of the Asante kingdom. Kumasi is often regarded as the commercial capital of Ghana; with its Kejetia central market rivalling Onitsha in Nigeria as West Africa's largest open-air market. Part of Kumasi's relative prosperity is derived from the timber from the forest of the surrounding regions. It is also known for its local enterprises and artisan skills, particularly in the areas of furniture-making and vehicle engineering, which serve clients from surrounding countries (KMA, 2006).

Given the strategic location and political dominance, Kumasi has developed into a major commercial centre with major trade routes. The strategic location has also placed Kumasi with the prominence of the principal transport terminal and has contributed to its pivotal role in the vast and profitable distribution of goods in the country and the sub region. Consequently, the city has grown thereby making it second to Accra in terms of land area, population size and socio-economic activities. The undulating topography, beautiful layout and greenery have accorded it the great accolade of being the "Garden City of West Africa" (KMA, 2006).

3.1.1 DEMOGRAPHY

Ashanti Region is currently the second most urbanized in the country after Greater Accra Region with a population of 4,725,046 estimated in the provisional 2010 census. The population of Kumasi has grown rapidly over the inter-censual periods from 346,336 in 1970, 487,504 in 1984 and 1,170,270 in 2000 when the last census was held. Between 1984 and 2010, the population had increased over 200%. Based on the D-Plan of the KMA for 2006–2009, the current estimated population growth rate is 5.47% per annum (KMA, 2006).

Although population is increasing rapidly, that of the Central Business District (CBD) comprising Adum, Asafo and Ashtown has continued to reduce over the years. On the other hand areas such as Ayigya, Dichemso and Tarkwa-Maakro which were small communities have grown into densely populated residential areas with 20,000- 40,000 people (KMA, 2006). The reason for this is that residential accommodations in the CBD are being converted into commercial use and areas which used to be covered with "greens" have now been converted into residential areas. Furthermore, several business districts have evolved which have the likelihood of reducing the immense pressure Adum, Ashtown and Asafo are experiencing today.

3.1.2 CLIMATIC CONDITIONS

The climate of Kumasi is tropical and falls within the wet sub-equatorial type, (KMA, 2006). Two distinct rainfall peaks are experienced in June and September. Harmattan in Kumasi often starts around mid-November to early December. Relative humidity on normal days ranges from a maximum of 100% in the mornings to 60% at 15:00 GMT and then rises again as the sun sets. This high humidity is due to the fact that Kumasi is located in the Forest Zone of Ghana. Kumasi is also known to experience high rainfall levels as compared to most areas and regions in the country. Western Region is known to have the highest rainfall amounts in the country. The average minimum and maximum temperatures in Kumasi are about 21.5°C and 30.7°C respectively (KMA, 2006).

3.1.3 TOPOGRAPHY, GEOLOGY AND SOIL TYPE

The Metropolis lies within the plateau of the south-west physical region which ranges from 250 m-300 m above mean sea level (KMA, 2006). The Kumasi Metropolitan area is dominated by the middle Precambrian rock. The effect of this unique geological structure in the metropolis has both positive and negative impacts on the local economy. The very existence of the Precambrian rock has led to the development of the construction industry in the metropolis. The basic soil within the basin is silty clay loam which is moderately slow to slowly permeable resulting in fairly high runoff rates. This soil supports maize, cassava, cocoyam and plantain.

The major soil type of the metropolis is the Forest Ochrosol. The detailed soil associations are the following: Kumasi – Offin Compound Association; Bomso – Offin Compound Association; Nhyanao – Tinkong Association; Bomso – Suko Simple Association; Bekwai– Oda Compound Association and Bekwai – Akumadan – Oda Compound Association. It is a very rich type of soil that has made it possible for a lot of foodstuff (vegetables, plantain, cassava etc) to be grown in the periphery (KMA, 2006).

There are a few small-scale mining activities and the proliferation of stone quarrying and sand winning industries. Even though these have created employment opportunities, the uncontrolled extraction of these resources poses environmental hazards.

3.1.4 THE DRAINAGE SYSTEM IN KUMASI

According to Friends of Rivers and Water Bodies - a Kumasi-based environmental non-governmental organisation (NGO), there are about 77 streams and rivers in the Kumasi Metropolis. Zakaria (2000) also indicates that there are basically two major rivers in Kumasi part of which form tributaries for all the other rivers. The rivers are the Owabi and the Oda rivers. The city is divided into five Basins by series of ridges running generally in a north-south direction. These drainage basins are Kwadaso Basin, Subin Basin, Aboabo Basin, Sisai Basin and Wewe Basin. The basins drain north to central portions of the city (Figure 3.2). Just like most urban areas in Ghana, Kumasi has seen rapid infrastructure development but its major problem is the inadequacy water drainage facilities.

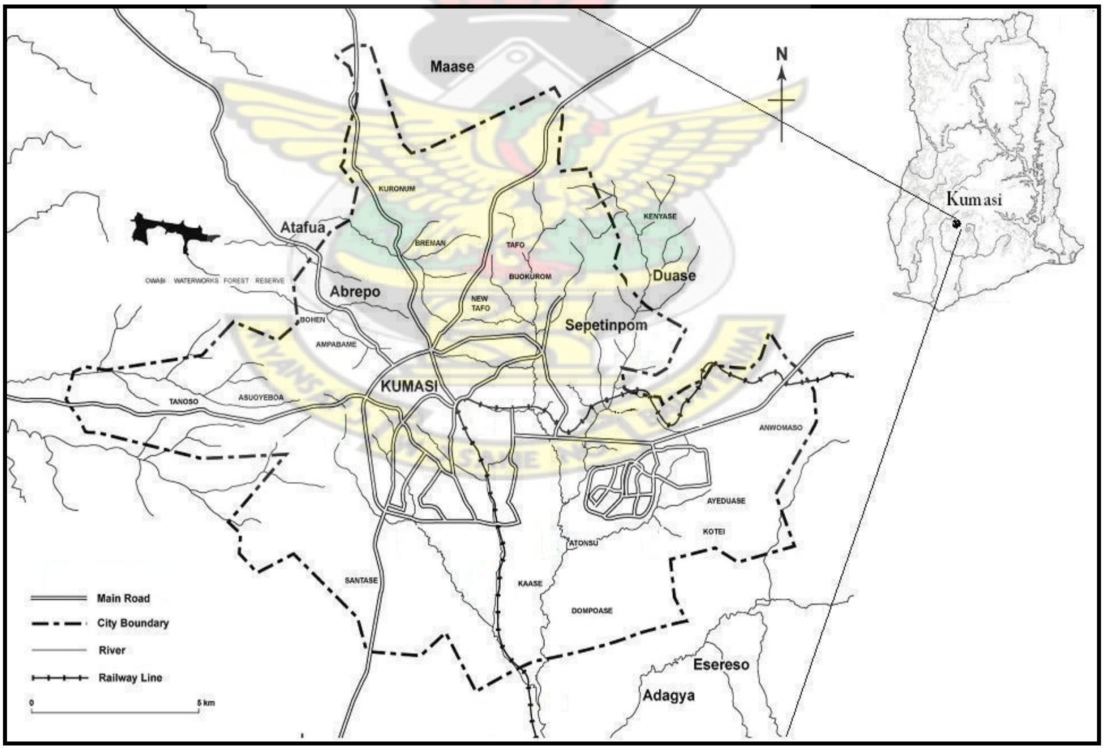

Figure 3.2: Map of KMA showing major towns, drainage and streets

3.1.5 LAND USE AND VEGETATION

The city falls within the moist semi-deciduous South-East Ecological Zone. Predominant species of trees found are Ceiba, Triplochlon, and Celtis with Exotic Species. The nutrient-rich soil has promoted agriculture in the periphery. A patch of vegetation reserve within the city has led to the development of the Kumasi Zoological Gardens, adjacent to the Ghana National Cultural Centre and opposite the Kejetia Lorry Terminal. This has served as a centre of tourist attraction. In addition to its scenic beauty as a tourist centre, its other objectives include education, preservation of wildlife, leisure and amusement. Apart from the zoological gardens, there are other patches of vegetation cover scattered over the peri-urban areas of the metropolis. However, the rapid spate of urbanization has caused the depletion of most of these nature reserves (KMA, 2006).

The Kumasi Metropolitan Authority (KMA) is responsible for domestic waste management, while industries are responsible for their own wastes. The KMA has a strategic plan for sanitation, and bye-laws governing the city's public health and environmental sanitation.

3.2 RECONNAISSANCE SURVEY OF WETLANDS IN KUMASI AND SELECTION OF STUDY SITES

Following a reconnaissance survey, several wetlands with different degrees of anthropogenic impacts as a result of social and economic activities were identified. These impacts also originated from different distances away from the wetlands. However, the study targeted those wetlands which originated from distances not more than 100 m buffer. Following a detailed study of drainage maps of Kumasi and use of aerial photography, a physical inspection of these drainage channels were done (Figure 3.3).

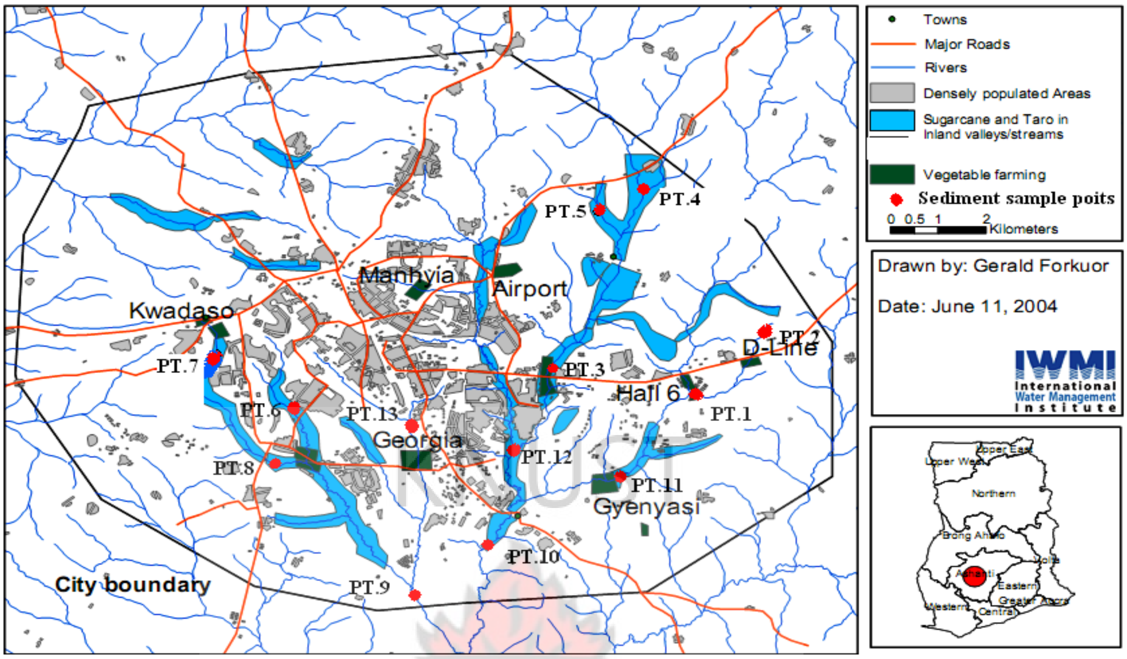

Figure 3.3: Some major drainage of the KMA and sampling sites
(Source IWMI, 2004)

Using a handheld GPS (Germin 62S), all natural water courses in the metropolis and its peri-urban regions were traced. During this physical inspection, all wetlands were noted and registered on the GPS. The data gathered was used to validate the information gathered from the digitised drainage maps and aerial photography acquired from the Survey Department Division of the Land Commission.

Based on the information from this survey, the major wetland sites of ecological, landscape, economic and social interests were identified and chosen for the study are associated with the following rivers: Aboabo, Bantama, Kwadaso, Sisai, Subin, and Wewe. Sediment sampling sites of these wetlands were carefully selected. Wetlands of ecological interests included, but not limited to, areas with at least 50 m of wetland vegetation on both sides of the water channel. Areas with economic and social interest (e.g. dye industries, car wash, agriculture, settlement etc) directly affecting or bordering the wetlands were selected for detailed ecological studies.

3.3 DATA COLLECTION

Remote sensing, geographic information systems (GIS), and emerging integrated resources management approaches offer mechanisms in the management of wetlands (Silvius *et al*., 2000). Basically, data for this research were obtained from primary and secondary sources. The former involved field acquired data (GPS coordinates of soil site, soil samples, interviews etc.) while the latter included data from relevant literature, survey maps, remote sensing imagery related to the study area.

3.4 ON-GROUND INVENTORY OF WETLANDS IN KUMASI

The climate, hydrology and physicochemical characteristics were captured. These properties are pH, dissolved oxygen (DO), temperature, salinity, total dissolved solids (TDS), conductivity. The heavy metals [lead (Pb), copper (Cu), total phosphorus (P_{total}), zinc (Zn), mercury (Hg), Nikel (Ni), Arsenic (As), Chromium (Cr) and Cadmium (Cd)] that may be typical of urban wetlands and land use inventory were also captured and classified.

3.4.1 SEDIMENT SAMPLING

A map was prepared of the area to be covered in a survey showing different sampling unit boundaries. A V-shaped cut with a spade was used to remove a 1-2cm slice of soil. The sample on the blade of spade was collected with a trowel and put in a sample bag. The samples were well labelled and details of the sample written on the information sheet. The sample bags were carefully sealed. The samples were taken to the laboratory for heavy metal determination by atomic absorption spectrophotometry.

3.4.2 SOIL PREPARATION AND ANALYSIS

Wet Digestion

A mixture of HNO_3 and $HClO_4$ in the ratio of 9:4 was used for sample digestion. It is known as di-acid digestion. Perchloric acid (HNO_4) was used primarily for increasing the efficiency of oxidation of the sample as $HClO_4$ dissociates in to nascent chlorine and oxygen at high temperature, which increases the rate of oxidation or the digestion of the sample.

One g of grounded soil sample was taken for analysis. It was placed in a 100 ml volumetric flask, and 20 ml of acid mixture was added to the contents were mixed by swirling. The flask was placed on a hotplate in the fumehood and heated, starting at 80-90 ^oC. Heating continues until the production of red NO_2 fumes ceases. The contents were further heated until a colourless mixture was formed. After cooling the contents of the solution is filtered through No. 1 filter paper and made up with distilled water to 100-ml. A solution was poured into appropriate containers for spectrographic analysis (Motsara and Roy, 2008).

3.4.3 DETERMINATION OF METALS BY ATOMIC ABSORPTION SPECTROPHOTOMETRY

Pre-treatment of samples before aspiration

i) The sample was mixed thoroughly by shaking and a portion filtered through 0.45 μM pore size membrane filter paper, using vacuum filtration.

ii) The filtered sample was acidified with concentrated nitric acid to pH 2 or lower and aspirated and the concentration of the samples calculated.

Fundamentally, quantitative analysis by atomic absorption spectroscopy was used to convert samples and standards into solutions, comparing the instrumental responses of standards and samples, and using these comparative responses to establish accurate concentration values for the element of interest.

1. a solution which contains no analyte element (the analytical blank) was formed.
2. a series of calibration solutions containing known amounts of analyte element (the standards) were made.
3. the blank and standard were atomize in turn and measured the response for each solution.
4. a calibration graph showing the response obtained for each solution was plotted.
5. the sample solution are atomized and their response measured.
6. the concentration of the sample from the calibration were determined, based on the absorbance obtained for the unknown.

3.4.4 COMPUTATION OF MODIFIED DEGREE OF CONTAMINATION OF SOIL SAMPLES

Abrahim and Parker (2008) presented a modified and generalized form of the Hakanson (1980) equation for the calculation of the overall degree of contamination at a given sampling or coring site. The modified formula was generalized by defining the degree of contamination (mC_d) as the sum of all the contamination factors $\left(C_f\right)$ for a given set of estuarine pollutants divided by the number of analyzed pollutants.

$$mC_d = \frac{\sum_{i=1}^{i=n} C_f^i}{n}$$

Where n = number of analyzed elements and i = ith element (or pollutant) and C_f = Contamination factor. However the Cf requires that at least five surficial sediment samples are averaged to produce a mean pollutant concentration which is then compared to a baseline pristine reference level, according to the following equation:

$$C_f = \frac{M_x}{M_b}$$

Where M_x and M_b respectively refer to the mean concentration of a pollutant in the contaminated sediments and the pre-industrial "baseline" sediments. Using this generalized formulae to calculate the mC_d allowed the incorporation of as many metals as the study may analyze with no upper limit. The modified degree of contamination, mC_d as proposed in the present study, was based on integrating and averaging all the available analytical data for the set of sediment samples.

For the classification and description of the modified degree of contamination (mC_d) in sediments the following gradations were proposed:

$mC_d < 1.5$	Nil to very low degree of contamination
$1.5 \leq mC_d < 2$	Low degree of contamination
$2 \leq mC_d < 4$	Moderate degree of contamination
$4 \leq mC_d < 8$	High degree of contamination
$8 \leq mC_d < 16$	Very high degree of contamination
$16 \leq mC_d < 32$	Extremely high degree of contamination
$mC_d \geq 32$	Ultra high degree of contamination (Abrahim and Parker, 2008)

3.5 SPATIAL DATA COLLECTION

3.5.1 GPS SITE MAPPING

Wetland locations based on factors of vegetation and water proximity were assessed and delineated with hand-held GPS (Germin 62S). GPS coordinates were also picked for areas that could easily be referenced on a remote sensing image. These included centres of roundabouts, road junctions, edges of conspicuous buildings etc. The sampling sites were superimposed or determined from the remotely sensed imageries that were used for the study.

3.5.2 SATELLITE IMAGERY REPRESENTATION

In an attempt to spatially represent and delineate wetlands in the study area, various Geoeye satellite images were downloaded to cover the KMA. The images were the most recent remote sensing image of 10th August, 2010. To enhance accurate and precise fussing of these images, a 30% overlap was allowed. With the aid of Microsoft Paint the individual images were appropriately merged using the 30% overlap and edges identifiable features on the image. To achieve the required local coordinate or grid system, the image was georeferenced using coordinates of intersections of roads and centres of roundabouts that can be identified on the image. These points were accurately picked with a handheld GPS in the local coordinate system and all other manipulation and analysis were performed in ArcGIS 9.2 interface.

With Breen's (1991) definition of wetland in mind, the Northern and Eastern (X, Y) coordinates of points around the major wetland in the study area were picked. This describes a buffer/delineation of actual extent of these wetlands. This was achieved in ArcGIS 9.2 by superimposing those delineating points on the remote sensing image.

3.6 COLLECTION OF SOCIOECONOMIC DATA

The identification of the actual stakeholders and assessment of their interests and the way in which these interests affect the wetland management in the wetland area was documented as general characteristics and present use and vegetation cover. From the list of stakeholders, various data collection strategies were employed to solicit the needed information.

3.6.1 WETLAND ASSOCIATED SOCIOECONOMIC ACTIVITIES

All socioeconomic activities in and around the wetlands were identified. Some of these included but not limited to the following categories: car washing bay, farmers, carpenters, tie and dye manufacturers.

A structured questionnaire (Appendix I) was developed to collect socioeconomic information on wetland associated communities. Initially, 15 sets of a questionnaire were administered to the six wetland areas to pre-test the set questions. In all, 90 sets of a questionnaire were administered to respondents from 6 identified wetland locations (Aboabo, Ahinsan, Atonsu, Asokore Mampong, Dakudwum and Kwadaso Estates). Thus 15 sets were administered at each location.

In addition to the questionnaire, interviews (see Appendix I) were conducted with 5 respondents who were engaged in the following economic activities within the 100 m buffer zone from the wetland; agriculture, batik tire and dye, carpentry/saw mill, car fitting and car washing bay operators.

3.6.2 GOVERNMENTAL AND NON-GOVERNMENTAL AUTHORITIES

The Kumasi Metropolitan Authority (Environment and Sanitation Unit) and the Town and Country Planning Department (TCPD) who are responsible for managing wetlands were contacted. First informal visits were made to the identified organisations and the researcher and research idea introduced. Through informal chats, the relevant personnel were identified. Official introductory letters were then sent to these identified personnel and where necessary, the heads of Department to introduce the research. The specific involvement of the organisation/personnel in this research was specified and sought. Interview sessions were held with the different organisations. Information on research, policy, activities on wetlands in Kumasi was sought.

CHAPTER FOUR

RESULTS

4.1 SPATIAL REPRESENTATION AND MAJOR LULC FEATURES OF WETLANDS IN KUMASI

The final classification product of the GeoEye 2010 imagery provides an overview of the major landuse/landcover (LULC) features of the Kumasi Metropolitan area (Figure 4.1).

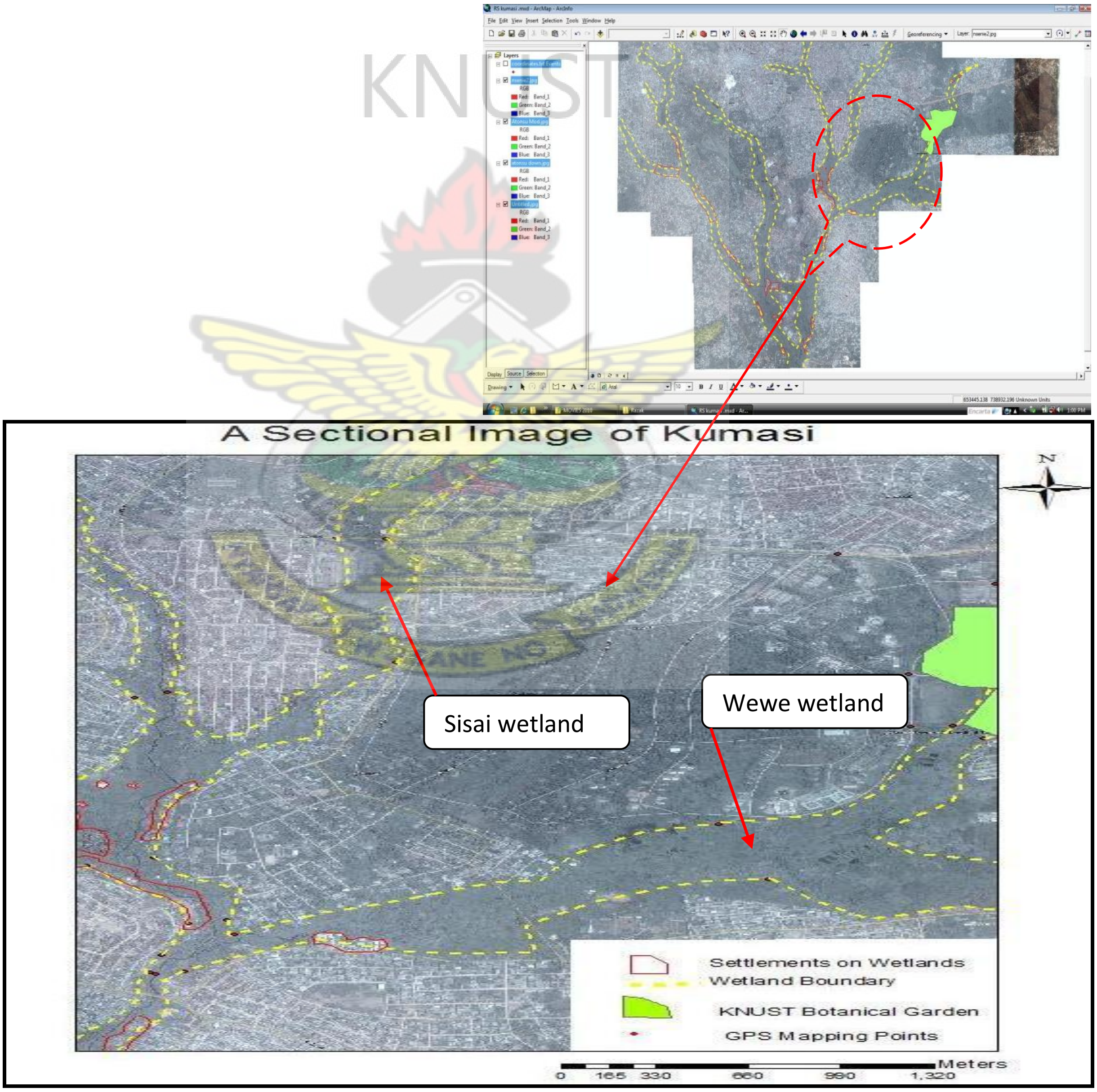

Figure 4.1: A Classified image of LULC in the KMA

From the sectional image showing part of KNUST (Wewe wetland) and Ahinsan (Sisai wetland), it was possible to see LULC pattern such as part of the KNUST botanical garden, wetlands in those areas and settlements that clearly encroach the wetlands. The coordinates of points that delineate the features and attribute data set in terms of the overall landscape describing the areas on the image were recorded (Appendix II).

4.2 PHYSICOCHEMICAL CHARACTERISTICS OF THE WETLANDS

Some physicochemical parameters namely DO, pH, temperature, salinity, TDS and conductivity were measured on the streams of wetlands in Kumasi (Figure 4.2).

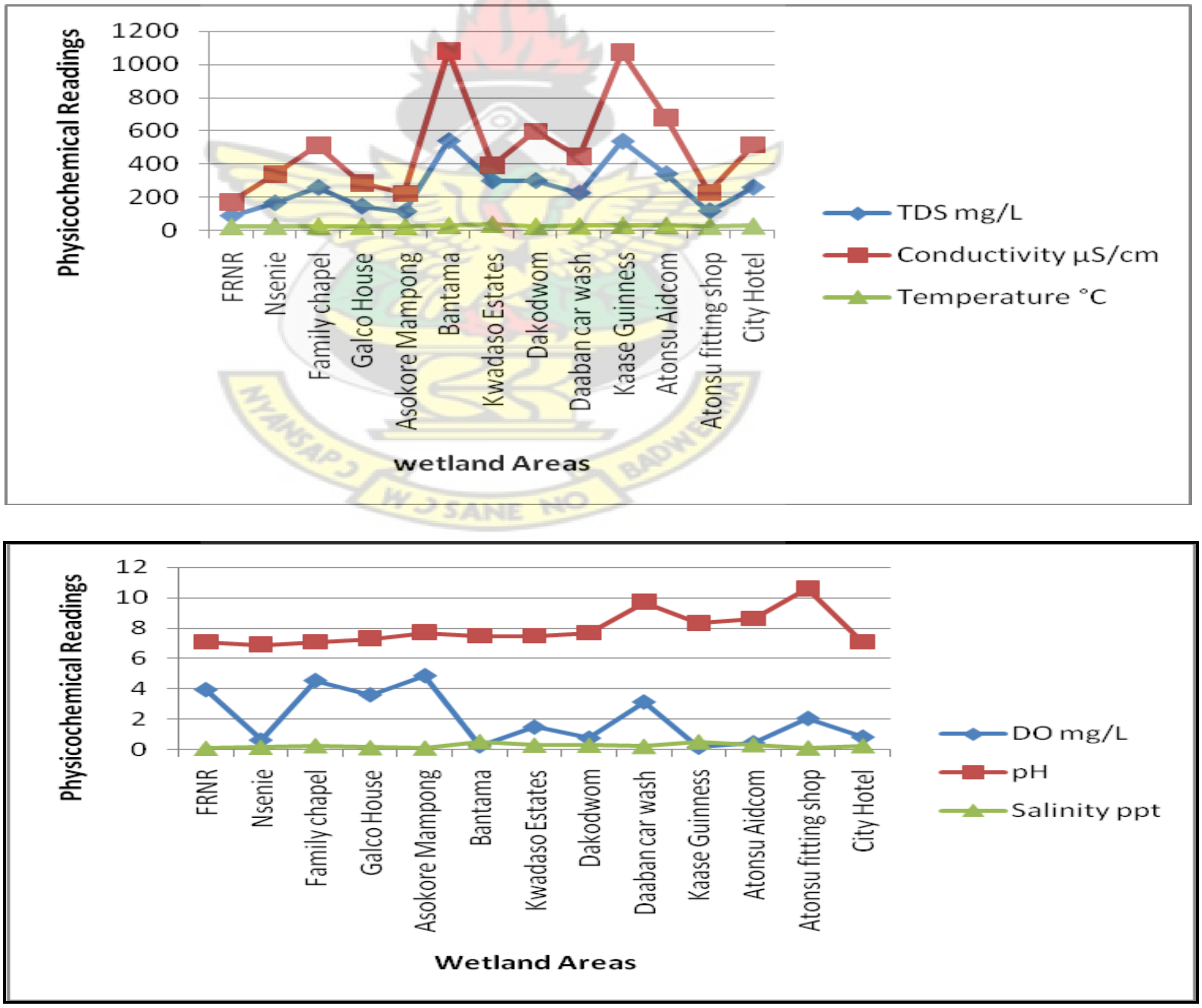

Figure 4.2: Some physicochemical parameters of some wetlands in Kumasi

On account of the physicochemical characteristics of the wetlands in Kumasi, the water had a pH ranging between neutral and alkaline (6.88 to 10). Atonsu fitting shop and the car washing bay at Daaban showed a high level of pH of 10.6 and 9.7 respectively. The DO levels ranged between 0.16-3.94 mg/L.

4.3 SEDIMENT POLLUTION LEVELS

A comparison of heavy metal concentration in the sediment of each study site (Figure 4.3) indicates that total phosphate contamination factor values were highest (36.2) especially at Kaase Guiness area followed by Atonsu Fitting Shop (32.8) and downstream at Atonsu Saw mill (26.2) suggesting an extremely high to ultra high degree of contamination on the Abrahim and Parker (2008) scale. Arsenic values were relatively low ranging from 0.7 at Asokore Mampong (nil to very low degree of contamination) to 13.8 and 12.2 (very high degree of contamination) at Atonsu fitting shop area and Kwadaso Estate respectively.

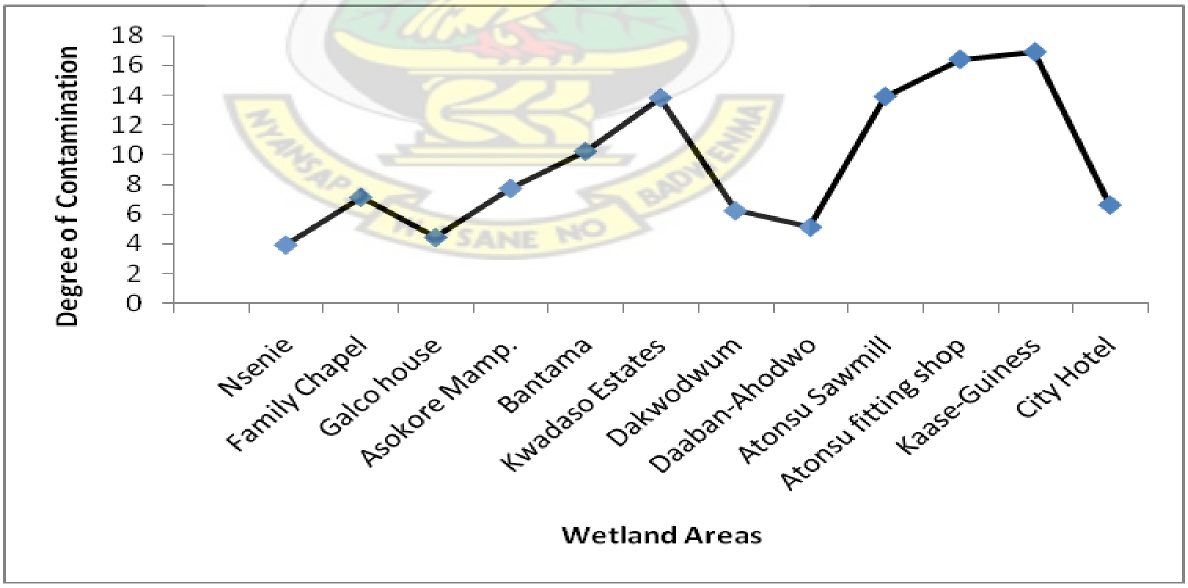

Figure: 4.3 Modified degree of contamination (mC_d) for heavy metals in Kumasi

Mercury (Hg) levels were found to be close to each other ranging from 9.1 to 15.6 (Appendix III). Higher concentrations can be found in areas near the industrial firms and places of higher agricultural activities (eg. Atonsu, Kaase-Guiness and Family Chapel).

Zinc (Zn) C_f were as low as 3.8 and 4.5 at City Hotel and Nsenie respectively but astronomically high values of 25.6 and 27.8 at Kaase Guiness and Atonsu Fitting Shop respectively. Copper C_f value in samples were again highest at Atonsu Fitting shop (12.4) and Kaase Guiness (13.4), while nickel C_f in the entire sample sites were found to be relatively low for all sites except Atonsu Sawmill and Kaase Guiness with C_f values of 13.2 and 18.1 respectively. Chromium and Cadmium C_f for the entire sample site were relatively low (0.9 - 9.3 and 2.3 - 12.7 respectively).

The classification and description of the modified degree of contamination (mC_d) in sediments as presented by Abrahim and Parker (2008) is as follows:

$mC_d < 1.5$	Nil to very low degree of contamination
$1.5 \leq mC_d < 2$	Low degree of contamination
$2 \leq mC_d < 4$	Moderate degree of contamination
$4 \leq mC_d < 8$	High degree of contamination
$8 \leq mC_d < 16$	Very high degree of contamination
$16 \leq mC_d < 32$	Extremely high degree of contamination
$mC_d \geq 32$	Ultra high degree of contamination

The streams at Nsenie can be described as moderately contaminated (3.9) a value that corresponds to $2 \leq mC_d < 4$ on the contamination graduation scale. Part of the Sisai wetland recorded extremely high degree of contamination ($16 \leq mC_d < 32$) at Kaase Guiness (16.9) and Atonsu Fitting Shop (16.4) areas.

Minimum values of C_f for total phosphate (3.3 and 3.5) were noticed for sediment at Nsenie and Asokore Mampong respectively, whilst the maximum C_f was recorded at the sampling sites located at Kaase-Guiness (15.2) and Atonsu Fitting Shop (32.8) areas. Family Chapel, Bantama, and Kwadaso Estates had considerably very high contamination factor values for all the heavy metals, whilst sites around Asokore Mampong and Galco House recorded a moderate to high contamination for these metals. Apart from High school junction and Kaase Guiness areas, all stations recorded low-moderate contamination factor for Cu, Cd, Cr and Ni. Hg and Zn exhibited very high to extremely high contamination for almost all sites.

4.4 SOCIOECONOMIC ACTIVITIES AND ITS EFFECTS ON WETLANDS IN KUMASI

In order to assess the impacts of the various stakeholders on the wetlands, 90 set of questionnaire were administered to people living along wetlands. Fifteen set of this questionnaire were administered to respondents living along wetland communities at Aboabo, Ahinsan, Atonsu, Asokore Mampong, Dakodwom.and Kwadaso Estate.

4.4.1 DEMOGRAPHIC CHARACTERISTICS OF HOUSES IN KUMASI

Out of 15 people interviewed from the 6 wetland areas who had no formal education, 40% live in Compound houses, 33.3% storey buildings, 13.7% live in boys' quarters, single rooms and wooden structures. Very few respondents 6.7% with middle school/JHS education live in compound houses and self-contain. Most respondents interviewed who had post-secondary and tertiary education (85%) lived in compound houses, self-contained and semi-detached houses (Figure 4.4).

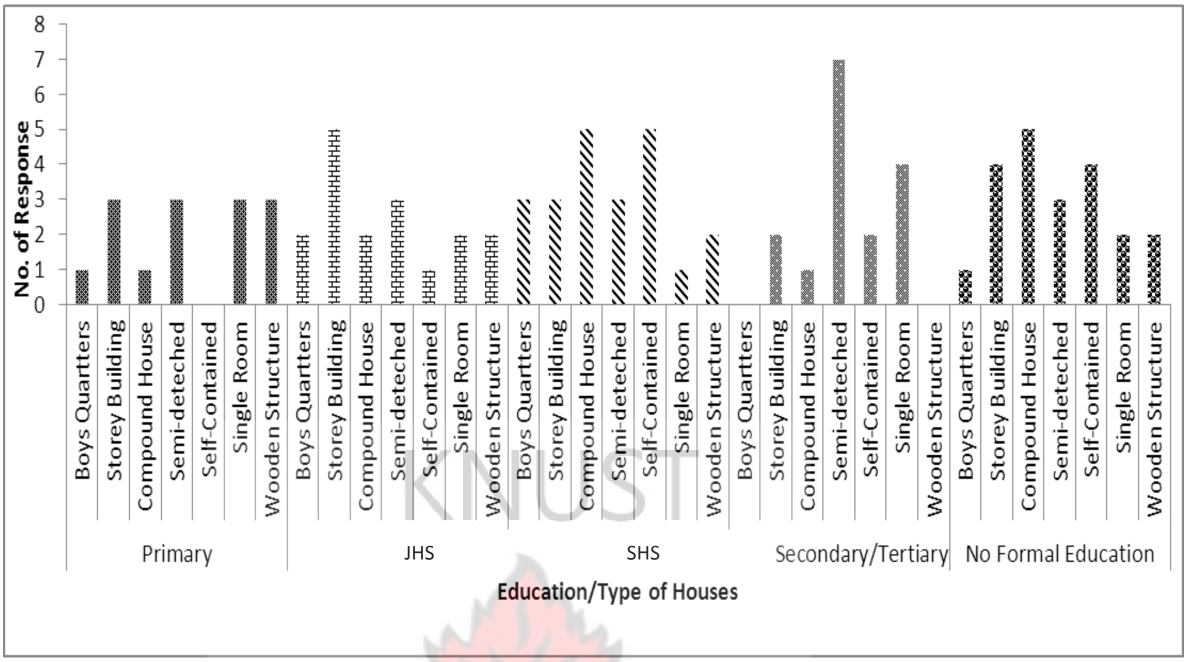

Figure 4.4: Levels of education and type of houses of respondents in Kumasi

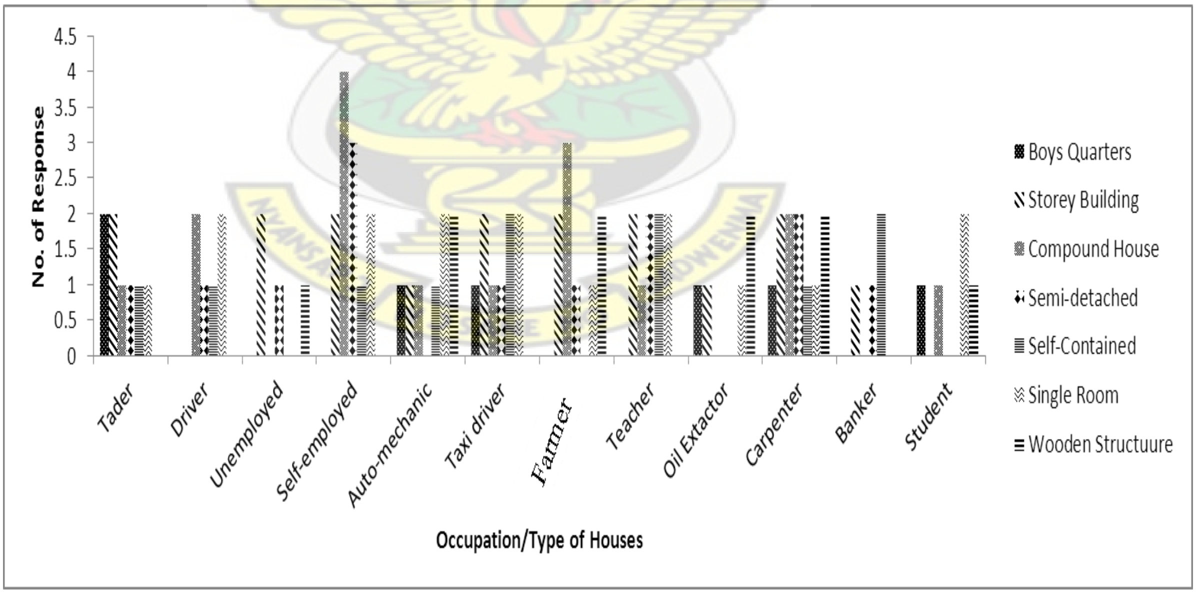

Figure 4.5: Occupation and type of houses of respondents in Kumasi

The analysis of data revealed that out of 15 respondents 33.3% live in storey buildings, compound houses, semi-detached and self-contained houses. These respondents are traders, teachers, farmers and taxi drivers (Figure 4.5).

Out of 15 people interviewed from each wetland area who had post-secondary or tertiary education, 53.33% of them would complain to authorities when their homes are flooded. Forty percent of respondents who had no formal education would normally dredge the stream, create channels or mostly do nothing when faced with flood. Averagely, 20% of respondents who had secondary education would pump water from their homes, create channels, move till water subsides, dredge or create embankment to try and curb the situation (Figure 4.6).

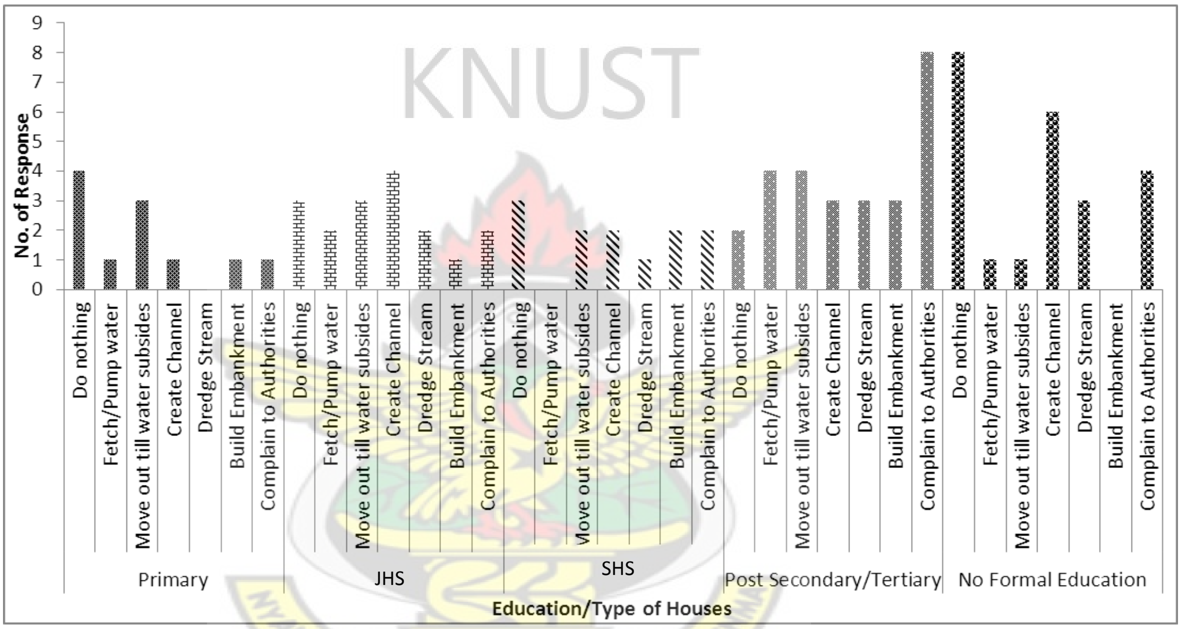

Figure 4.6: Educational levels and type of response to floods in the suburbs of Kumasi

4.4.2 ANTHROPOGENIC ACTIVITIES ON WETLANDS IN KMA

The summary statistics display the comparative use of the wetland in Kumasi (Figure 4.7). Waste disposal, settlement and carpentry are the major land use of the wetlands. The mean distribution for waste disposal is 3.4 whereas hunting, tie and dye, fish and recreation is between 1.1-1.7.

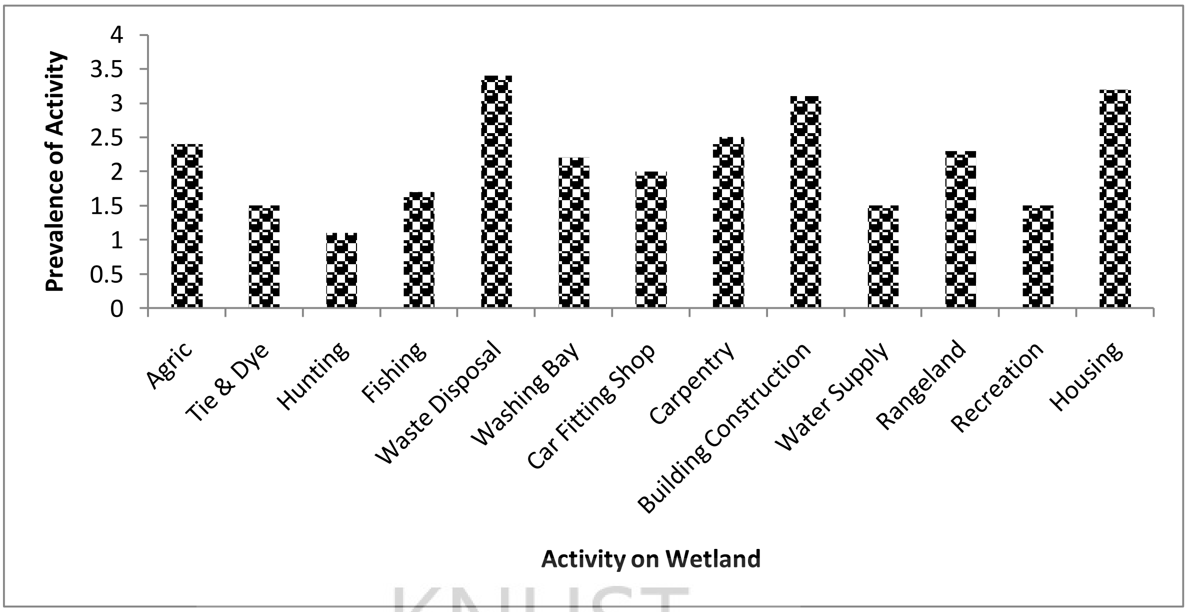

Figure 4.7: The major anthropogenic activities on wetlands in KMA

4.4.3 REASONS FOR BUILDING ON WETLANDS

When respondents were asked for what reason they choose to stay on wetland areas, 44.5% believe wetland areas are cheap, while 25.2% believe wetland are 'no man's land'. Out of 90 respondents interviewed, 22.7% live along wetlands because of some economic again. Only 7.6% living along wetlands actually make use of the streams (Figure 4.8).

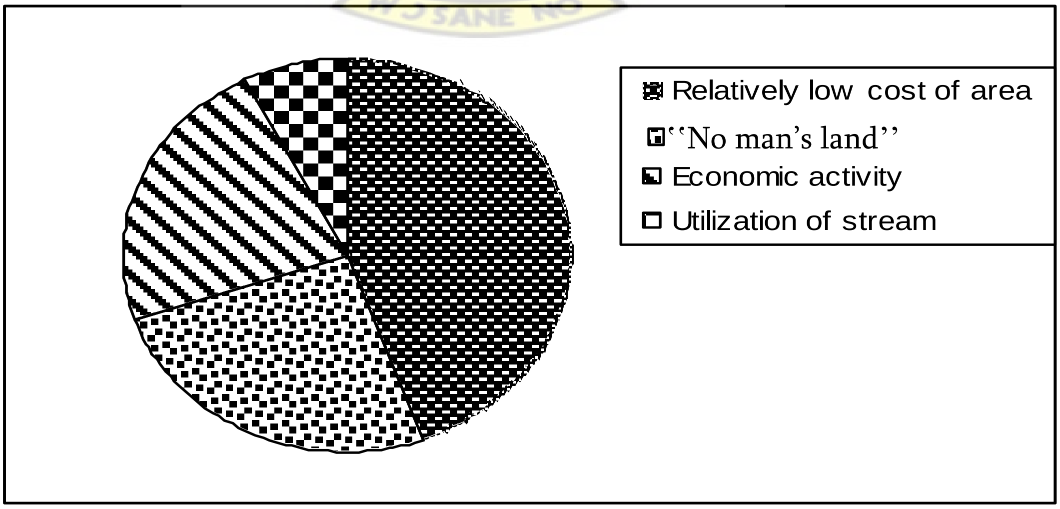

Figure 4.8: Respondents reasons for building on wetlands in Kumasi

4.5 FLOOD DATA AND FLOODING IN KUMASI

The June, 2009 flood cases in Kumasi prompted the KMA to earmark about eighty houses to be demolished. Many flood prone areas in Kumasi, particularly the Oforikrom sub-metro, experienced flooding, forcing residents to evacuate their premises. Many houses were submerged by flooding as a result of the heavy downpour which lasted for almost three hours, while properties worth millions of Ghana cedis were destroyed. On the 23rd of June 2009, over 790 people were affected by floods at Anloga alone. The total number of people affected that year totaled 2,180 excluding people unaccounted for (Figure 4.9).

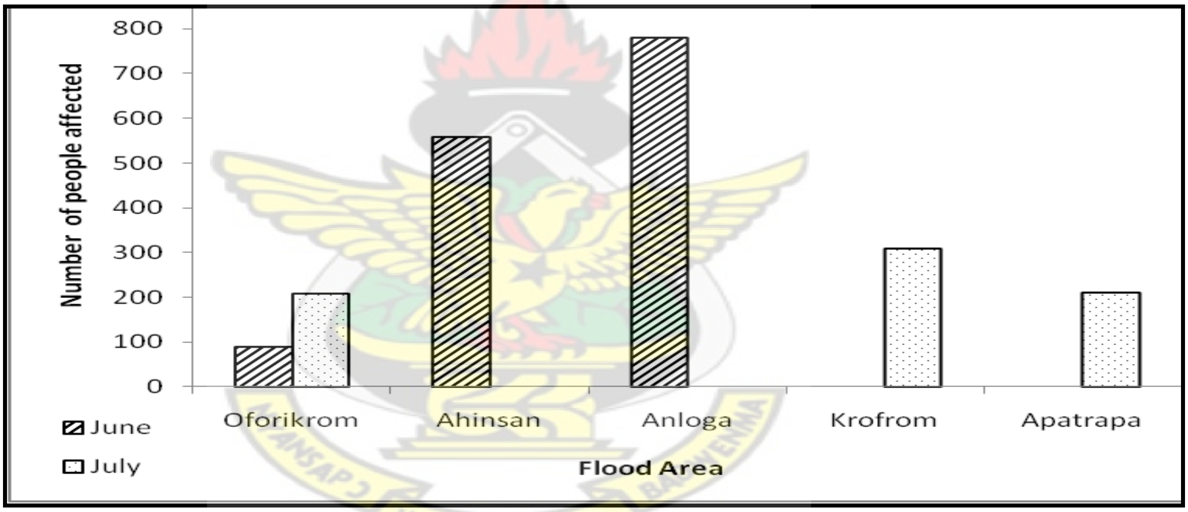

Figure 4.9: Distribution of floods in the various communities in the KMA in 2009

The communities in the study area were asked to respond to the prominence of flooding in the area. In Dakodwom, Asokore Mampong and part of Ahinsan, 50% respondents indicated perennial flooding while in Aboabo, Atonsu, High school Junction all respondents (100%) noted perennial flooding. Respondents gave a wide range of responses on the issue of adaptations to flooding (Table 4.10).

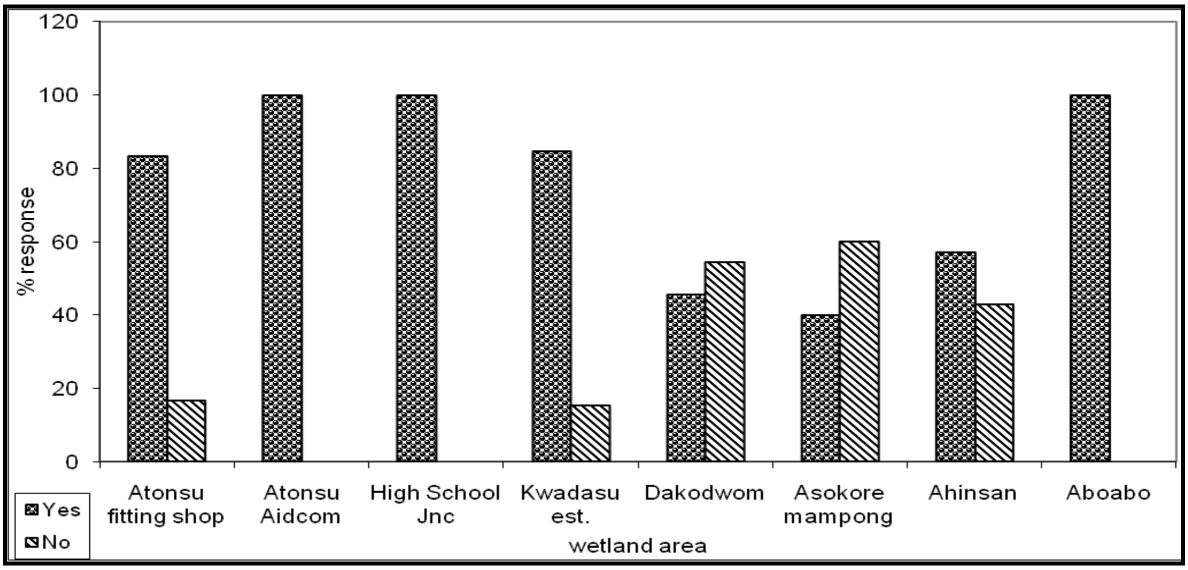

Figure 4.10: Community response to incidence of flooding in Kumasi

Fifty percent of the people interviewed at Atonsu frequently stayed put and did nothing when hit by floods. Between 50%-100% would not probably resort to moving out till water subsides, dredging stream or complaining to authorities. This pattern runs through almost all the other study sites, except for Aboabo where community members would explore all options including complaining to authorities when hit with floods (Figure 4.11).

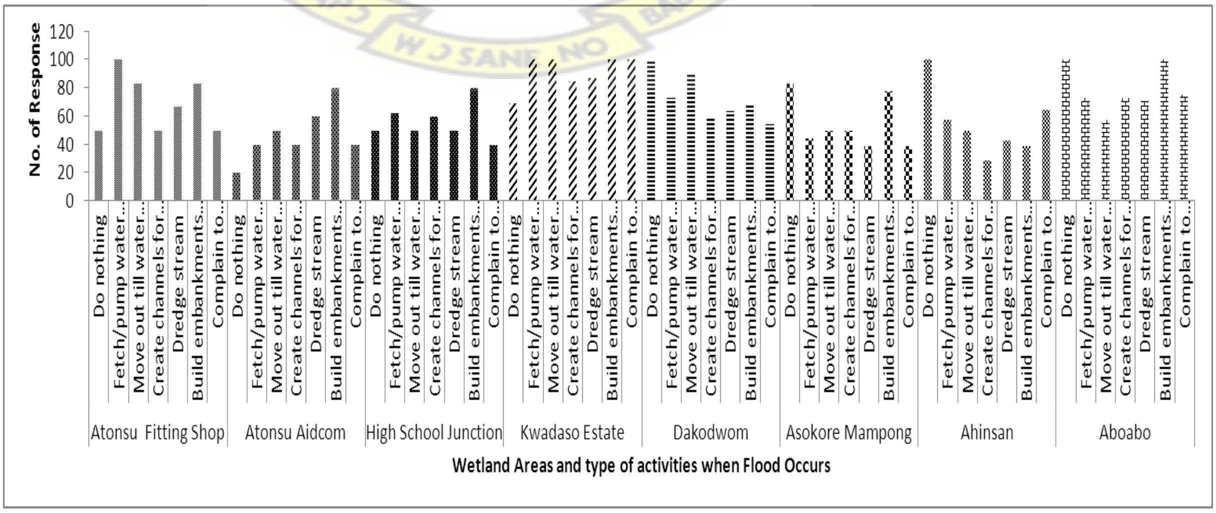

Figure 4.11: Wetland community adaption to floods in Kumasi

4.6 WETLAND MANAGEMENT IN KUMASI

The recent development in wetlands in Kumasi is the conversion of wetland to storm drains. This managerial decision by the KMA to control the perennial flooding in the metropolis has resulted in construction of trapezoidal drain over the Aboabo and part of the Sisai stream completely disturbing the ecosystem and functions of those wetland. However, the intent and purpose of these drains have been defeated since residences have used the drain for their refuse disposal. A drain of about 2.5 m depth, has over three quarters of it filled with solid waste. Consequently, buildings close to these drains get flooded up to the rafter (plate 4.1and 4.2).

Plate 4.1: A river channel at Aboabo converted into a storm drain

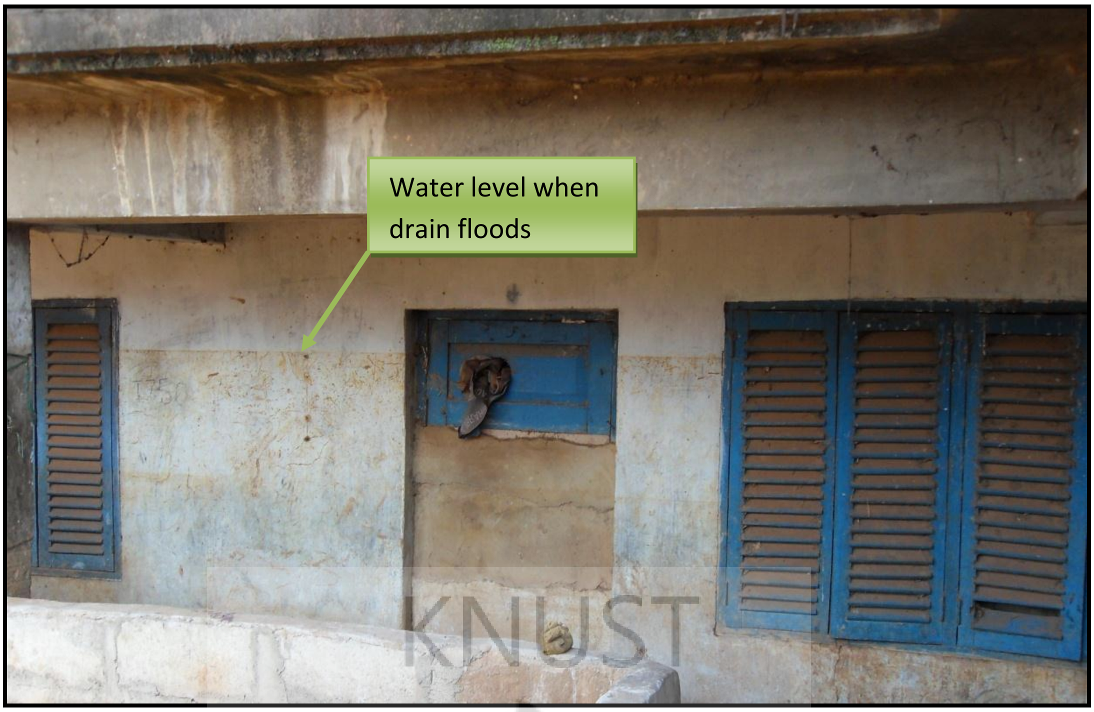

Plate 4.2: A building at Aboabo showing the height of flood water

Over 90% of respondents interviewed agreed that there were no significant management practices that any of the agencies is undertaking to educate, regulate and protect these ever dwindling wetlands (Figure 4.12). Twenty two percent responded that there were some dredging activity by KMA and radio announcement made over the years to caution people about possibility of floods and 4% responded that there is the construction of storm drain in some area like Anloga and Aboabo.

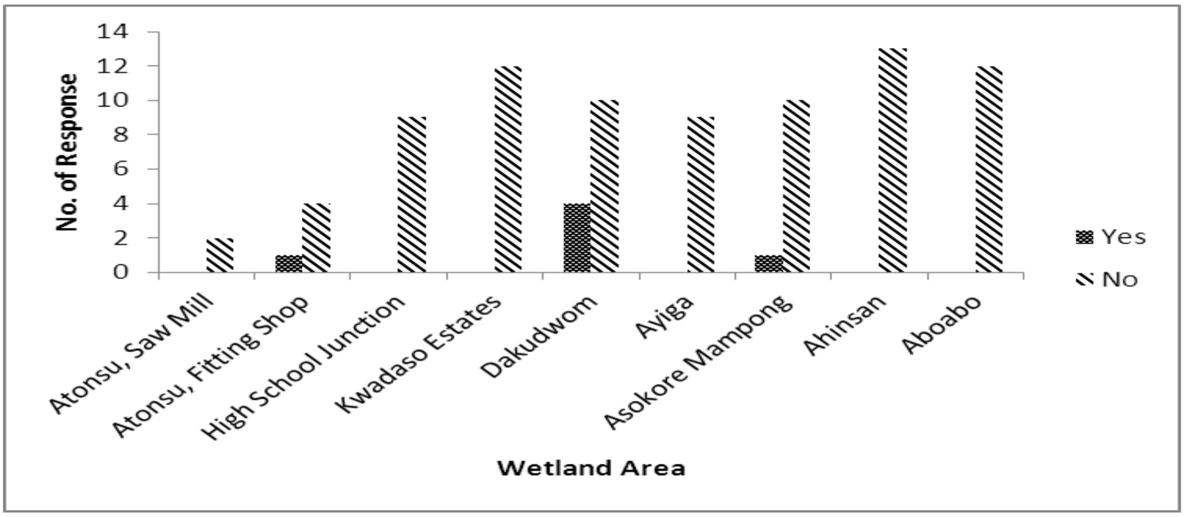

Figure 4.12 Wetland areas residence response to management practices in Kumasi

4.6.1 GOVERNMENT POLICIES

In response to the frequency of notification of defaulters, all the 3 local agencies interviewed indicated uncountable notification as their response. It was clear that the TCPD are actually not responsible for prosecuting offenders; however, they sometimes mark houses in the boundaries of wetland and the actual demolishing is assisted by police and in the demolishing processes, as inhabitants sometimes do no cooperate. The Building Inspectorate Unit under KMA Engineering Department is the body responsible for the demolishing exercise. Out of 90 respondents interviewed, 80% agree that no demolishing exercise have been carried out in their area (Figure 4.13).

The response from questionnaire administered shows that no educative seminar has ever been organized. However, in 2010 there was a sensitization program on Fox FM a private radio station in Kumasi, on how lands can be owned and protected with special emphasis on reserved areas.

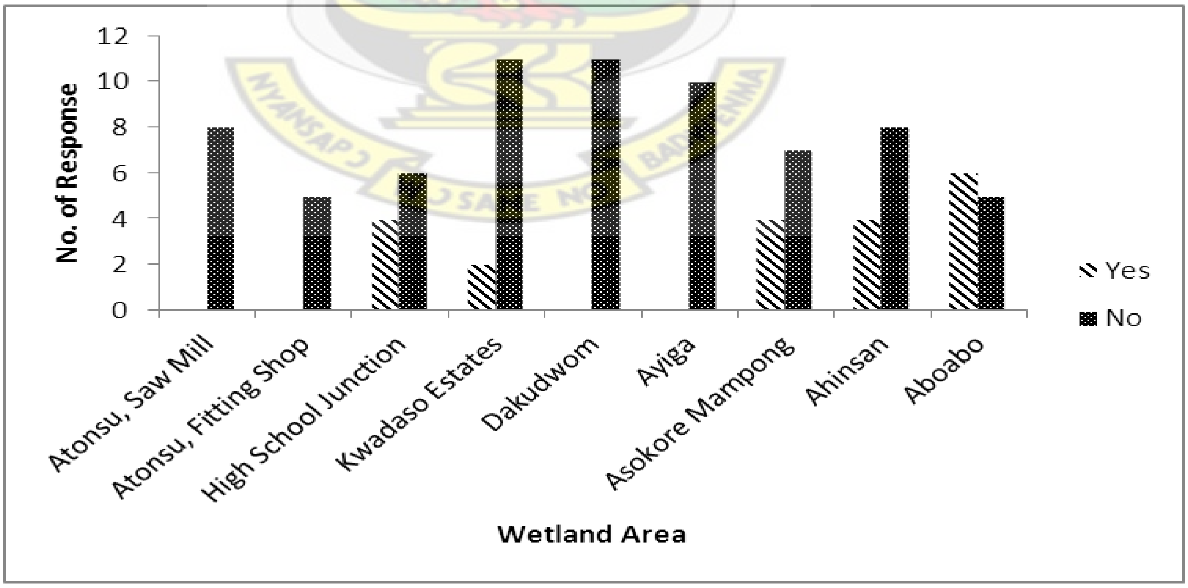

Figure 4.13 Respondents view to demolishing of structures on wetlands in Kumasi

4.6.2 GOVERNMENT AGENCIES AND TRADITIONAL MANAGEMENT PRACTICES

People living in the major communities along the wetland were asked which agencies were in-charge of wetlands to seek their level of knowledge of wetland issues (Figure 4.14). The results revealed that most community members interviewed are certain and rank the KMA highest as responsible for maintaining wetlands. The chiefs and assembly men were rated second to the KMA as responsible for maintaining wetlands in the study area. The TCPD, Hydrological Services Department and Non-Governmental Organization (NGO) were rated lowest with regards to their responsibilities towards wetlands (Table 4.14).

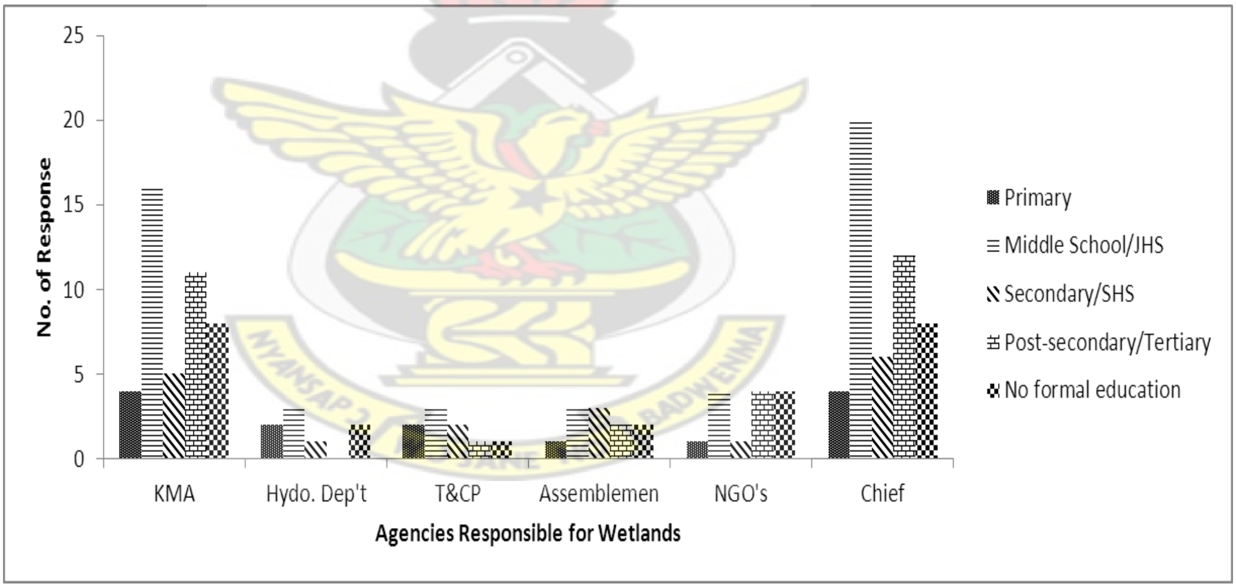

Figure 4.14: Agencies responsible for maintaining wetlands in Kumasi

Out of the 90 respondents interviewed at all the wetland sites, about 70% agree that there has been no attempt by any organization to move people living on wetlands. Similarly, respondents were asked which factors thwarted the demolition of buildings on water ways. Respondents with post-secondary or tertiary education believed that lack of political will, poverty levels and cost of demolition were the major factor obstructing government agencies from pulling down these buildings (Figure 4.16). About 40% of respondents with middle school/JHS and Secondary school education suggested political influence, change in government and corruption as the major cause (Figure 4.16).

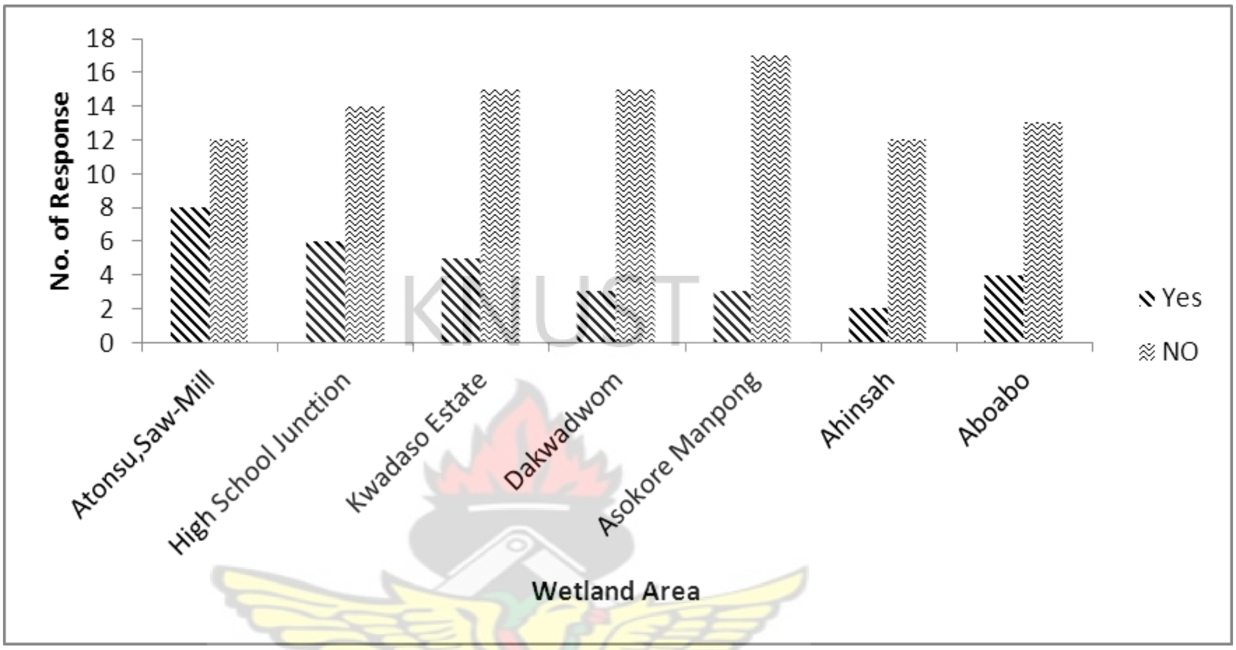

Figure 4.15: Response to attempt to relocate people on wetlands in Kumasi

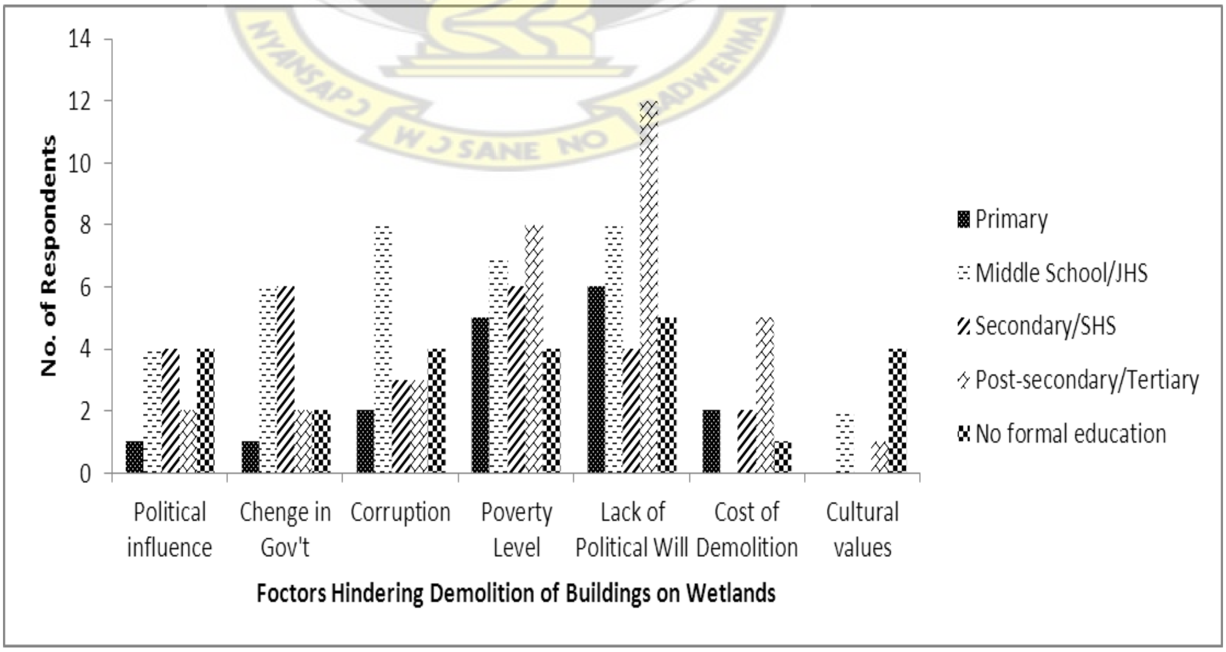

Figure 4.16: Factors obstructing the demolition of buildings on waterways

CHAPTER FIVE

DISCUSSION

5.1 SPATIAL DISTRIBUTION OF WETLANDS IN KUMASI

This study has revealed that, basic remote sensing techniques can be used as a tool to acquire ecologically relevant information on wetlands that are larger than the resolution of the classified images.

The boundaries of the 6 major urban wetlands in Kumasi were mapped based on Breen’s (1991) definition. A careful interpolation of these delineating points well defined the boundaries of all the major wetlands understudy in Kumasi. In contrast, it was inadequate and unjustifiable to assume 50-100 m buffer as outline of wetland (Aboabo, Bantama, Dakodwom, Kwadasu Estate, Sisai and Wewe) in this study. Tiner (1989) agrees with this accession and explains that some wetland areas extend far beyond 100 m or any such constant buffer value. There is the tendency that part of the wetland may be left out in the mapping process or are so small that the buffer would include non-wetland areas. This occurrence is show in Figure 2.2 and 2.3. However, an on-ground inventory and mapping in the study adequately defined the true extent of each wetland. The Sisai and Wewe streams are most encroached upon at areas such as Atonsu, Ahinsan and High School Junction. This may be due to the relatively cheap cost of wetland areas. Other places like Dakodwum and Kwadasu Estates have recently seen a sprawl of top class hotels, Churches and residential buildings as indicated by response from community members in these areas.

Logically, more wetlands were classified in the rainy season than in the dry season. These seasonal differences most probably result from the many temporary wetlands that are flooded in the area during the rainy season. However, some wetlands such as the Bantama, Aboabo and that sited at the Kwadasu Estates which were too small to be detect during the dry season could probably become larger and detectable in the wet season. The occurrence of these wetlands may therefore be misinterpreted and falsely contribute to this apparent higher number of wetlands. To evaluate these deviations, high spatial resolution satellite imagery or aerial photographs are indispensable (Tiner, 1993).

A ground survey in the dry season revealed that at least 88% of wetlands present in the area were not detectable by the remote sensing image used in this study, due to their small size. Unlike the Bantama and Aboabo wetlands which were relatively small and could not be detected, larger wetlands like the Sisai and Wewe were visible to the geo-eye image resolution considered under this research. All analyses and conclusions in this study thus apply only to the larger detectable wetlands. Research on the effect of wetland isolation requires very high spatial resolution images, since small wetlands are important habitats for amphibians (Semlitsch and Bodie, 1998) and may act as stepping-stones in-between the larger ones (Lafferty and Swift, 1999; Semlitsch, 2002).

5.2 PHYSICOCHEMICAL AND HEAVY METAL CONCENTRATION IN THE WETLANDS

DO is the measure of the degree of pollution by organic matter, the destruction of organic substance as well as self-purification of the water bodies. It reflects interaction with the overlaying air because oxygen from the atmosphere is dissolved in the water (Chiras, 1998) and it is one of the most significant tests for measuring the quality of water. The standard for sustaining aquatic life is stipulated to be 5 mg/L (Horne and Goldman, 1994). Concentration below 2 mg/L adversely affects aquatic and biological life while the concentration below 2 mg/L may lead to death of fish. Dissolved oxygen ranged from 0.16-3.94 mg/L. The dissolved oxygen concentration of the samples showed that the samples were oxygen deficient due to the fact that a lot of solid waste and wastewater drain into these streams. Except for area such as FRNR, Asokore Mampong and Kwadaso Estates all of the other sample sites in this study had DO below kill level for aquatic life (Figure 4.2). This could be attributable to high level of filth and effluence from homes and industries at areas such as Atonsu, Kaase Guinness and Bantama. The effluence from the Guinness industry at Kaase drains directly into these streams which could have resulted in low level DO and an alkali pH. APHA (1992) suggests that wastewater from sewage treatment plants often contains organic materials that are decomposed by microorganisms, which use oxygen in the process. Other sources of oxygen-consuming waste include storm water runoff from farmland or urban streets, feedlots, and failing septic systems.

Hydrogen ion concentration or pH is the indicator of acidity or alkalinity of water. It is a measure of the effective concentration (activity) of hydrogen ions in water. Water having a pH range of 6.5-8.5 will generally support a good number of aquatic species. Only a few species can tolerate pH values lower than 5 or greater than 9 (Harrison, 1999). The mean values of pH obtained ranged from 6.5-9.0 (Figure 4.2). These pH values were normal to unpolluted freshwater (Sawyer, 2003). They were also within the recommended ranges (6.5-9.5) as stipulated by both WHO. Thus, the pH for most of the streams investigated can be said to be favorable for aquatic life as supported by existing literature, with the exception of wetland near the Atonsu Fitting Shop area where the pH was slightly higher (10.6). The presence of high pH could be attributed to the activities such as car washing bays, effluence from bath rooms and kitchen which produces a lot of alkali compounds from detergents etc.

Dissolved solids (DS) include those materials dissolved in the water, such as, bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. These ions are important in sustaining aquatic life. However, high concentrations can damage cells of organisms, make water turbid, reduce photosynthetic activity and increase the water temperature (Mitchell and Stapp, 1992). In figure 4.2, all wetland sites in Kumasi recorded TDS values (86 - 540 mg/L) which are below the required WHO standard of 500 to 1,200 mg/L. Factors affecting the level of dissolved solids in streams in Kumasi may include fertilizer run-off used on farms, wastewater and septic effluent, soil erosion, decaying plants and animals, and geological features in the area which are very noticeable scenes in the study area.

Conductivity, which reflects the mineral/ionic status of water, ranged between 172 μS/cm at FRNR wetland area and as high as 1081 and 1074 μS/cm at the Bantama and Kaase Guinness rivers respectively (Figure 4.2). However, WHO recommends 400 μS/cm (Hayashi, 2004). The high conductivity level was probably due to pollution from detergent, tie and dye and bleaching from domestic and industrial effluents joining the stream in the vicinity.

With regards to an overall measure of heavy metal contamination applicable to estuarine or coastal sediments, the average mC_d of the entire sample site was estimated at 9.4, with mC_d values generally between 8 to 16 on the Abrahim and Parker (2008) scale. Overall, the range of mC_d values indicates a very high degree of contamination in the whole of wetlands in Kumasi. The variation observed were probably due to various factors such as trace metal contents of all the soil and crops, geographical location, fertilizers and fungicides applied in the area, environmental pollutions due to automobile emissions, industrial effects, other agricultural activities and weathering of rocks.

Sediments in the Atonsu and Ahinsan drainage system and surrounding environment actively accumulate heavy metals, improving the quality of the aquatic ecosystem. These observations are in agreement with those of Parizanganeh *et al*., (2007); Durán and González, (2009). However, this phenomenon poses a risk of secondary water pollution by heavy metals under sediment disturbance and/or changes in sediment chemistry

Metal concentrations of sediment in this study were greater than those found in the Hackensack River and Newark Bay studies in the USA, which were 10 ± 6 mg/kg Cd, 237 ± 222 mg/kg Cu, 2.1 ± 2.6 mg/kg Hg, 39 ± 49 mg/kg Ni, 42 ± 571 mg/kg Pb, and 395 ± 403 mg/kg Zn (Bonnevie *et al.*, 1994). Even though heavy metal concentration in vegetation were not determined in this study, it was also found that submerged litter from wetland plants accumulated heavy metals in excess of sediment concentrations. This fact is also confirmed by similar results observed by Windham *et al.*, 2004 study. Bonnevie *et al*. (1994) determined that Cu, Pb, and Zn adsorption was greater than that of Cr and Hg. It could therefore be inferred from these studies that the vegetation in wetlands of Kumasi could also contribute to the high buildup of heavy metal in wetlands in this study.

Across all the sites under study, zinc and phosphate concentrations were high (confirmed by similar results observed by Windham *et al.*, 2004 study). These metals were predominant in sample site at Atonsu sawmill and Kaase Guiness areas. The presence of these metals could be due to the fact that most domestic wastewater from our bathrooms and kitchens contain soap and drain into these wetlands. High level of Zinc could be due to the presence of metal scraps in waste materials disposed into wetlands

The concentration of phosphates (0.233 - 1.6 mg/g) obtained in this study is quite higher than the WHO acceptable limit (0.062 - 0.186 mg/g). This can be attributed to the occurrence of farms at distance less than the 50 m buffer as prescribed by the Ghana Environmental Protection Agency. Other common sources of high phosphate concentration in stream at Atonsu fitting shop, Kaase Guiness and Bantama areas (Figure 4.3) could be attributed to wastewater and septic effluents, detergents, fertilizers, soil run-off (as phosphorus bound in the soil will be released), industrial discharges, and synthetic materials which contain organophosphates, such as insecticides. According to the United Nations World Water Development Report 'Water for people Water for life' (2003), farmers put fertilizers and pesticides on their crops so that they grow better. But these fertilizers and pesticides can be washed through the soil by rain, to end up in rivers. If large amounts of fertilizers or farm waste drain into a river the concentration of nitrate and phosphate in the water increases considerably.

The presence of mercury in the stream sediments in the study areas are in the range of 0.04-0.36 mg/L. The lethal levels on fish range from 1 mg/L for tilapia, to 3 mg/L for guppies and 2 mg/L for crustacean (Cyclops abyssorum) (Mance, 1987). Comparing the results from this study to that provided by Mance (1987) for lethal levels for aquatic lives, the presences of mercury in the sediment are favorable for fish lives. However, the water from these wetlands used for irrigation purposes may lead to bioaccumulation of heavy metals in cultivated plants (Barmen and Tiner, 1999) and may have toxic impact on aquatic fauna. The presence of mercury in a contaminated stream sediment can be presumed to come from anthropogenic rather than natural sources as suggested by the New Jersey Geological Survey in the USA (Dooley, 1992). The traces of mercury can be attributed to household sources such as paint, past use of mercurial pesticides and point sources such as landfills which drains into the streams in Kumasi.

In general, the concentrations of heavy metals suggest high level contamination at all sites under consideration. Even though some few sites such as Asokore Mampong and FRNR showed low concentration (arsenic 0.0097 mg/g) these metals are very toxic in very small doses. A persistent exposure/consumption directly or indirectly may have devastating effect on human health.

Although people in the Kumasi Metropolis do not use the water from these wetlands/streams for drinking, livestock and other aquatic species consuming this water may be affected through long term exposure. Furthermore many of these wetlands serve to recharge the ground water aquifer. Hence, contamination of the wetlands might lead to the contamination of ground water. Stoppage of dumping industrial effluents, sewage and garbage may help in conserving the wetlands in the city which apparently function as groundwater recharge sites, provide habitats for a large number of flora and fauna including migratory birds, and is a major source of freshwater fish in the city.

5.3 SOCIO-ECONOMIC ACTIVITIES AND ITS EFFECTS ON WETLANDS IN KUMASI

Results indicate that majority (64%) of respondents were engaged in various economic activities such as farming, fishing, car washing, crop production, livestock production (figure 4.7) at areas such as Atonsu, Aboabo, Ahinsan and Dakwodwom. The activities are located on wetlands so that the waste products of these small enterprises could be discharged into the streams without any difficulty or cost. The diversity of economic activities in the study area indicated the need for more land to accommodate various land uses and the need for space to dispose wastes generated from these economic activities. These findings are similar to the study conducted by Baur *et al*., (2000) and UN (2009) who argued that different land use systems may have different impacts on wetland values direct or indirectly as a result of land use practices of the stakeholders (upstream or down-stream). Also according to Copeland *et al.*, (2010), Kangalawe and Liwenga (2005) and Ramsar (2009) poor farming and waste disposal practices have led to land degradation along with negative impacts on wetlands.

Thirty-Six percent of all churches and hotels in Kumasi are sited on wetlands around Bantama, Daaban and Dakodwom areas. In all these areas, the lands where acquired cheaply or donated as gifts by the chiefs. There is a high demand for wetlands goods and services to be wisely used. This implies that decision made by majority (64%) in the course of land use and other economic activities can affect water quality and other wetland values. This argument is similar to observation made by Falkenmark *et al.* (1999) who indicated that, exploitation of land resources has undesirable effects on the ecosystems, thus it is essential to understand how humans interfere with the landscape system.

5.4 FLOODING IN KUMASI

The haphazard development of structures along river banks most of the time results in loss of vegetation that protects the water bodies and further causes flooding during rainy season with its attendant problems such as loss of properties, outbreak of cholera and sometimes even death. The results of this study is no different from the study conducted by Forkuor (2010) who indicates that river bodies such as Subin and Aboabo rivers in the metropolis threaten community members in similar manner. The combined effects of the situation mentioned above threaten the availability of fresh water for the people of Kumasi in particular.

Although there are many factors that contribute to flooding in the study area such as choked drains, settlement and waste disposal on wetland etc, the amount of seasonal rainfalls affect the level of flooding in Kumasi. According to Chan (1997), some causes of urban floods are improper land use and channelization of natural waterways, failure of the city protection dikes, and inflow from rivers during high stages in urban drainage system. Other causes of urban flooding are surcharge due to blockage of drains and street inlets by silt and garbage and inadequate street cleaning practices (Kolsky and Butler, 2002). Apart from areas such as Dakodwom and Kwadasu Estate, most of the wetlands at Aboabo, Ahinsan and Atonsu are choked with domestic waste. Poor urban management practices have also contributed to flooding (Andjeilkovic, 2001). Areas such as Aboabo and Ahinsan where the wetlands have been converted to storm drains, residents have resorted in disposing their wastes into these drains.

The areas prone to flooding are Oforikrom, Atonsu, Aboabo, Anloga, Asafo, Asokwa and Breman (Figure 4.9). In 2009, over 971 community members at the Anloga area alone were affected by flood the effect is the loss of valuable property of residents (NADMO, 2009).

5.5 THE CURRENT STATE OF WETLAND IN KUMASI

The spatial distribution of wetlands and trends of development along the wetlands in urban Kumasi are typical of inland areas, primarily following the socioeconomic business district immediately surrounding the wetland (Figure 4.1). These development patterns appear to be associated with the primary transportation routes and eventually create a sprawl effect at the nodal points of the CBD and buildings such as hotels and churches occupy locations along the six major wetlands in Kumasi. Blake *et al.,* (1997) in an inception report - "Kumasi Natural Resources Management Research Project, stated that, rapid urbanization, for the most part unchecked by strategic planning considerations, has rendered the present land use pattern far more complex. Due to the land tenure system operating in Ghana, the traditional chiefs in Kumasi have become the major driving force behind land use changes, as more land and wetland areas are sold out to churches and individuals for residential development (Blake *et al.*, 1997). In accordance with this accession, the wetlands in Kumasi have seen massive encroachment culminating in high degree of pollution as discussed above.

The only wetlands in Kumasi that have seen some maintenance over the years are the KNUST botanical garden and Otumfuo garden at Dakudwom. The vegetative presence of the KNUST botanical garden has been preserved over the years hosting some significant fauna i.e. snakes and other reptile. At Dakudwom, the garden has grown some plants and animals where have contributed in the preservation of water level of the stream.

5.5.1 WETLAND POLLUTION AND LAND DEGRADATION

The extent of water pollution in the metropolis is worrying and the situation continues to exacerbate. This is as a result of the flouting of fundamental hygienic practices in the metropolis. Effluents discharged into the Subin River from the septic treatment plant at Kaase could be contributed to the polluted state of wetland downstream (Tables 4.3 and 4.4). At Anloga, toilets have been built on the Sisai stream. The extent of pollution suffered by the streams that traverse the metropolis is so devastating that they are only good for carrying sewer from kitchens and bathrooms.

Wetlands in almost all the study areas have been degraded for farming, settlement and other socioeconomic activities (Figure 4.7). The improper disposal of scraps from old refrigerator part, saw dust and other related woodworks at Anloga into the Sisai stream threaten its flow and life. Charcoal burning at Anloga area and the activities of abattoir operators at Atonsu has extensively encroached upon the Sisai wetland and these activities send fumes of smoke and other pollutants into the air and also rendering the land bare.

The need to increase agricultural output from wetlands has lead in some cases to the complete cultivation whole wetland with two crops per year. There are indication that soil fertility of double cropped wetlands is rapidly exhausted and within several years the water table falls to a level where it cannot continue to support agriculture. Under these similar conditions, many wetlands in Illubabor in Nigeria are used as grazing grounds for cattle although this is often a short-lived benefit as the trampling action of cattle aids the process of soil compaction, mineralization and erosion (Afework *et al.,* 2000). The degradation of wetland in this manner and the associated loss of functions and benefits has have dramatic effects the local communities in Kumasi. In one district of Bantama, the entire wetland has dried up such that the Liberty Chapel that has encroached on the wetland floods up in the less rain.

5.6 INSTITUTIONAL AND TRADITIONAL WETLAND MANAGEMENT SYSTEMS

The Government of Ghana through the Hydrological Services Department and KMA use two main approaches to reduce the possibility of flooding on the residents of Kumasi. One approach is the dredging and desilting of drains. The second approach is rebuilding of the drains to increase their sizes and to fortify them to accommodate large storm waters. Unfortunately, these drains are being used as refuse dump causing them to choke. With the exception of a few cases, most urban development projects that have been executed in Kumasi are divorced from land management (Thrift, 2007). The methods adopted by KMA to manage and reduce the incidence of flooding are not holist and all encompassing. A well defined national policy is needed to manage wetlands. A clearly published statement by a national or sub-national government to guide rational decisions and actions for the wise use of wetlands, often with measurable goals, timelines and commitments, plus budgets for action (Koopmanschap, 2005).

Although such policies exist in Ghana in the statutory books, their implementation has been hampered by the lack of political will, corruption, poverty level and change in governmental and cultural values (Figure 4.16). It is imperative that these policies are linked to other land, soil, water, air, wildlife conservation and economic development policies in order to secure the wise use of the nation's wetlands and meet international wetland conservation responsibilities. Koopmanschap (2005) suggested the prevention of further wetland loss and encourage the rehabilitation of the nation's wetlands by: Maintaining their integrity, preserving their genetic diversity; and ensuring that the enjoyment and economic use of wetlands are sustainable.

Most of Kumasi lands are informal lands whose management lies with the traditional rulers (Figure 4.13). Only a few cases of government owned lands have management plans. Another reason is the absence of coordination between government land managers such as the KMA, TCPD and the traditional landowners who sell lands (Figure4.14). Also, there is lack of consistency in the layout of informal lands and state owned lands. The inconsistency in layout is due to absence of consultation by

TCPD with traditional landowners despite the fact that the latter controls most of Kumasi lands.

The unawareness of chiefs of the benefits and need to protect wetlands, for example, might have contributed to the cheap sale of wetland areas to potential developers. It appears therefore, that the traditional land tenure system has contributed to the problem of haphazard residential development in Kumasi (Thrift, 2007). The traditional rulers, therefore, stand to be blamed partly for the uncoordinated residential development and urban sprawl leading to flooding in Kumasi.

A strong traditional base for protection of wetlands through indigenous management systems exists in Ghana (Anku, 2006). Most wetlands and their resources have been protected and regulated in the past through varied traditional practices, depending on the beliefs of the traditional area that claims ownership. These traditional practices involve customary laws or taboos, which determine rights to land and resource use. They include the enforcement of sanctions for violation by the responsible authority. Many wetlands have cultural and heritage values. The Sakumo lagoon, for instance is regarded as the abode of "gods" (Anku, 2006). They are therefore revered and protected through various traditional practices aimed at maintaining and preserving them.

Roggeri (1995) described traditional wetland knowledge as those interventions or techniques, which integrate the objectives of development with the maintenance of wetland functions and values. As in Zambia, the traditional knowledge institution still prohibits cultivation of headwaters of rivers and streams. This ensured all year round stream flow and the protection of lagoons and fish breeding grounds (Mangetane and Ashibey, 2001). Modern day failure to comply with the taboo system has resulted in loss of agricultural lands in Zimbabwe and loss of water bodies in Ghana (Ashibey, 1995).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This study has presented an assessment of wetland ecosystem decline in Kumasi by using GIS, physicochemical, heavy metal sediment test and questionnaire to relevant stakeholders as tools in the analysis.

An attempt was made to capture and delineate as accurate as possible the extent of the boundaries of the wetlands as they exist. A map showing the wetland boundaries and settlement that have encroached upon these wetland was produced. Wetland areas at Atonsu, Ahinsan, Asokore Mampong, Dakudwom Aboabo, Kwadaso Estate have been encroached upon with buildings, farms, car fitting shops, washing bays and carpentry shops.

The Kaase Guiness and Atonsu fitting shop areas recorded the most polluted mC_d (16.9 and 16.4) while Nsenie recorded the least mC_d of 3.9. The overall degree of contamination factor is 9.4 (very high degree of contamination) on the Abrahim and Parker (2008) scale. The sediment and water sample do not meet the WHO limits for the trace metals and the physicochemical properties which mean that wetlands in Kumasi are polluted.

The incidence of perennial flooding in Kumasi and its environs has had destructive effect on the functioning of the wetlands as hydrological stability and control of flooding leading to destruction to property and sometimes lost of lives. The communities have adapted to flooding by dredging the streams, creating channels for water, creating embankment at the shoulders of the stream and sweeping away the flood water. It is only in extreme cases that people vacate their home and return after the flood subsides.

Wetlands in Kumasi are undergoing negative transformation and hence losing their social, economic, and environmental values due to the unsustainable ways including waste disposal, agricultural activities and settlement in which these wetlands are being used.

6.2 RECOMMENDATIONS

Good land use practices should be promoted so as to reduce the impacts that have been caused on wetlands due to poor land use practices. This may be achieved through the following strategies:

I. The KMA and TCPD should make sure that all buildings and socioeconomic activities within the buffer zone (50 m) are prohibited and existing structures demolished.

II. Construction of storm drains over wetland should give way to the fencing of those wetlands.

III. Chiefs and Assemblymen in conjunction with the KMA should make sure that water channels are desilted regularly and waste disposal sites provided and managed well by the assembly.

IV. NADMO as the first responder to flood disasters must be given the responsibility of delineating and generating maps for all the areas which flood in Kumasi on a yearly bases using for example GPS unit.

V. The KMA,TCPD and other NGO’s should replicate the KNUST botanical garden and Otumfuo garden at Dakudwom on other wetland areas at City Hotel, Nsenie and Atonsu Monaco areas to improve and protect these areas.

VI. Further research in academic and research institutions should be carried out on integration of remote sensing and aquatic ecology.

REFERENCES

Abrahim, G. and Parker, R. 2008. Heavy metal contaminants in Tamaki Estuary: Impact of city development and growth, Auckland, New Zealand. Environmental Geology, 42, 883–890.

Adarkwa, K.K and Oppong, R.A. 2007. Poverty reduction through the creation of a liveable housing environment: A case Study of Habitat for Humanity International Housing Units in Rural Ghana. Emerald Journal of property Development, 25(1):7-26.

Adger, W.N. 1995. Working Group Reports-Management in Wetland Ecosystems. In Carbon Sequestration in the Biosphere: Processes and Prospects. NATO ASI Series. Series 1. Global Environmental Change: Vol.33:217-226.

Afework H., Abbot, P.G. and Wood, A.P. 2000. Appropriate techniques for sustainable wetland management, Report for Objective 4, Metu and Huddersfield: EWRP and the University of Huddersfield.

Andjeilkovic, I. 2001. Guidelines on Non-Structural Measures in Urban Flood Management. Paris: IRTCUD. 50.

APHA, 1992. Standard methods for the examination of water and wastewater. 18th ed. American Public Health Association, Washington, DC.

Arnold, C. and Gibbon, J. 1996. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. Journal of the American Planning Association, 62:243-258.

Ashibey, E.D.A. 1995. Indigenous Knowledge systems and prudent natural resource management. In: Indigenous Knowledge systems and Natural Resource Management in Southern Africa.

Baur, P. Mandeville, N. Lankford, B. and Boake, R. 2000. Upstream/Downstream Competition for Water in the Usangu Basin, Basin Tanzania. Proceedings of the

British Hydrological Symposium in Newcastle University, Newcastle, September 6 to 8, 2000.

Bhatti, J.S. and Preston, C.M. 2006. Carbon dynamics in forest and peatland ecosystems: preface. Canadian Journal of Soil Science 86:155–58.

Bonell, M. and Balek, J. 1993. Recent Scientific Development and Research Needs in Hydrological Processes of Humid tropics: 167-260.

Bonnevie, N.L., Huntley, S.L., Found, B.W. and Wenning, R.J. 1994. Trace metal contamination in surficial sediments from Newark Bay, New Jersey. Science of the Total Environment, 144 (1.3), 1.16.

Breen, C.M. 1991. Are intermittently flooded wetlands of arid environments important conservation sites? Madoqua 17(2): 61-65.

Bermen, F. and Tiner, R.W. Jr. 1999. (eds.) Wetlands Ecology and Conservation: Emphasis in Pennsylvania. Pennsylvania Academic of Sciences, Easton, PA, USA.

Blake, B., Kasanga, K., Adam, M., Gyabaah, K.N., Pender, J., Quashie-Sam, S.J., Warburton, H. and Williams, K. 1997. "Kumasi Natural Resources Management Research Project. Inception Report. Natural Resources Institute. The University of Greenwich. UK and University of Science and Technology, Kumasi, Ghana.

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands, Technical report WRP-DE-4, U.S. Army engineer waterways experiment station, Vicksburg, MS. NTIS No. AD A 270 053.

Bullock, A. and McCartney, M.P. 1996. Wetland and river flow interactions in Zimbabwe. L'hydrolgie tropicale: géoscience et outil pour le développment (Actes de la conf? rence de Paris, mai 1995). IAHS 238, 305-321.

Center for Watershed Protection. 2003. Impacts of Impervious Cover on Aquatic Ecosystems. Watershed Protection Research Monograph Number 1.

Chan, N.W. 1997. Increasing flood risk in Malaysia: Causes and Solutions. Disaster Prevention and Management, Vol. 6, pp.72-86.

Chiras, D.D., 1998. Environmental Science. A systematic Approach to sustainable development. 5th ed. Wadsworth Publishing Co., Washington D.C.

Christensen, N. L., Baruska, A.M., Brown, J.H., Carpenter, S., D'Antonio, C., Francis, R., Franklin, J.F., MacMahon, J.A, R. Noss, R.F., Parsons, D.J., Clausniter, D. and Huddleston, J.H. 2002. Wetland Determination of A Southeast Oregon Vernal Pool and Management Implications, Wetlands (22) 4–December 2002.

Copeland, H.E., Tessman, S.A., Girvetz, E.H., Roberts, L., Enquist, C., Orabona, A., Patla, S, Kiesecker, J. 2010. A geospatial assessment on the distribution, condition, and vulnerability of Wyoming's wetlands. Ecological Indicators, 10: 869–879.

Cunningham, W.F. and Cunningham, M.A. 2002. Principles of Environmental Science: Inquiry and Application. McGraw Hill Companies, Inc., NY, pp 418.

Cunningham, W.P. and Saigo, B.W. 1999, Environmental Science: a global concern, WCB/McGraw Hill, Ch.11, p. 237.

Da Rocha, B.J. and Lodoh, C.H.K. 1999. Ghana Land Law and Conveyancing (2^{nd} Edition). DR & L Publishing, Accra, pp 614.

Detenbeck, N.E., Galatowitch, S.M., Atkinson, J. and Ball, H. 1999. Evaluating perturbations and developing restoration strategies for inland wetlands in the Great Lakes Basin. Wetlands 19:789–820.

Dewey, J.C., Schoenholtz, S.H., Shepard, J.P. and Messina M.G. 2006. Issues Related To Wetland Delineation of a Texas, USA Bottomland Hardwood Forest Wetlands, 26 (2):410–429.

Dhar, O.N. and Nadargi, S. 2002. Hydro meteorological aspects of floods in India. *Natural Hazards*, Vol. 28, pp. 1- 33.

Dingman, S.L. 2002. 'Physical hydrology', Prentice Hall Inc., NJ, USA, pp. 646.

Dixon, R.K. and Krankina, O.R. 1995. Can the terrestrial biosphere be managed to conserve and sequester carbon? In Carbon Sequestration in the Biosphere: Processes and Prospects. NATO ASI Series. Series 1. Global Environmental Change: Vol. 33: 153-179.

Dooge, J.C.I. 2003. Linear theory of hydrologic systems. EGU reprint series. European Geoscience Union, Katlenburg-Lindau, Germany, pp327.

Duarte, C.M. and Agusti, S. 1998. The CO_2 Balance of Unproductive Aquatic Ecosystems. Science 281: 234-236.

Falkenmark, M. Andersson, L. Castensson, R. Sundblad, K. Batchelor, C. Gardiner, J. Lyle, C. Peters, N. Pettersen, B. Quinn, P. Rockstrom, J. Yapijakis, C. 1999. Water as a Reflection of Land Use: Options for Counteracting Land and Water Mismanagement. Sweden: Stockholm Ltd.

Findlay, C.S. and Bourdages, J. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14:86–94.

Food and Agriculture Organization of the United Nations, 2000. Data on location of dams for Africa provided to WRI for PAGE Analysis. FAO Rome, Italy.

Furnas, M.J. 1992. The behavior of nutrients in tropical aquatic ecosystems. p. 29-68. In: Connell, D.W. and D.W. Hawker (eds.). Pollution in Tropical Aquatic Systems. CRC Press Inc., London, U.K.

Ghana Statistical Services, 2002. 2000 Population and Housing Census. Special Report

Grunwald, S. 2006. What do we really know about the space-time continuum of soil landscapes? p. 3–36. In S. Grunwald (ed.) Environmental Soil-landscape Modeling: Geographic Information Technologies and Pedometrics. CRC Press, New York, NY, USA.

Gwin, S.E. Kentula, M.E. and Shaffer, P.W. 1999. Evaluating the effects of wetland regulation through hydrogeomorphic classification and landscape profiles. Wetlands 19:477–489.

Hails, A.J. 1996. Wetlands, Biodiversity, and the Ramsar Convention: The Role of the Convention on Wetlands in the Conservation and Wise Use of Biodiversity. Gland, Switzerland: Ramsar Convention Bureau.

Hakanson, L. 1980. Ecological risk index for aquatic pollution control, a sedimentological approach. Water Research, 14, 975–1001.

Harrison, R.M., 1999. Understanding our Environment: An introduction to Environmental Chemistry and pollution. 3rd Ed. The Royal Society of Chemistry, UK.

Hayashi, M. 2004. Temperature-electrical conductivity relation of water for environmental monitoring and geophysical data inversion. Environ. Monit. Assess., 96: 199-128.

Horne, A.J., Goldman, C.R. 1994. Limnology; McGraw Hill Inc. USA.

Intergovernmental Panel on Climate Change, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Janssen, G. and Hemke, K. 2004. Ground water models as civil engineering tools, FEM_MODFLOW, Karlovy Vary, Czech Republic.

Jin-Yang, C., Bernard, A.E., Suresh, M. and Harbor, J. 2003. GIS Based Long Term Hydrologic Impact Evaluation from Watershed Urbanization, 39: 623-635.

Junk, W.J. 2002. Long-term environmental trends and the future of tropical wetlands. Environmental Conservation, 29 (4): 414-435.

Kabii, T. 1996. An Overview of African Wetlands. Technical Officer for Africa, Ramsar Bureau, Switzerland.

Kangalawe, R.Y.M., Liwenga, E.T., 2005. Livelihoods in the wetlands of Kilombero Valley in Tanzania: Opportunities and challenges to integrated water resource management. Physics and Chemistry of the Earth, 30: 968–975.

Kolsky, P. and Butler, D. (2002) Performance Indicators for Urban Storm Drainage in Developing Countries. Urban Water, 4: 137-144.

Koopmanschap, E. 2005. Policy and Institutional Aspects in Wetland Conservation and Management. International Agricultural Centre (IAC),Wageningen, the Netherlands.

Kumasi Metroplitan Assembly, 2006. A Profile of Ashanti Region of Ghana. Pp.43

Kulser, J.A. and Kentula, M.E. 1992. Wetland creation and restoration: the status of the science. Washington, DC: Island Press.

Lawson, T.B. 1995. Fundamentals of Aquacultural Engineering. New York: Chapman and Hall.

Lafferty, K.D. and Swift, C.C. 1999. Ambrose, R.F. Extirpation and recolonization in a metapopulation of an endangered fish, the tidewater goby. *Conserv. Biol.*, *13*: 1447-1453.

Leopald, L.B. 1997. Water, Rivers and Creeks. University Science Book Press, Sausalito, CA. Pp185.

Lloyd, R. 1992. Pollution and Freshwater Fish. West Byfleet: Fishing News Books.

Mance, G. 1987. Pollution Threat of Heavy Metals in Aquatic Environments. London: Elsevier.

Mangetane, G.K., Asibey E.A.O. 2001. An Overview of African Indigenous Knowledge for sustainable Development. Scandinavian Seminar College: African Perspectives of Policies Supporting Sustainable Development.

Marsalek, J., Rochfort, Q. and Savic, D. 2001. "Urban Water as a Part of Integrated Catchment Management". In: Maksimovic et al. "Frontiers in Urban Water Management: Deadlock or Hope". IWA Publishing. 2001.

Matos, J.E., Welty C. and Packman, A.I. 2002. Stream-Groundwater Interactions and Near Stream Flow Systems: The Influence of Aquifer Heterogeneity and Stream Meandering on Three dimensional Hyporheic Exchange Flows American Geophysical Union, (AGU) Fall Meeting,pp. 887.

McClanahan, T.R. 1994. Kenya Coral Reef Lagoon Fish: Effects of Fishing, Substrate Complexity, and Sea Urchins. In: Coral Reefs Journal of the International Society for Reef Studies. Vol 13 No. 4, 1994.

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: wetlands and water. Water Resources Institute, Washington, DC. E-report accessed on July 2006 at http://psdn.org.ph/wetlands/index.htm

Ministry of Lands and Forestry, 1999. Management Ghana's Wetlands: National Wetland Conservation Strategy. The Republic of Ghana.

Mitchell, M.K. and Stapp, W.B. 1992. Field Manual for Water Quality Monitoring, an Environmental education program for schools. GREEN:Ann Arbor, MI.

Mitsch, W.J. and Gosselink J.G. 2000. Wetlands, third ed. Van Nostrand Reinhold, New York, USA.

Mitsch, W.J., and Gosselink J.G. 1993. Wetlands. second ed. New York: John Wiley & Sons, Inc.

Mueller, H., David, K., Helsel, A. and Dennis, R. 1999. Nutrients in the Nation's Waters-Too Much of a Good Thing? U.S. Geological Survey Circular 1136. National Water-Quality Assessment Program. http://water.usgs.gov/nawqa/circ-1136.html.

Mulligan, M. and Wainwright, J. 2004. Modeling and model building, In: Wainwright J, Mulligan M (eds) Environmetal modeling: finding simplicity in complexity. John Wiley, West Sussex, England.

Murphy, P.N.C., Ogilvie J., Connor K. and Arp P.A. 2007. Mapping Wetlands: A Comparison of two Different Approaches for New Brunswick, Canada Wetlands, 27(4): 846–854.

National Deserter Management organization. 2009. The flooding situation in the Ashanti Region. Special Report.

Nyarko, B.K., Diekrüger B. and Rodgers C. 2006. Modeling floodplain extent in the White Volta Basin: an application of the list flood FP model, poster presented at the EGU General Assembly 2006, 02-07 April 2006–Vienna, Austria.

Oguntoyinbo, J.S. & Oguntala, A.B. (1982) Urban flooding in Ibadan: A Diagnosis of the Problem. *Urban Ecology*, 7: 39- 46.

Owusu, S.E. 2001. Housing Supply and Demand in Kumasi. In Adarkea, K. K. And J. Post (eds): The Fate of the Tree: Planning and Managing the Development of Kumasi, Ghana. Thela, Amsterdam and Woeli, Accra, pp 101-103.

Ozesmi, S.L. and Bauer, M.E. 2002. 'Satellite remote sensing of wetlands', Wetlands Ecology and Management, 10(5): 381-402.

Peterson, C.H., M. Turner, M.G. and Woodmansee, R.G. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications 6:665–91

Patterson, J.H. 1999. Wetlands and Climate Change Phase 1: Feasibility Investigation on the Potential for Crediting Wetland Conservation as Carbon Sinks.

Prigent, C. 2001. Remote sensing of global wetland dynamics with multiple satellite datasets, Geophysical Research Letters, 28 (24): 4631-4634.

Ramsar Convention Secretariat, 2006. The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971), 4th ed. Ramsar Convention Secretariat, Gland, Switzerland.

Ramsar Convention Secretariat, 2009. Strategic Framework and Guidelines for the Future Development of the List of Wetlands of International Importance of the Convention on Wetlands. 3rd Edition. Switzerland: Gland.

Rivas, R. and Caselles, V. 2004. 'A simplified equation to estimate spatial reference evaporation from remote sensing- based surface temperature and local meteorological data', Remote Sensing of Environment, 93: 68-76.

Richardson, C.J. 1994. Ecological functions and human values in wetlands: A framework for assessing impact. Wetlands, 14: 1-9.

Riekerk, H. and Korhnak L.V. 2000. The Hydrology of Cypress Wetlands in Florida Pine Flatwoods. Wetlands 20(3):448-460.

Roggeri, H. 1995. Tropical Freshwater Wetlands: A Guide to Current Knowledge and Sustainable Management. Kluwer Academic Publishers, Dordrecht, Netherlands.

Rundquist, D.C., Narumalani, S. and Narayanan, **R.M.** 2001, A review of wetlands remote sensing and defining new considerations. Remote Sensing Reviews, 20: 207- 226.

Semlitsch, R.D., Bodie J.R. 1998. Are small, isolated wetlands expendable? *Conserv. Biol. 12*, 1129-1133.

Sawyer, C.N. McCarty, P.L. Parkin, G.F. 2003. Chemistry for Environmental Engineering and Science. 5th edition. Mc Graw Hill Co. New York.

Semlitsch, R.D. 2002. Critical elements for biologically based recovery plans of aquatic-breeding amphibians. *Conserv. Biol. 16*, 619-629.

Silberbauer, M.J. and King, J.M. 1991. The distribution of wetlands in the South-Western Cape Province, South Africa. *South Afr. J. Aquat. Sci.17*, 65-81.

Silvius, M.J., Oneka M. and Verhagen, A. (2000). Wetlands: Lifeline for people at the edge. Phys. Chem. Earth, 25:645-652.

Spectacular, 2012. Village on silts on water. http://www.nzulezo.com/. Accessed on February 23, 2010

Thrift, C. 2007. Sanitation Policy in Ghana: Key Factors and the Potential for Ecological Sanitation Solutions. Stockholm Environment Institute

Timberlake, J. 2008. Biodiversity of the Zambezi Basin Wetlands: Review and Preliminary Assessment of Availability Information, Phase 1 Final Report.

Tiner R.W. 2003. Geographically Isolated Wetlands of the United States. Wetlands 23:494–516.

Tiner, R.W. 1993. Field Guide to Coastal Wetland Plants of the Southeastern United States. University of Massachusetts Press, Amherst, MA, USA.

Tiner, R.W. Jr. 1989a. Wetland boundary Delineation. P. 231-248. In S.K. Majumdar, F.J.

Turner, R.K., Van den Bergh, J.C.J. M., Soderqvist, T., Barendregt, A., Van der Straaten, J., Maltby, E. and Van Ierland, E.C. 2000. Ecological-economic analysis of wetlands: scientific integration for management and policy. Ecological Economics, 35:7–23.

Twilley, R.R. 2007. Coastal Wetlands & Global climate change Gulf Coast Wetland Sustainability in a Changing Climate. Louisiana State University.

United Nations, 2009. Water in a Changing World. The United Nations World Water Development Report 3: London, UK: Earthscan.

United Nations, 2003. World Water Development Report 'Water for people Water for life' p. 85 Assessed 15th June 2011 at http://www.lenntech.com/rivers-pollution-quality. htm

Windham, L., Weis, J.S. and Weis, P. 2004. Metals dynamics of plant litter of Spartina alterniflora and Phragmites australis in metal-contaminated salt marshes. Part I: Patterns of decomposition and metal uptake. Environmental Toxicology and Chemistry, 23: 1520.1528.

Xin, S. 2004. Inferring wetland hydrological conditions from remote sensing', MSc. Thesis, ITC, Enschede, The Netherlands, pp. 44.

Young, P.C. 2001. Database mechanistic modeling and validation of rainfall-flow processes. In: Anderson MG, Bates PD. Model validation perspectives in hydrological sciences. John Wiley, Chichester.

Zakaria, A. 2000, Environmental Implications of Urban Landuse; A case study of waterlogged areas in Kumasi (Aboabo and Anloga). MSc thesis, Department of Material Engineering. College of Engineering, KNUST Kumasi. Pp.88

APPENDICE

APPENDIX I: SOCIO ECONOMIC SURVEY OF WETLAND ASSOCIATED COMMUNITIES IN KUMASI

Area…………………………………....... Type of house...

Date……………………………………

INTRODUCTION

The researcher is a student of the Kwame Nkrumah University of Science and Technology working on urban wetlands in Kumasi. The information you provide will be treated as confidential and will be used only for academic purposes.
Thank you for your time and cooperation.

1.0 Background Information

1.1 Age: below 20yrs [ ] 20-30yrs [ ] 30-40yrs [ ]
40-50yrs [ ] 40-45yrs [ ] above 50yrs [ ]

1.2 Sex: Male [ ] Female [ ]

1.3 Education: Primary [ ] Middle School/JHS [ ] Secondary/SHS [ ]
Post-secondary/Tertiary [ ] No formal education [ ] Other [ ]

1.4 Occupation: …………………………. Household size:............................

2.1 Do you own the house you live in Yes [ ] No [ ]

2.2 How did you get access to this land?

Family inheritance [ ] Chief [ ] Bought from another person [ ]
Rented [ ] Squatter [ ]

2.3 For how long have you been living in the area? Below 5years [ ]
5-10 years [ ] 10-15 years [ ] 15-20 years [ ] more than 20 years [ ]

Please rank the following options according the criterion below:

0= no change/no influence/no contribution/nothing, 1=… 2= … 3=… 4=… in increasing order to 5=highest increase/most influential/most contribution.

2.4 What do you do for a living?

Job types	0	1	2	3	4	5
1. Trading						
2. farming						
3. Artisan (e.g. car fitting/Saw milling/carpentry etc)						
4. Tie and dye manufacturing						
5. Oil extracting (palm oil/palm kernel oil etc)						
6. Formal sector job						

7. Nothing/unemployed/dependant						
8. Others, please specify						

2.5 What are the predominant economic activities in this area?

Activity/use of land at time of moving in	0	1	2	3	4	5
1. Agriculture (vegetables, animals, etc)						
2. Tie and dye industries						
3. Hunting						
4. Fishing						
6. Car washing bays						
7. Car fitting/spraying shops						
8. Carpentry/sawmill						
9. Trading						
10. Other (specify)						

2.6 What is/are the uses of this stream/wetland to the people of this area?

Uses	0	1	2	3	4	5
1. Agricultural purposes						
2. Tie and dye industries						
4.Waste disposal						
5. Car washing bays						
6. Car fitting shops						
7. Carpentry						
4. Water supply						
5. Plant products						
6. Fish products						
7. Forage area for cows sheep and goats						
8. Recreation/tourism						
9. Other, Please state						

2.7 What are the major land use activities around the wetland (100m from water channel)?

Activities	0	1	2	3	4	5
1. Agriculture (vegetables, animals, etc)						
2. Tie and dye industries						
3. Hunting						
4. Fishing						
5. Waste disposal						
6. Car washing bays						
7. Car fitting shops						
8. Carpentry						
9. Building construction						
10. Water supply						
11. Rangeland/forage area						

12. Recreation/tourism						
13. Housing						
14. Others, please specify						

2.8 What have been the effects of these activities (2.7) on the environment/wetland?

Change	0	1	2	3	4	5
1. Channel width (size of the river)						
2. Water depth						
3. Number and type of living organisms (e.g. fish, plants)						
4. Storm flow (amount of water in the river/channel immediately after rainfall)						
5. Suitability of water for domestic/industrial purposes						
6. Others, please specify						

3.1 What changes have you observed in the wetland vegetation since you first settled?

Change	0	1	2	3	4	5
1. Plant species diversity						
2. Number of woody plants (e.g. trees)						
3. Number of herbaceous plants (e.g. grasses)						
4. Distribution of plants						
5. Density of plants						
6. Plant cover						
7. Loss of some species						
8. Presence of new species						
9. others please specify						

4.1 Buildings in wetland areas are major problems in Kumasi, affecting and polluting river bodies? Strongly agree [ ] Agree [ ] Disagree [ ] Not sure [ ]

4.2 What are some of the effects building on wetland areas have on our environment?

Effects	0	1	2	3	4	5
1. Nothing						
2. Causes flooding						
3. Makes the environment dirty						
4. No place to dump wastes anymore						
5. Does not make the city beautiful						
6. Other, please specify						

4.3 Why do you think people build in wetland?

Reasons	0	1	2	3	4	5
1. Wetland areas are cheap						
2. Make use of the stream						
3. Do their economic activities						
4. It is “no man’s land”						
5. Other, please specify						

4.4 Have you experienced flood in this area? Yes [ ] No [ ]

4.5 If yes, how long do the floodwaters take to recede?

less than 5 days in a year [ ]   less than 10 days in a year [ ]

less than 15 days in a year [ ]   less than 20 days in a year [ ]

less than 25 days in a year [ ]   About a month in a year [ ]

4.6 How do you deal with floods as an individual and community?

Activities	0	1	2	3	4	5
1. Do nothing						
2. Fetch/pump water out of flooded areas						
3. Move out till water subsides						
4. Create channels for easy flow of water						
5. Dredge stream						
6. Build embankments along stream						
7. Complain to authorities						
Others, please specify						

4.7 Have you ever been educated on the usefulness of a wetland? Yes [ ] no [ ]
Give the name(s) of the organization(s) if yes.

…………………………………………………………………………………………

…………………………………………………………………………………………

4.8 Has there been any attempt by an organization to move you from this site?
Yes [ ] No [ ],
Name them if yes.

…………………………………………………………………………………………

…………………………………………………………………………………………

4.9 What will make you move out of this place?

Motivation/reason	0	1	2	3	4	5
1. Nothing, I love it here						
2. Given money to move						
3. New land/plot somewhere						
4. When I make some money						
5. When the water gets too much						
6. When we are forced						
7. I am already preparing to move						
8. If I am provided alternative shelter						
9.Other, please specify						

4.10 Do you think the wetland should be protected? Yes [ ] No [ ]

4.11 How are you and your community protecting this wetland?

Activities	0	1	2	3	4	5
1. We are doing nothing						
2. Stop waste disposal on wetland						
3. Stop building too close to wetland						

4. Create channels for easy flow of water						
5. Dredge stream						
6. Build embankments along stream						
7. Stop all economic activities on wetland						
8. Complain to authorities						
Others, please specify						

4.12 Have houses in this neighbourhood ever been marked for demolition?

Yes [ ]   No [ ]

If yes, when   less than 2 yrs age [ ]   2-5 yrs ago [ ]

5-10 yrs ago [ ]   more than 10 yrs [ ]

4.13 Has any demolition been carried out in this area?   Yes [ ]   No [ ]

4.14 Do you support the demolition along water ways?   Yes [ ]   No [ ]

4.15 Who are responsible for the management of the wetlands in Kumasi?

Agencies	0	1	2	3	4	5
1. KMA						
2. Hydrological Services Department						
3. Town and Country Planning Department						
4. The community and Assemblyman						
5. NGOs (e.g. IWMI)						
6. The chief/land owners						
7. Others, please specify						

4.16 Are there any on-going management practices to protect the wetland?

Yes[ ]   No [ ]

4.17. What factors affect the implementation of wetland policies and management plan?

Factors	0	1	2	3	4	5
1. Political influence						
2. Change in government						
3. Corruption						
4. Poverty levels						
5. Lack of political will						
6. Cost of demolition						
7. Cultural values						
8. Other, please specify						

4.18 Do you know any of the laws regarding building or sitting of infrastructure in wetland areas?   Yes [ ]   No [ ]   If yes what is it

SURVEY ON WETLAND ASSOCIATED NGOs AND GOVERNMENTAL AGENCIES IN KUMASI

Area………………………………......
Date…………………………………..

INTRODUCTION

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Background Information

Name……………………………   Title...

Institution...

1.1In your opinion; what has been the overall change in the state of the wetland? (Please tick one box only per wetland type)

Date	0	1	2	3	4	5
1. 1980-1985						
2. 1985-1990						
3. 1990-1995						
4. 1995-2000						
5. 2000-2005						
1. 2005-2010						

1.2 What are the tasks of officers-in- charge of developments on wetland areas?

1.3 How often do developers who flout the regulations come to your notice?

1.4 What punitive measures are there for such offenders?

1.5 I Are these punitive measures effective?   Yes [ ]   No [ ]

1.6 How can the effectiveness be improved?

1.7 Are prospective (building) developers aware of these regulations/rules?

1.8 How often does your outfit organise educative seminars?

1.9 What medium do you use for such educative forum?

1.10 Are there any risks/dangers your inspectors/ officers face in visiting development sites in wetland (e.g. from land guards, mob attack, etc)?

1.11 Under what circumstances can a building on wetland be pulled down?

1.12 Are there maps showing wetland areas?

1.13 What major constraints affect the implementation of wetland management plan?

1.14 How do non-economic variables other than per capita income, such as the features of the political system, and some cultural values, affect the implementation of wetland policies and management plan?

APPENDIX II: COORDINATES DELINEATING WETLANDS SAMPLED AND THE ASSOCIATED CURRENT LANDUSE OR COVER

SN	Location Northern(N)	Eastern(E)	Name/Attribute	General Characteristics	Present Use/Cover
1	737977.5681	658233.8511	KNUST Grasag	Swampy and waterlogged	Reeds, grasses and sedges, Horticultural garden
	738072.4766	658126.0862	KNUST Grasag		
	739564.2245	658809.6645	Tech Police Stn		
2	740361.5708	659418.4635	Nsenie	Fallow and drained out	Far encroached by buildings. Stream almost non-existing
	740337.0246	659427.7486	Nsenie		
	739200.9723	658932.1479			
	739197.1379	658785.4121	Nsenie		
3	739488.8478	656116.5896	Family Chapel	Partly fallow with arable crops	Encroachment by churches e.g. Family Chapel, Carpentry fitting shop
	739494.4798	655938.4546	Family Chapel		
	738549.023	656149.9973	Ahensan		
4	736498.6021	655575.4175	Atonsu fitting	Mostly fallow with arable crops	Fitting/Carpentry shop, settlement, filling station and waste disposal site
	736609.1097	655550.5332	Atonsu fitting		
	735108.2163	654866.8460	Monaco		
	736202.9416	655299.8526	High School		
	736212.0866	655275.2571	Junction		
	736342.3229	655320.4851	Wewe+Sisai		
	736222.0901	655396.5507			
5	735777.1682	653544.3344	Kaase Guiness	Partly fallow with arable crops	Stream converted to storm drain, encroached by buildings, car fitting and spraying shop
	735773.8292	653449.1368	Kaase Guiness		
6	735283.4194	652725.7067	Daaban Car wash	vegetative cover and car wash	Encroachment by buildings, cleared and used as car wash, water is far approach
	735062.198	652701.7547			
7	737420.4747	651346.955	TUC	No cultivation: Trees and grasses	Ornamental garden and horticulture. Water supply
	737475.1237	651116.473	TUC		
8	739175.4177	659075.3261	KNUST	No cultivation: full of Trees, grasses and animals	In its natural status. For recreational use
	739144.8213	658274.7225	Botanical		
	738461.5035	657968.7593	Garden		
	737333.6295	657290.8297			
	736914.0417	657472.4057			
9	733266.7843	654417.7603	Kwadaso	Cultivation of palm tree, breadfruit; part as dumping site	Encroachment by churches and settlement. Stream disappearing
	732868.6001	654201.1013	Estate		
	732610.9513	653949.3083			
	734566.7751	652584.9773			

	737184.2513	651056.6521	Kwadaso		
	737374.3681	651303.6739	Estate		
10	737359.9209	653088.5633	Adeibeba	Drained area for banana cultivation,	Encroached by buildings; Banana, sugar cane, sedges
	737477.0339	653439.9025			
	736582.3719	655415.7641			
	737016.6821	655050.1585			
11	737078.0253	655293.0777	Aboabo	Swampy and waterlogged	Encroachment by building; stream converted to a storm drain and used as waste disposal
	737016.6821	655050.1585			
	738324.5199	655339.6985			
	738285.2601	655219.4659			
	739988.1483	654689.4603			
12	740737.0265	656834.5105	Aboabo		
	738806.1491	651859.3531	City Hotel	No cultivation: full of grasses	In its natural status
	738806.1491	651859.3531			

APPENDIX III: MODIFIED DEGREE OF CONTAMINATION (MC_d) AND CONTAMINATION FACTOR (C_f) FOR HEAVY METALS IN THE VARIOUS SITES IN KUMASI

	Contamination factor										
Sample sites	**As**	**Cu**	**Pb**	**Hg**	**Zn**	**Cr**	**PO_4**	**Cd**	**Ni**	**ΣC_f**	**mC_d**
Nsenie	2.70	3.10	7.00	11.5	4.50	0.90	3.30	3.70	1.30	35.20	3.90
Family Chapel	6.40	3.90	11.0	10.9	17.3	1.90	14.1	4.30	1.00	64.30	7.10
Galco house	8.00	2.20	6.20	9.10	6.30	2.00	8.00	5.00	1.00	39.80	4.40
Asokore Mamp.	0.70	1.50	12.3	15.6	26.9	0.30	3.50	8.70	0.90	69.50	7.70
Bantama	7.50	1.70	30.8	14.5	20.7	4.00	17.3	2.30	0.70	91.90	10.2
Kwadaso Estates	13.8	7.10	26.0	14.2	31.2	5.50	23.5	12.7	4.20	124.4	13.8
Dakwodwum	8.90	3.20	11.7	14.4	4.40	4.90	10.3	4.70	2.00	55.50	6.20
Daaban-Ahodwo	8.60	2.00	11.0	12.9	1.20	5.30	8.80	4.00	0.80	46.00	5.10
Atonsu Sawmill	9.90	9.10	32.3	13.4	17.6	5.90	26.2	7.70	13.2	125.4	13.9
Atonsu fitting shop	12.2	12.4	37.7	15.7	27.8	7.00	32.8	10.7	3.20	147.4	16.4
Kaase-Guiness	6.90	13.4	35.9	15.2	25.6	3.10	36.2	4.30	18.1	151.8	16.9
City Hotel	11.9	3.40	16.4	11.1	3.80	9.30	8.90	5.70	1.20	59.60	6.60